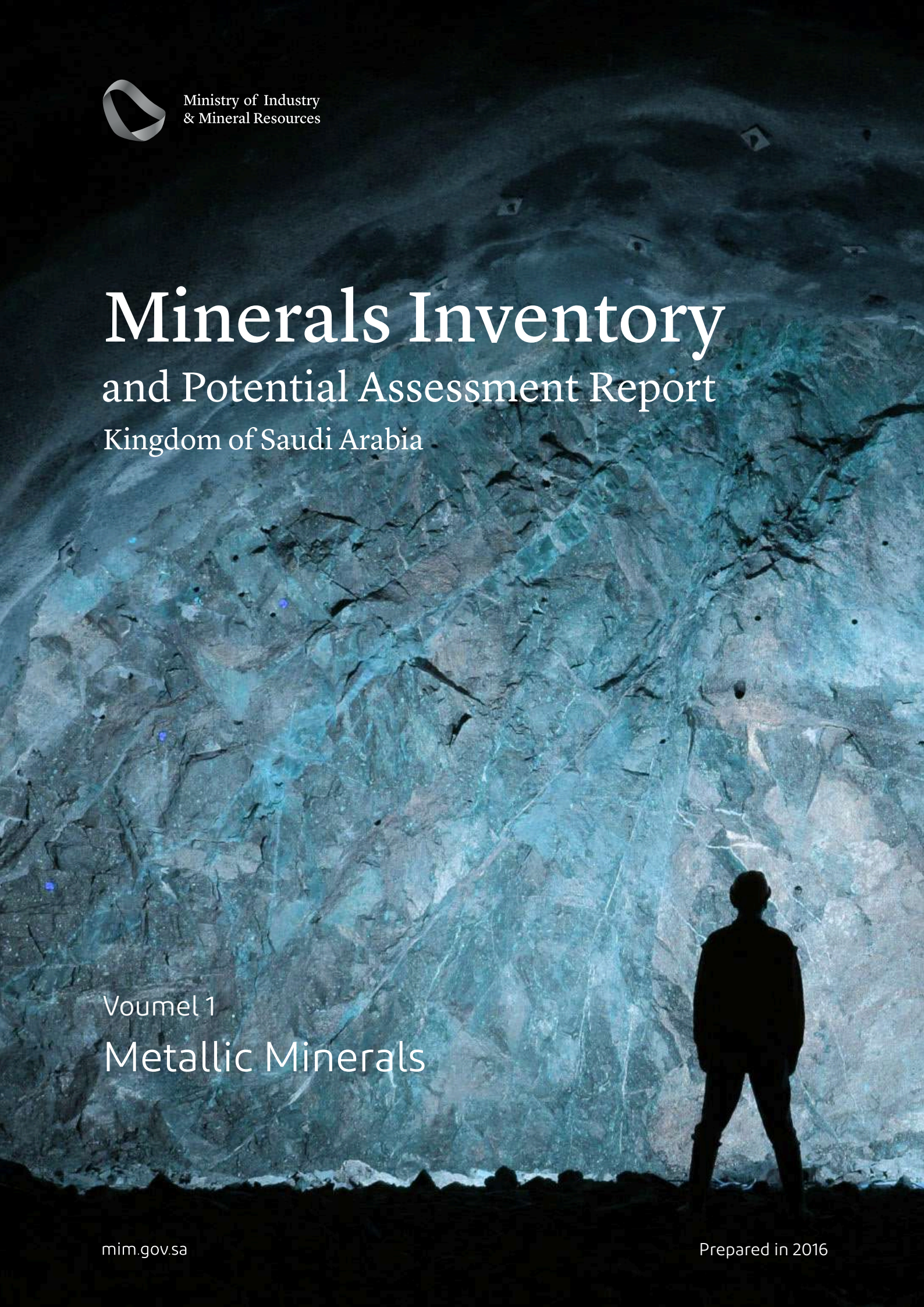

Ministry of Industry
& Mineral Resources

Minerals Inventory

and Potential Assessment Report

Kingdom of Saudi Arabia

Voumel 1

Metallic Minerals

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Prepared in 2016

COMPREHENSIVE MINING STRATEGY PROJECT

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MINISTRY OF PETROLEUM AND MINERAL RESOURCES
JEDDAH, KINGDOM OF SAUDI ARABIA
1436-1437 A.H. 2015-2016 C.E.

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Components of the Comprehensive Mining Strategy Project

Task	Report Number	Title	Format
1.0 & 1.3	MOP-CR-16-1	Mineral Potential Assessment and Economic Viability - Executive Summary	PowerPoint Presentation
1.0 & 1.3	MOP-CR-16-2A	Minerals Inventory and Potential Assessment Report, Volume 1: Metallic Minerals	Word Document
1.0 & 1.3	MOP-CR-16-2B	Minerals Inventory and Potential Assessment Report, Volume 2: Industrial Minerals	Word Document
1.1	Unnumbered	GIS Maps (1:250,000 Map Consolidation Project	ARC GIS Maps
1.2	MOP-CR-16-3	New and Niche Attractive Applications	PowerPoint Presentation
2.1	MOP-CR-16-4	Report on Mining Hubs	Word Document
2.2	MOP-CR-16-5	Infrastructure Requirements	Excel Tables
2.3	MOP-CR-16-6	Utilities Requirements and Costs	Excel Tables
3.1	MOP-CR-16-7	Job Families Table	Excel Tables
3.2	MOP-CR-16-8	Report on Staffing Levels Across All Projects	Excel Tables
4.1	MOP-CR-16-9	Technologies in Upstream and Midstream and Mineral Exploration	PowerPoint Presentation
4.1	MOP-CR-16-10	Technologies in Upstream and Midstream	PowerPoint Presentation
4.2	MOP-CR-16-11	Metallurgical Innovation Technology and Metallurgy Innovation Center	PowerPoint Presentation
4.3	MOP-CR-16-12	Top Technologies for Projects	PowerPoint Presentation
5.1	MOP-CR-16-13	Exploration Technical Requirements and Guidelines	Word Document
5.2	MOP-CR-16-14	Mining Technical Requirements and Guidelines	Word Document
5.3	MOP-CR-16-15	Beneficiation Technical Requirements and Guidelines	Word Document
5.4	MOP-CR-16-16	Midstream Technical Requirements and Guidelines,	Word Document
5.5	MOP-CR-16-17	EHS Technical Requirements and Guidelines Management System	Word Document
5.6	MOP-CR-16-18	EHS Technical Requirements and Guidelines Environmental	Word Document
5.7	MOP-CR-16-19	EHS Technical Requirements and Guidelines Health	Word Document
5.8	MOP-CR-16-20	EHS Technical Requirements and Guidelines Safety	Word Document
6.1	MOP-CR-16-21	National Geological Database Requirements	PowerPoint Presentation
6.2	MOP-CR-16-22	National Geological Database - Baseline SDS-DMMR Database	PowerPoint Presentation
6.3	MOP-CR-16-23	National Geological Database - IT Specifications	Word Document
6.4	MOP-CR-16-24	Report on National Drill Core Library Up-Grade	Word Document
7.1	MOP-CR-16-25	Value Chain Assessment	Excel Table
7.2	MOP-CR-16-26	Executive Summary for the Comprehensive Mining Strategy Project	Word Document

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1. EXECUTIVE SUMMARY

1.1 INTRODUCTION

This Mineral Potential Assessment report is a component of the Comprehensive Mining Strategy Project undertaken by Watts, Griffis and McOuat Limited ("**WGM**") and its partners during the period September, 2015 through June, 2016. The project is for the Deputy Ministry for Mineral Resources ("**DMMR**") of the Kingdom of Saudi Arabia ("**KSA**"). The purpose of the Comprehensive Mining Strategy Project is to evaluate the potential for the Minerals Sector in Saudi Arabia to contribute to the national economy, and to estimate what supporting infrastructure is required to allow the sector to achieve its potential. This report deals strictly with the question of mineral potential.

Saudi Arabia in general, and the Arabian Shield particularly, is under-explored in respect to the solid minerals. Whereas the petroleum and gas sectors are well developed, it has only been in the last few decades that mining industry has started to develop in the Kingdom, and growth has been relatively slow. Unlike oil and gas deposits, economically viable gold, base metal, specialty metals and other solid mineral deposits have a small footprint and can have a complex geometry. It is possible to drill a hole entirely through the centre of a gold deposit and not intersect economically interesting mineralization. The decisions made when exploring for these mineral deposits require a high degree of knowledge and experience to determine not only what survey tools should be used, but the particular manner in how they are used and where they are deployed. Although industrial mineral deposits are usually found on surface and mined in quarries, thus mostly eliminating the need for blind drilling, these minerals tend to be low-value bulk commodities. They must be close to market to be economically viable, and many are subject to stringent market specifications and a symbiotic relationship between the user (buyer) and the producer (seller). If a producer fails to meet his customer's requirements, the producer will lose the client. These forces have acted on the mining sector in the Kingdom, and while the industrial minerals sector has generally flourished as small and medium sized enterprises, development in the metallic minerals industries has been slower. Notwithstanding that fact, enormous undiscovered mineral potential exists in the Kingdom as will be demonstrated in the Metallic Minerals and Industrial Minerals Volumes which comprise this report.

1.2 SOURCES OF INFORMATION AND DATA GAPS

The DMMR provided a project library for review that totalled 3,935 documents, including maps and appendices which were provided separately. This information base was largely composed of reports by the Saudi Geological Survey ("**SGS**"), the DMMR, the United States Geological Survey ("**USGS**") and the Bureau de Recherches Géologiques et Minière ("BRGM") of France, as well as companies such as British Steel, Riofinex and others. The information provided was augmented by published and unpublished technical reports on Saudi Arabia from WGM's own library. Although it has recently become clear that the information provided lacked some geological reports that dealt with recent SGS activities on mineral

prospects, reliance on WGM's 1992 study for the DMMR ensured that the pre-1991 information base was covered in whole. Other references on the Arabian-Nubian Shield and its mineral deposits were taken from the Journal of African Earth Sciences. This body of information was augmented by selected sections taken out of feasibility studies completed for Ma'aden on its successful exploration projects which resulted in discoveries such as Mansourah, Humaymah and Duwayhi. These reports were not complete, but they did contain vital information on Mineral Resources and Mineral Reserves. That information also appeared in Ma'aden's annual reports which provided a minor amount of supplementary information on some current exploration projects. Other complete feasibility studies, such as the report on Mawarid's Jabal Dhaylan zinc project, were also available. Unfortunately, due to DMMR access to information rules, WGM did not have access to exploration reports by companies which would have contributed greatly to this study.

WGM has enjoyed more than 40 years of working in Saudi Arabia in a variety of roles. It has been overall manager for some of the work carried out by the DMMR and the SGS, and has acted as a consultant to many exploration and mining companies operating in the Kingdom. Its assignments have ranged from developing exploration strategies and managing exploration projects to being lead contractor for the initial underground development of the Al Masane zinc-copper mine. WGM has completed or partnered in the completion of many feasibility studies, and has provided guidance to such groups as Ma'aden and SABIC concerning the economic viability of mineral deposits. WGM has also provided guidance to the DMMR in respect to mineral policy, development of training programs, infrastructure requirements and investment promotion. WGM therefore brings to this assignment a vast amount of experience that goes beyond the strict contents of the library provided for the Mineral Potential Assessment.

1.3 OVERVIEW OF THE EXISTING MINERAL SECTOR LANDSCAPE IN SAUDI ARABIA

Mining projects are assets that are very capital intensive to develop and mineral exploration programs are the only means available to replace mineral assets. In mature mining areas, replacement becomes increasingly difficult as the favourable mineral belts are more highly explored, often with a history of work spanning 100 years or more. No such situation exists in Saudi Arabia. Although systematic geoscience research and localized mineral exploration programs were initiated in the 1960s and '70s, about 50 years ago, much of this work has been carried out by government institutions rather than private companies. That difference is not trivial, because governments tend to build frameworks of information whereas companies attempt to discover mines.

The enormous mineral potential of the Kingdom has only been recognized in the past 20-30 years. Concepts pertaining to the geological framework of the Arabia Shield and our understanding of deposit formation are constantly evolving, yet even now the picture is less than complete. In part this is due to the time needed to establish a geoscience framework that is sufficient to identify mineral potential. This has been the essential role of the Saudi Geological Survey ("**SGS**"). It requires time to develop and support or reject ideas concerning the existence of mineral deposits which are generally hidden from the eye. Deposits are mineral concentrations that exist at such grades and in such quantities that they can support economic

extraction and mineral production. In practical terms, a mineral deposit is much like an iceberg – while some evidence on surface may exist, a deposit is not available for the eye to see or the mind to easily grasp. Yet the concept of potential must be sold to private investors.

With only a fledgling private sector mineral industry, it was left primarily to the State mining company Petromin (now Ma'aden) and the SGS to act in a leading role as an explorer. In the beginning, the focus was on sites that had been mined in the distant past, and the early exploration programs were focused on ancient mine sites such as Mahd adh Dhahab and Al Masane. In part, that focus was also based on recommendations offered by various ex-Saudi surveys such as France's Bureau de Recherches Géologiques et Minières ("**BRGM**"), the United States Geological Survey ("**USGS**") and others. The mandate of these geoscience organizations was to provide the necessary foundation for understanding the geological framework of Saudi Arabia. That mandate included initiating reconnaissance exploration programs, however many of these programs employed equipment and techniques that were poorly suited as tools for exploration. Many prospects were initially dismissed as having little or no value by geologists with little or no company experience appropriate to exploration. In many cases, these decisions were based on poor quality data, insufficient information or incorrect exploration concepts. In many cases, the early workers may have been overwhelmed by the simple fact that so many targets existed that they chose only the most outstanding mineral occurrences as being "favourable". The abundance of occurrences and constrained work schedules did not favour the sustained systematic exploration needed to make discoveries. Many excellent targets currently exist simply because they were largely disregarded in the past. In some specific cases, even excellent initial drilling results were insufficient to overcome a pervasive negative approach to exploration. Exploration is a game best played by teams of optimists and realists. Individuals who see only a glass half-empty have no place on this team[1].

This Mineral Potential Assessment was therefore impacted by the nature of the work done previously and by the quality of the data generated. WGM's reviewers and authors determined that the only viable means to assess the mineral wealth of the Kingdom was to evaluate the quality and completeness of the underlying data such that previous conclusions and recommendations could be illuminated, and in this way either accepted or rejected on a prospect by prospect basis.

Commodity cycles are another factor that impacted the quality of the work done in the past. All exploration planners must be aware of the potential impact of mineral and metal prices on revenue streams and their ability to fund exploration out of existing cash-flow, and to justify development based on anticipated economic models. For example, significantly lower gold prices in the past have clearly influenced what was considered to be an economically interesting gold occurrence. Those occurrences thought to be of low potential received less attention, lower levels of exploration funding and often suffered from unimaginative exploration planning. This had the unavoidable result of gold occurrences being down-graded and forgotten

[1] It is said that people can see the world in a glass of water: it is either half-full, or half-empty. Those who are optimists, as most exploration geologists are, see the glass as half-full.

until such time as prices justified a reassessment. However, the stigma of being of "low potential" was often inscribed in such a manner as even renewed exploration simply repeated the work carried out in the past. Obviously, this approach is self-defeating. New models and new approaches are required if exploration is to result in a successful outcome. Exploration, in its purest sense, requires time for models to be tested and amended, for appropriate exploration techniques to be developed and applied, and for data to be compiled and properly evaluated. The decision may yet be to abandon the prospect, however that decision is only reasonable when all exploration models have been systematically tested in accordance with industry best-practices and the prospect has failed to clear the viability hurdle set by the explorer. As mineral markets evolve and commodity prices change, that hurdle or benchmark must be reassessed such that projects which become viable are no longer ignored. In the case of industrial minerals, the viability may vest as much (or more) in market conditions or infrastructure requirements as in the actual production of a mineral commodity.

It is said that the key to the future lies in understanding the past. The full mineral potential of Saudi Arabia can only be realized if the exploration process is approached with the view that the potential is real and that opportunity exists. The glass is half full; not half empty. By understanding the weaknesses or limitations of work carried out in the past on a prospect by prospect basis, we can properly assess whether real exploration potential exists, or whether any specific prospect has been completely and adequately explored and should be set aside. This is the key that starts the process. Once the exploration process has been initiated, it must be fueled by an enlightened approach to exploration models, the use of industry best-practices standards and procedures, the management of qualified geoscientists, sufficient levels of investment properly scheduled and persistence. Most of all, persistence is needed because the path from mineral discovery to deposit delineation is never a straight line. Kirkland Lake Gold, a junior Canadian Mining company, is mining a new gold mine under the Town of Kirkland Lake, Canada. Over a period of more than 100 years, more than 24 million ounces of gold was been produced from 7 mines adjacent to the town, and yet this 9 million ounce deposit was hidden all that time. The path to discovering new mines is uneven, prone to risk and set-backs, and never easy. There is no reason to believe that the undiscovered Saudi deposits predicted in this Mineral Potential Assessment will be any easier to find. Some deposits will be found in coming years, however some will elude discovery for decades to come, or for economic reasons they will escape development until some distant time when higher commodity prices allow for more robust mineral economics (e.g. Ghurayyah).

1.4 THE PRINCIPAL METALLIC MINERAL DEPOSITS

The metallic minerals assessed during this study are listed in Table 1. The potential for Saudi Arabia to produce metals is largely vested in the deposits that serve as sources for gold, copper, zinc, lead and silver. These types of deposits are known to exist in the Kingdom. They are present in sufficient size and grade to create a foundation of knowledge upon which future production can be assured simply by undertaking the exploration needed to discover and delineate new deposits (mines) that are yet to be discovered. While potential exists in the longer term for other metals, this production will be inextricably tied to commodity

markets and metal prices, and continuing exploration to fully define known resources and to discover new resources. Good examples are the Wadi Sawawin iron deposit and the Ghurayyah Zr-Nb-Y-Ta-U deposit, both of which are severely challenged under current market supply conditions and also at current and anticipated future commodity prices.

Table 1
Summary of Metallic Minerals for Review

Orogenic Gold	Vein Au+Ag & Disseminated Au	Arabian Shield / Cenozoic Flood Basalt
VMS	Cu, Au, Zn, Ag, Pb	Arabian Shield / Cenozoic Flood Basalt
Cu-Ni-PGE	Magmatic and Other Deposits	Arabian Shield / Cenozoic Flood Basalt
Nb-Ta-REE	Intrusion-Related Deposits	Arabian Shield / Cenozoic Flood Basalt
Porphyry Copper	Porphyry-Type	Arabian Shield / Cenozoic Flood Basalt
Chromium	Ophiolite-Type Deposits	Arabian Shield / Cenozoic Flood Basalt
Porphyry (or vein) Sn-W-Mo	Intrusion-Related Deposits	Arabian Shield / Cenozoic Flood Basalt
Iron Ore	Layered Deposits	Arabian Shield / Cenozoic Flood Basalt / Arabian Platform / Red Sea Coastal Plain
Pb-Zn Outcrops	Hosted in Sedimentary Strata	Arabian Shield / Red Sea Coastal Plain
Thorium	All Deposits	Arabian Shield / Arabian Platform - Red Sea Coastal Plain

The potential of the aforementioned focus group (Au, Cu, Zn, Pb and Ag) is based on a clear understanding of the geological setting of these deposits, examples being orogenic gold deposits and volcanogenic massive sulphide ("**VMS**") deposits. However, as is the case with porphyry copper potential, our understanding of the geological setting of some classes of deposits in Saudi Arabia is imperfect, and while the settings are well known in some parts of the world, we have not yet demonstrated the viability of the model in the Kingdom. With this uncertainty in mind, we cannot address the question of potential with any clarity or conviction, but equally, we cannot dismiss these deposits types as impossible. Future exploration programs are warranted and they must assist in building the geoscience information base as well as providing practical information relating to exploration and economic geology.

1.5 ASSESSING AND MODELLING MINERAL POTENTIAL

Some of the minerals (metals) found in Table 1 occur in mineral belts, defined by an association with either a structural zone or a specific sequence of rock formations. These minerals were initially assessed in respect to the geographic distribution of the belt on a prospect by prospect basis. As all the prospects within the belt subscribed to the same metallogenic model, individual prospects could be compared to assess relative favourability, notwithstanding differences in the level or quality of previous exploration. Other minerals or deposit types were found to occur in association with specific rock types that do not occur in belts. These mineral prospects were assessed as single population to identify individual occurrences that had greater potential then their peers.

For those prospects occurring in well defined mineral belts, EMINERS software, developed by the United States Geological Survey ("**USGS**"), was used as a tool in estimating the resource potential of the various gold, VMS base metal, and Ni-Cu-PGE belts in the KSA. The software requires the user to name the mineral belt to be evaluated and to choose an appropriate metallogenic model for the expected type of mineralization. The user is also required to in-put the number of new deposits that is expected to be found with continuing exploration, as well as the potential for no new deposits to be discovered. EMINERS generates a probabilistic outcome estimating the resources in total tonnes and contained metals for the number of predicted deposits at various levels of confidence: 10%, 50% and 90%.

WGM evaluated the basis for the EMINERS metallogenic models and found certain aspects of the models to contain in-puts not relevant to the Saudi context. In consultation with geologists at the USGS in Denver, Colorado, WGM modified the models to allow improved alignment with Saudi geology such that the results generated closely resembled the known deposits in the Kingdom. In this manner, the evidence offered by known mineral deposits (mines) in the Kingdom was used to gauge the EMINERS outputs. The predicted resources (tonnes of ore and contained metal) were allocated between the estimated number of new deposits (mines) in accordance with evidence provided from other deposits in the KSA and globally. This generated a list of undiscovered mines within each mineral belt.

In general, WGM concluded that the 50% base case confidence level was under-estimating the potential resources, and that the 10% confidence level offered forecasts that could better accommodate the known deposits in the Kingdom. WGM believes that the actual potential is vested somewhere between the 50% base case scenario and the 10% outcome, and favouring the 10% outcome. WGM realizes that this view may seem overly optimistic, however, experience in mineral belts in Canada has clearly shown that a great amount of time is required for the full potential of a belt to be realized, and so this view must be considered in the context of long-term exploration investment. In practical terms, the mineral wealth of the KSA will not be unlocked by any date selected arbitrarily, and can only be unlocked through continuing, persistent and systematic exploration.

For those prospects that do not occur in well defined belts, WGM used a weight-of-evidence approach to assess the potential for new deposits based on the available geoscience and mineral prospect information. This approach allowed WGM to assess the likelihood of continuing exploration to discover economically interesting mineralization. In instances where substantial exploration has been completed, and no economically viable deposit has been found, WGM concluded that the potential for a mineable deposit was very low, probably nil. If the exploration base was inconclusive for reasons of improper historical techniques, lack of appropriate testwork or the prospect had not been sufficiently tested, WGM recommended additional exploration as a means of continuing the work on a mineral commodity that might at some time be discovered in an economically viable deposit. For those minerals where a significant sub-economic deposit exists, WGM weighed the potential for additional deposits based on the assumption that on-going exploration could elevate the existing deposit to the level required to exceed the threshold of economic viability. Only one deposit type, limestone hosted zinc-lead mineralization along the Red Sea Coastal Plain, enjoyed a positive result from this analysis.

1.6 POTENTIAL FOR METALLIC MINERALS

The metallic minerals assessed during this study are listed in Table 1. In this study, the potential for new gold, VMS-type base metal and Ni-Cu-PGE deposits in each of these belts is influenced positively by:

- the presence and distribution of existing mines or feasibility-level projects;
- an abundance of similar mineral occurrences irrespective of individual status;
- strong spatial associations between known occurrences and geological features that characteristic each deposit model;
- geological favourability on a prospect level based on known factors and compatibility with recognized deposit models;
- strong historical exploration results, and the current status of known prospects; and,
- the overall dimensions of the belt, with size being a favourable feature.

Not all mineral belts enjoy a complete set of favourable features, however most are present in one way or another. At this time, the number of belts having a producing mine is relatively low compared to the number of belts identified. This is an artifact of the relatively low level of exploration in the Kingdom compared to other mature mining areas, and the number of belts lacking a mine should be looked upon as an indicator of high potential for new discoveries.

The number of new (undiscovered) gold mines is summarized in Table ES-1 and the 50% base case probability outcome is highlighted. Using these results on a belt by belt basis, and rounded to the nearest number of complete deposits, WGM re-assessed the geology and attributed the predicted resources to open-pitable and underground mineable deposits (Table ES-2). The 50% base case scenario results in an overall average grade of mineralization that is similar to what current mines are achieving in the region. The result also produces open pit mine grades that approximate what Ma'aden is mining at the moment and UG grades that are economically interesting. The deposits shown in the EMINERS model have an average size of 41.4 Mt grading 1.69 g Au/t. The Saudi examples in the model are slightly smaller and lower grading with an average size of 31.3 Mt and an average grade of 1.48 g Au/t. Effectively, the model suggests that larger Saudi deposits have yet to be discovered. Certainly there are giant deposits in the Arabian Nubian shield such as Sukari (Egypt) with resources of 174 Mt grading 1.27 g Au/t and Hassai (Sudan) containing 34.5 Mt averaging 2.62 g Au/t.

Table ES-1
EMINERS Model for Orogenic Gold in the KSA

Confidence Level	Number of New Deposits	Total (Global) Resources			Gross In-Situ Value (US $) [1]
		(Mt)	(g Au/t)	(Ounces)	
10%	67	2,632	1.38	117,028,548	$145 billion
50%	46	941	1.80	54,398,984	$67 billion
90%	30	260	2.07	17,268,142	$21 billion

Note: [1] gross in-situ value is based on long-term commodity prices supplied to WGM by McKinsey as follows: Gold @ $1,225/ounce ; Silver @ $20.20/ounce

Table ES-2
Base Case Gold Resource Allocation Summary by Mine Type Using EMINERS Projections

Mine Type	Number of Mines	Global Resources		Average Deposit		
		Tonnes (millions)	Ounces (millions)	Tonnes (millions)	g Au/t	Ounces (millions)
Open-Pit	35	853.4	39.9	23.7	1.45	1,108,069
Underground	11	87.6	14.5	6.7	5.15	1,116,040

The predictive modelling of VMS Cu-Zn-Pb-Ag-Au deposits followed the same principles as used for the gold belts except that evidence indicates that these will be underground mines. Empirical observations regarding VMS deposit sizes, grades and mineral belt areas by various authors were used as a generalized guide in evaluating the results. For example, Sangster (1980) made a quantitative study of Archean and Proterozoic VMS mineral belts, and he concluded that the mineral belts have an average diameter of 32 km, containing an average of 12 deposits (density = .016 deposits/km^2). Other studies by Boldy expanded upon the resource distribution trends within belts. These studies, showing that the median deposit size of a producing mine is 1.8 Mt of base metals with a grade of approximately 6% (Cu+Zn+Pb), were used as a guide to assessing the EMINERS outcomes. The base metal resources are unevenly distributed in a VMS belt, with the largest deposit containing 67% of the total resources of the belt, and the remaining deposits allocated resources in diminishing amounts: 13%, 7.8%, 4.9%, 3.5% and 1.8%. The largest mineral deposit in a typical mineral belt would contain about 3.1 Mt of base metals which would be approximately equivalent to Boldy's (1977) upper mid-decile deposit containing 50 Mt of ore grading 1.94 % Cu, 4.82% Zn, 1.03 g/t Au and 62.4 g/t Ag. These deposits occur with a frequency of 4%. The second largest deposit would contain 0.598 Mt of base metals which would be approximately equivalent to Boldy's arithmetic average deposit containing 8.9 Mt grading 1.95% Cu, 4.51% Zn, 1.03 g Au/t and 52.8 g Ag/t. These deposits occur with a frequency of 7.5%.

At the 50% confidence level, EMINERS predicts that most of the belts will contain zero (0) to 21 Mt of base metal resources, and therefore they will not exceed the content typical of a mature VMS mineral belt. At the 10% confidence level the simulation estimated that the available undiscovered ore tonnages varied

from 4 Mt to 120 Mt, and that 12 of the 15 mineral belts will meet or exceed the total base metal content threshold of a mature VMS mineral belt. This indicates that there is significant freedom in many Saudi VMS mineral belts for the discovery of an upper quartile deposit (~3.7 Mt) or an upper decile deposit (~13.3 Mt), and even the discovery of a mid-upper decile deposit (~50-80 Mt) is possible. In contrast to the higher confidence results, the predictions at the 10% confidence level are more in line with what is currently seen in the Arabian-Nubian Shield.

The outcomes from the EMINERS conditional simulation are totalled and summarized for the 15 delineated VMS mineral belts as follows Table ES-3 for all confidence levels. For economic viability modelling, WGM selected the 50% confidence outcomes as its base case.

Table ES-3
EMINERS Model for VMS Base Metal Deposits in the KSA

Confidence Level	Number of New Deposits	Global Resources (Mt)	Global Resources (Contained Metal)					Gross In-Situ Value (US $) [1]
			Cu	Zn	Pb	Au	Ag	
			(tonnes)			(ounces * 1,000)		
10%	98	1,284	13,148,000	30,536,000	6,296,900	21,637	958,478	$222 billion
50%	45	189	2,234,000	4,383,900	448,900	1,865	95,938	$31 billion
90%	17	7	118,100	79,000	0	0	482	$1.1 billion

Note: [1] gross in-situ value is based on long-term commodity prices supplied to WGM by McKinsey as follows:
Copper @ $7,535/tonne; Zinc @ $2,161/tonne; Lead @ $1,754/tonne; Gold @ $1,225/ounce ; Silver @ $20.20/ounce

It is important not to falsely link potential with economic viability. Median sized VMS deposits (1.8 Mt of ore) and even modal-sized deposits (0.39 Mt of ore) may be economically viable depending on many factors such as location, infrastructure etc., and not every mineral belt will contain upper quartile or mid-upper decile sized deposits. An example of this is the Confederation Mineral Belt in Ontario, Canada where 19 VMS-type deposits and occurrences have been discovered, however only the largest at South Bay (1.59 Mt grading 1.84% Cu, 11.4% Zn, 72.2 g Ag/t) was ever mined.

In assessing the outcomes of EMINERS modeling, WGM concluded that it would be wrong to assign and potential for undiscovered deposits to a single confidence level. While choosing the 50% level provided a degree of safety or comfort, there is a likelihood that in some belts the 10% outcome will occur and in other belts the 90% outcome will occur. WGM's estimates for the number of undiscovered deposits were based on the number of quality prospects in each belt, yet the belts are not equally explored and this results in several fundamental questions such as: Is it reasonable to conclude that the Ar Rayn Belt has no potential for a 10 Mt deposit because the 26 Mt Khnaiguiyah deposit has already been found and this exceeds the maximum size limit for the predicted new discoveries in the belt? Unlike for the gold deposits, WGM concluded that an adaptive approach was probably best suited to predicting the resources for any given belt, however like that for gold, WGM concluded that on balance the best prediction lay between the 50% and 10% outcomes.

Three Ni-Cu-PGE ("**NCP**") belts were modelled by EMINERS using the same basic protocols as were used for the VMS-type deposits and with the understanding that the geometry of the deposits would dictate that any new mines would be developed as underground operations. There are no nickel deposits in the Arabian Shield with a significant mineral resource so the output from EMINERS modeling cannot be as reliably verified as is possible for gold and VS-type deposits. A summary of the results of WGM's probabilistic estimations and the EMINERS simulation data for the 3 delineated NCP mineral belts is presented in Table ES-4.

Table ES-4
EMINERS Model for Ni-Cu-PGE Deposits in the KSA

Confidence Level	Number of New Deposits	Global Resources (Mt)	Global Resources (Contained Metal)						Gross In-Situ Value (US $) [1]
			Cu	Ni	Co	Pt	Pd	Au	
			---------- (tonnes) ----------			---------- (ounces) ----------			
10%		66	539,000	747,000	106,000	124,423	221,197	96,774	$18 billion
50%	5.2	10	9,000	108,000	0	0	0	0	$1.7 billion
90%	0	0	0	0	0	0	0	0	0

Note: [1] gross in-situ value is based on long-term commodity prices supplied to WGM by McKinsey as follows:
Copper @ $7,535/tonne; Nickel @ $15,000/tonne; Cobalt @ $23,500/tonne; Platinum @ $1,350/ounce; Palladium @ $700/ounce; and, Gold @ $1,225/ounce

At the 50% level, EMINERS forecasts 5 new deposits with an aggregate tonnage of 10 Mt. The average grade calculates as 1.2% Ni and 0.1% Cu with no measurable Co, Pt, Pd or Au. This outcome is thought to be a good reflection of the current status of NCP project advancement in the Kingdom, however it probably is not a useful reflection of what might result from systematic and sustained exploration focused on this deposit type. In WGM's opinion, sustained effort should provide and outcome between the 50% and 10% confidence results. Discoveries are seldom made based on a single exploration program and it is only through persistent efforts, building new knowledge upon the foundation of older data, that new mineable deposits are assembled from smaller components. Individual orebodies may be found which by themselves are less than what is needed to sustain a viable mining operation; however the discovery of additional satellite orebodies in the proximity of the Jabal Mardah deposit would certainly change the economic outlook of this project. The Jabal Mardah project and others like it with a sub-economic resource base would be good places to begin the work needed to determine the true viability of this deposit type.

The EMINERS probabilistic approach was limited to the three aforementioned deposit types. One additional viable deposit type that occurs in a single belt was assessed using a weight-of-evidence approach: the Red Sea Zinc Belt. This belt is anchored by the marginally economic Jabal Dhaylan zinc-lead deposit, a limestone-hosted Mississippi Valley Type ("**MVT**") deposit south of Al Wajh. This deposit model is well known globally, and its prospective character is demonstrated in the region by examples on the Red Sea coast in Egypt and the Jabali Mine in Yemen. The geological setting of Jabal Dhaylan is classic in every respect. Given its MVT classification, it is WGM's opinion that the Jabal Dhaylan deposit with or without satellite deposits will be enlarged to approximately 10 Mt at 10% combined Zn+Pb, an

average size for such deposits globally. It is WGM's further opinion, based on clusters of similar prospects along the 350 km belt and the tendency for MVT deposits to cluster, that three additional deposits are likely to be found through sustained exploration. Based on the evidence provided, the predicted aggregate resources would total 40 Mt with an average grade of approximately 9% Zn and 1% Pb with anticipated silver grades of 10-20 g/t. These deposits would have an aggregate in-situ value of $8.7 billion. Further to this, the length of the belt offers a highly prospective target for on-going exploration. While the setting of the Red Sea rift basin is somewhat unique compared to other MVT districts, it is interesting to consider the 72 km long Viburnum Trend in Missouri which has production plus resources totaling some 369 Mt grading 5.4% Pb, 0.8% Zn, 0.12% Cu and 2.7 g Ag/t (USGS, 2013).

The remaining metals in Table ES-1 were assessed based on deposit model, geological setting, the presence of existing prospects, the level of exploration completed to date and commodity price trends. In some cases, such as for chromium, thorium and the light rare earth metals, no economic potential was offered by the known mineral occurrences in the Kingdom. In the case of other metals, varying levels of economic potential were recognized, contingent on continuing exploration making sizeable gains in respect to adding economically viable resources to existing prospects. This was true for two heavy rare earth prospects and a small collection of tin, tungsten and molybdenum occurrences. None of these currently offered a resource that was sufficiently defined in respect to size or grade to allow predictive modelling.

Considerable time has been spent on studies concerning the Ghurayyah Zr-Nb-Y-Ta-U deposit. It has often been referred to as a rare earth deposits, but it contains little such mineralization. Most recently, it has been explored by Tertiary Minerals Plc. of the United Kingdom as a source for Nb and Ta. Despite the promotional efforts of Tertiary with continues to refer to it as a "world-class deposit", Ghurayyah suffers from the same limitations that impact Wadi Sawawin: grade and mineralogy. Although the deposit is extremely large (>400 Mt), it is a very low grade source for all metals by global standards. Zirconium mines in Australia operate at 10X the Ghurayyah grade, and niobium is extracted from ores in Brazil with 3X the grade - these mines operate without a need to drill and blast the ore. While Ghurayyah's tantalum grade is interesting, higher grade sources are available and there exists considerable production capacity that is shelved at the moment. The yttrium grade is interesting, however the market is small. The processing of Ghurayyah ore would be extremely complex, but the single largest factor preventing development is the size of the niobium market, and the fact that Brazilian producers command 98% of global production from very low cost mines which have 50 years of reserves. Without a major change in mineral markets, which is extremely unlikely, WGM sees no potential for Ghurayyah to be developed in the foreseeable future. Any such change would act as a catalyst to re-start existing side-lined production, thus presenting renewed challenges to Ghurayyah.

Iron exploration has been a focus for the SGS for many years as a result of the discovery of the Wadi Sawawin deposit in the north-western Shield. Unfortunately, this deposit is quite small compared to its global peers and it is of marginal grade. Its development is further impeded by difficult mineralogy and high silica levels requiring substantial processing. The grade and metallurgical complexity of Sawawin preclude its development, and given the abundance of much higher grading ores, WGM sees no potential for this

deposit to be in production any time in the foreseeable future. Nevertheless, the geology of the belt of rocks which contains Wadi Sawawin is not well described in the available literature, and so potential may exist for additional deposits along strike. The existing knowledge of Wadi Sawawin does not allow one to make assumptions concerning the mineralogy of new deposits, and there is a chance that satellite deposits could have a more favourable composition.

In respect to mineral exploration, viable targets exist for porphyry copper deposits. One such target known as Suwaj is currently being tested by the SGS. Only in the last decade has the potential of the porphyry copper model been tested, and it is uncertain whether Suwaj or other prospects of this geological model will develop into an economically interesting deposit. Only continuing exploration and time will answer this question.

Lastly, in returning to gold, WGM looks to the Mahd adh Dhahab Mine and questions why greater attention has not been paid to epithermal mineralization. Many high-quality epithermal gold and silver targets exist in the KSA, yet few are explored. Even the Lahuf prospect, located only 11 km west of Mahd adh Dhahab has been only lightly explored. The same is true for the belt between the mine and Lahuf, and one can only ask the question, 'Why hasn't Ma'aden done more work here?'. If this mine and the prospect were located in a mature mining area, such as exists in Canada or Australia, it is safe to say that this belt would contain hundreds of exploration drill holes. Epithermal deposits tend to be isolated occurrences, and exploration needs to be directed at specific sites where such mineralization is possible. Much more work should be directed at exploring for this class of deposits.

1.7 ECONOMIC VIABILITY

The lack of economic viability of many of the metallic minerals (Cr, light REEs, Th, Fe, Nb-Ta-Zr) has been addressed in the foregoing section and will not be repeated here. The exploration potential for certain deposit types, porphyry-Cu, Sn, W, Mo and U is recognized but insufficient information exists to address the magnitude of the contribution that any of these might make to the Saudi economy. Immediate contributions are being made by gold and VMS-type (Cu-Zn-Pb-Ag-Au) deposits, and medium-term potential, contingent on future exploration, can be seen for additional contributions from magmatic Ni-Cu-PGE deposits and limestone-hosted Zn-Pb-Ag deposits.

While the gross in-situ value of the predicted undiscovered metallic mineral deposits has been reported in the foregoing section, gross metal value in the ground is relevant only to those who would compare mineral endowment on a national level. Metals cannot be extracted without incurring costs for discovery and significant costs for development and extraction. These costs may be compounded if the mine is found in a remote area that lacks infrastructure.

Using output from WGM predictive modelling, WGM modelled the deposits in each belt using its best estimate of production rates, processing options, capital costs and operating costs together with long term metal prices supplied by McKinsey to develop a financial model for each undiscovered metallic mineral

mine. The predicted mines were represented by open-pit and underground gold mines, underground mines on VMS-type deposits, open-pit Ni-Cu-PGE mines and open-pit zinc-lead-silver mines. WGM based its analysis on the 50% confidence level (base case) scenario, however WGM recognizes that this approach almost certainly under-values the resources by a significant margin as might be indicated by the difference in gross in-situ value of the under-pinning resources at the two confidence levels.

The **Orogenic Gold Belts** contain undiscovered gold resources that were allocated amongst the predicted number of deposits and subdivided into two groups: open-pitable deposits and those deposits likely to be mined predominantly as underground operations. In each case, the average grade was calculated to ensure that the grades were appropriate for the predicted types of mines. In this manner, the resources in the predicted underground mines were assigned a grade that was approximately 4-5 times higher than the resources assigned to an open pit operation. In total, 36 new open pit gold mines were predicted with and average size of 24 Mt grading 1.45 g Au/t and each containing 1.11 Moz of gold. The model predicted 13 new underground gold mines averaging 6.7 Mt and 5.15 g Au/t, containing 1.12 Moz of gold.

For all projects, irrespective of the metal, order-of-magnitude cost estimates were prepared for a range of typical mines in the Kingdom. WGM initially prepared personnel lists for typical small, medium and large mines, both open pit and underground: six lists in total. An annual throughput rate was selected that results in a mine life of approximately 10 years, although round numbers were chosen; for example 1 million tonnes per year or 750,000 tonnes per year. In the case of open pit mines, waste rock was modelled at a constant annual tonnage. Mining and maintenance personnel quantities were estimated based on a mining fleet analysis. For each mine, a few positions were assigned international salaries; for all other jobs filled by Saudi Nationals, wages and benefit estimates were based on the 2014 SGS report “Directory of Mining Services Cost in Saudi Arabia”. Quantities of consumables were prepared for each of the six models. Costs were prepared using information from WGM data sources and aligned for the Saudi context. Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine sites. Table ES-5 illustrates the equipment list required for a typical open pit gold mine, and this list also served as a base reference for other open-pit mines examined in this study. Personnel requirements for the Mining Department at a typical open pit gold mine are shown in Table ES-6. This gold mine is modelled at 1,500 t per day of ore with 7,500 t per day of waste rock for a total of 9,000 t mined per day, 7 days per week. The bench height could range from 5 m to 10 m and the haul road allowance is 25 m wide.

Capital cost estimates for Mining were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM and BBA data. The processing options considered were dependent on the metal. For gold, either whole ore cyanide-leaching or flotation followed by cyanide-leaching. Gravity recovery in the grinding circuit was included in both flowsheet options. In low grade cases, heap-leaching was considered as the processing option. In the absence of any metallurgical information, the whole ore cyanide leaching was used as the process option

In the interest of water conservation, 80% water recirculation was assumed along with filtration and dry stacking of tailings. Estimates for reagent consumption and major consumables for the process are based on industry norms. Processing and maintenance personnel requirements were based on international salaries in the lead and management roles and for all other jobs filled by Saudi nationals, wages and benefit estimates were based on the above-mentioned SGS report. Consumables prices were estimated using information from WGM data. Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine site costs for Processing. Processing capital cost estimates were prepared for each cost model. Estimates were based on the data sources available to WGM and its partners on this project.

Table ES-5

Typical Major Equipment Fleet – Open Pit Gold Mine

Item	Description	Quantity
Excavator	$10m^3$	1
Wheel Loader	$11m^3$	1
Truck, Haulage	91t	6
Wheel Loader, stockpile, etc.	$3.5m^3$	1
Drill, Production	229 mm, medium capacity	1
Dozer, Track	39t	1
Grader	4.3m	1
Crawler Drill & Compressor	Perimeter drilling	1
Water Truck	Medium	1
Service Truck	Standard	1
Mechanic Truck	Standard	1
Pick-Up Truck	Standard	7
Lighting Tower	Standard	3

Table ES-6

Typical Personnel Roster – Open Pit Gold Mine

Responsibility Level	Number	Responsibility Level	Number
Mine Superintendent	1	Mine Engineer	2
Mine Foreman	4	Surveyor	2
Clerk	2	Mining Technician	2
Shovel/Excavator/Loader Operator	8	Geologist	2
Haul Truck Driver	24	Sampler	2
Production Drill Operator	4	Maintenance General Foreman	1
Production Drill Helper	4	Maintenance Foreman	4
Heavy Equipment Operator	20	Maintenance Planner	1
Relief Operator	6	Heavy Equipment Mechanic	9
Blaster	1	Welder	4
Blasting Crew	2	Light Vehicle Mechanic	2
Service Truck Driver	2	Tool Crib Attendant	4
Labourer	3	Maintenance Assistant	4
Mine Technical Superintendent	1	**Total - Mining - Open Pit**	**121**

Each mine was considered as a typical remote location and self-contained with an accommodation village for personnel and diesel power generation along with the facilities necessary to mine and process the

deposit and carry out the associated maintenance. General and administrative ("**G&A**") costs were estimated to reflect all the operating costs inside the mine gate including security, insurance, and environmental costs. Personnel costs and consumables costs were combined to provide an estimate of the operating cost per tonne for G&A. G&A capital cost estimates were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM and BBA data.

For gold, the 12 general cost models (six mine types with two processing options) were then used to guide the preparation of individual cost models for 16 deposits that have advanced information on tonnes and grade. Some of these have recent Feasibility Studies or Preliminary Economic Estimates with estimated plant feed tonnage and grade, open pit waste:ore ratio, mining fleet based on haulage profiles, and/or reagent quantities based on industry averages.

The undiscovered gold projects are assumed to produce gold bullion which is sent to a refinery for final smelting and refining. The model assumes a 1% of revenue charge for the smelting and refining of the gold bullion.

Of the 47 gold mines modelled 41 exceeded a 10% internal rate of return ("IRR"), ranging from 10.1% to 61.1%. These 41 mines had an average IRR of 21.6%, with an average net cash flow ("NCF") of approximately US $36.52 per tonne of ore and an average life-of-mine net cash flow of $356 million, or a total of $14.9 billion for all projects.

WGM's sensitivity analysis examined changes in project IRR, NCF and Discounted NCF in response to changes in metal prices and operating and capital costs, run from -40% to +40% to reflect the accuracy of the input data and to determine how robust each project is. In general, the IRR remains positive until the gold price is reduced by approximately 35% to $800. In other words, even at $800 gold, the project would break even and the original capital investment returned. The project is less sensitive to operating and capital costs and if either is raised by 40%, the IRR would still be approximately 10%. In all cases the changes in capital costs have a greater impact when discounting as most of the capital costs are incurred at the beginning of the project.

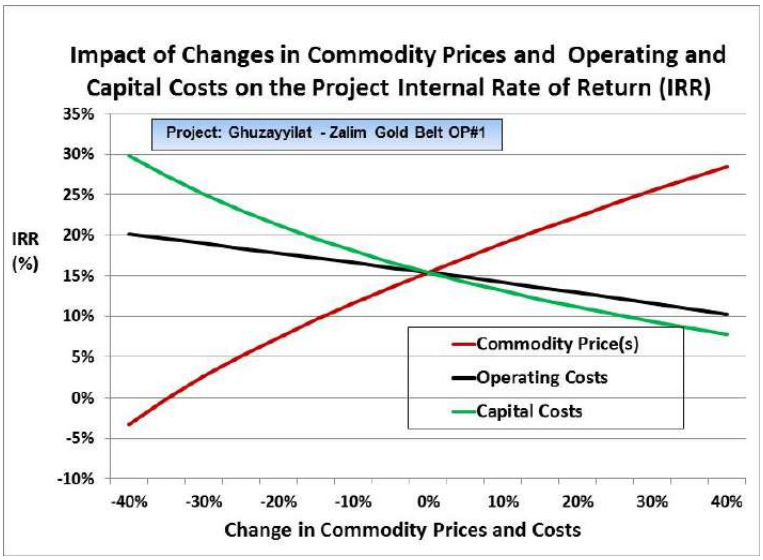


Chart ES-1: Example Spider Diagram of IRR Sensitivity Analysis for Mine Operation #1 in the Ghuzayyilat-Zalim Gold Belt

Like with gold, the **Volcanogenic Massive (base-metal) Sulphide ("VMS") Belts** contained a significant number of deposits. Only underground mining operations were modelled for these deposits, with an on-site concentrator producing copper and zinc concentrates. Equipment requirements are summarized in Table ES-7. Gold and silver that is typically present in this style of mineralization would be recovered for credit in the concentrates. Lead contents were not economically significant.

Table ES-7
Typical Major Equipment Fleet – Underground VMS Mine

Item	Description	Quantity
Production Drill	89 mm	1
Development Jumbo Drill	1 boom	1
Rock Breaker	Hydraulic	1
Load-Haul-Dump machine	7 t	2
Truck, Haulage	30t	3
Truck, Haulage	15 t	2
Rock bolting rig		1
Scissor lift truck		2
Explosives Truck		1
Grader	Underground	1
Service Truck	Standard	1
Utility Vehicle	Standard	8

Capital cost estimates for Mining were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM and data from its partners. The following tables illustrate the equipment and personnel requirements for the Mining Department at a typical underground mine. The mine is modelled at 1,000 t per day of ore, 5 days per week. Long-hole open stopes are assumed, with trucks hauling the ore up an access ramp to surface.

Mining and maintenance personnel quantities were estimated based on a mining fleet analysis (Table ES-8). As with gold mines, quantities of consumables and related costs were estimated using price information from WGM data sources and the project library. Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine site costs for mining.

As with the gold deposits, each of the mines was considered to be remote and developed as a self-contained site with camp accommodation for the workforce and a diesel power generation facility. The undiscovered VMS base metal projects will produce a copper and a zinc concentrate where the copper concentrates also includes payable gold and silver. The anticipated process flowsheet would consist of two flotation circuits in sequence to recover the metal concentrates which would be filtered and dried prior to shipment from the site. In the interest of adapting the mill capacity to satellite deposits that may be trucked to the concentrator, parallel process lines at 50% of the mill capacity were included in the flowsheet of the medium and large-scale concentrators. WGM has included typical mining industry smelter contracts to calculate the "Net Smelter Return" to the project. Operating costs were estimated based on the development of personnel requirements and major consumables for each mine site. Capital costs were developed from WGM and BBA data for similar operations.

Table ES-8
Typical Personnel Roster – Open Pit Gold Mine

Responsibility Level	Number	Responsibility Level	Number
Mine Superintendent	1	Mine Engineer	2
Mine Captain	3	Surveyor	1
Shift Boss	6	Mining Technician	2
Clerk	3	Geologist	3
Jumbo Drill Operator (Prod. & Dev.)	9	Sampler	3
LHD - Truck Driver	21	Maintenance General Foreman	1
Rock Bolter	12	Maintenance Foreman	3
Relief Operator	4	Maintenance Planner	1
Blaster	6	Heavy Equipment Mechanic	8
Service Truck driver	3	Welder	3
Services Miner	12	Automotive Electrician	1
Mine Labourer	32	Maintenance Assistant	16
Mine Technical Superintendent	1	**Total: Mining Underground**	**157**

In order to assess the economic viability of each project, WGM created an Excel spreadsheet that integrates ore resources, grades and metal recoveries, capital and operating costs into a single economic model. This model includes calculations for depreciation of the capital infrastructure, corporate taxes payable to the government, various economic parameters including earnings before interest taxes depreciation and amortization ("**EBITDA**"), internal rate of return ("**IRR**"), net cash flow ("**NCF**") and net present value ("**NPV**") at various discount rates etc.

The model also captures material consumption data including diesel fuel, explosives, electrical consumption, water consumption, specific processing consumption including cyanide, lime and grinding media.

Of the 52 VMS base metal mines modelled, 49 showed a positive IRR, ranging from 22% to 66%. The belts these occurred in produced average IRR's ranging from 30% to 52%. The overall average IRR was 42%. Of this group, the average NCF per tonne of ore was US $76.82 with an average life-of-mine NCF of $1.15 billion, or $56.4 billion for all projects.

In the case of the EMINER projects predicted at the 10% confidence level, WGM projected capital and operating costs by fitting curves to the original costs. While these are less accurate than the costs used in the 50% probability cases, WGM believes that they are sufficiently accurate to reflect the accuracy of the EMINER estimates themselves.

As with the predicted gold mines, sensitivity analysis was carried out to test the robustness of each project by increasing and decreasing the metal prices, and capital and operating costs by ±40%. Typically a project with a base 15% IRR will still be marginally profitable if the metal prices drop by 35% and will still be quite profitable even if operating or capital costs increase by 40%. The analysis demonstrated that the projects were the most sensitive to commodity prices, however even with a decrease of 40%, 21 projects remain positive and 12 of those generate an IRR exceeding 10%. In contrast, the projects remain profitable even if capital and operating costs increase by 40%. In fact with capital costs increased by 40%, the 49 projects remain positive and 48 generate an IRR in excess of 10%. Likewise for a 40% increase in operating costs, all 49 remain profitable and 43 generate an IRR greater than 10%.

Although WGM initially prepared personnel lists for typical small, medium, and large mines, both open pit and underground, six lists in all, only open pit mining was predicted for the undiscovered **Nickel-Copper-PGE ("NCP") Mines**. As with the gold and VMS projects, mining and maintenance personnel quantities were estimated based on a mining fleet analysis, and the same models were used. The undiscovered NCP mines are predicted to be open pit mines. An annual throughput rate with a low stripping ratio was selected that results in a mine life of approximately 10 years, although round numbers were chosen; for NCP mines either 500,000 tonnes per year or 100,000 tonnes per year. Mining of waste rock was modelled at a constant annual tonnage. All other cost data for personnel and consumables were in accordance with estimated for the other mine types.

The processing required for this style of mineralization has a sensitivity to the grade-recovery relationship and usually requires production of one low-grade concentrate (12 to 15% Ni) to achieve economic recovery of the nickel. The requirement to fine grind the ore to allow production of a separate copper concentrate is usually not an option, and the one concentrate produced will contain Ni along with some Cu and PGE's which unfortunately are likely to provide no identifiable credit in the smelter returns. In other words, the smelter will simply take the value (credits) received from these associated metals into its own revenue stream. The flowsheet used will have a crushing and grinding circuit followed by a multiple stage flotation

circuit producing a single concentrate for filtering and drying for transport from the site. The process would employ a high recycle of water and filtering and dry stacking of the tailings to reduce water consumption. The sites envisioned would be self contained with an accommodation camp and power generation as included in the gold and VMS projects detailed in the foregoing sections.

The EMINERs output for predicted Ni-Cu-PGE deposits was substantially different when comparing the 50% and 10% confidence levels. At the 50% base-case confidence level, the 3 undiscovered NCP mines modelled had an IRR ranging from 9.6% to 17.2%, and averaging 14.7%, or marginal at best. The average NCF per tonne of ore was US $36.00 with an average total life-of-mine NCF of $347 million. The nickel grades are also lower than usual for most operating nickel mines. On the positive side, these are forecast to be open pit mines which enjoy much lower mining costs. **This improved substantially at the 10% confidence level due to the addition of other metals (Co, Pt, Pd and Au) to the resource base and an increase in the size of the resource base. The number of mines also increased to 10, largely in the Wadi Kamal Belt. At this level of confidence the IRR ranged from 17.1% to 111.9%, and averaging 20%. The high value IRR is an outlier created by the Al Bajaydi Belt and represents a very small deposit with low capital investment due to its ore being processed at a separate mill. The average NCF per tonne of ore was US $39.77 with a total life-of-mine NCF of $2,437 billion for all the NCP mines.**

The WGM consensus view is that the **Red Sea Zinc Belt** has the potential to host 4 10 Mt deposits grading 9% Zn and 1% Pb with an average silver content of 15 g/t. On the basis of the existing geological evidence, WGM believes that all of these deposits would be open pit operations with relatively little overburden stripping. The order-of-magnitude mining cost estimates, equipment and mining equipment lists used previously for modelling open-pit gold mines were used in modelling these zinc-lead-silver mines, each initially containing 10,000,000 tonnes of ore and operating with a throughput of 1 million tonnes per annum resulting in a 10-year mine life. Mining of waste rock was modelled at a constant annual tonnage. As previously stated, mining and maintenance personnel quantities were estimated based on a mining fleet analysis, with a few positions assigned international salaries and all other jobs filled by Saudi nationals.

The type of mineralization present in the Red Sea Zinc Belt, often referred to as “oxide-zinc”, commonly requires extensive testing to determine the optimum flowsheet. Only limited metallurgical testwork has been completed at Jabal Dhaylan, and consequently there is no well defined processing route for the known deposit, or predicted deposits. Whole ore calcination followed by electric arc furnace (“**EAF**”) treatment and recovery of zinc and lead in condensers in the off-gases could become an economic treatment process for this style of mineralization. High grade zinc metal would be produced at the mine site as well as lead and silver metal. Although commercial applications of the technology are not available, studies completed by Mintec were referenced in considering application of this technology in the economics of the carbonate hosted Zn-Pb-Ag deposits in the Red Sea Belt. Capital and operating costs for the scale of projects considered were factored from the Mintec estimates that were reported to be + or - 50%. To reduce capital costs, WGM has assumed that a hydrometallurgical plant to produce zinc metal will not be constructed,

and that the mines will produce a high-purity electric arc zinc-oxide dust which will command a premium price.

Each mine was considered as a typical remote location and self-contained with an accommodation village for personnel and diesel power generation along with the facilities necessary to mine and process the deposit and carry out the associated maintenance. General and administrative ("**G&A**") costs were estimated to reflect all the operating costs inside the mine gate including security, insurance, and environmental costs. Personnel costs and consumables costs were combined to provide an estimate of the operating cost per tonne for G&A. G&A capital cost estimates were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM sourced data. The forecast metal prices were long-term estimates provided by McKinsey.

Individually, these mines show an IRR of 15% with a net cash flow of $65.91 per tonne of ore. On mine closure, the net cash flow ("NCF") to the mine would be $659 million. The group of four mines would generate approximately $2.64 billion in NCF. If the mines clustered in such a manner that the number of production facilities could be reduced through sharing, then the overall economics of the clustered mines would improve dramatically.

The results for Jabal Dhaylan show that the projects are likely to be cash-flow positive, and there is reasonable potential in the non-sulphide (oxide-type) Red Sea zinc deposits. However, judging by the information available, much work needs to be done especially in respect to metallurgical testing. The Jabal Dhaylan remains an exploration project at this time, arguably one of the better base metal projects in the Kingdom. Increasing zinc prices could lower the hurdle size and/or grade required for this deposit to be minable.

Lastly, for some minerals, knowledge of the specific industries is needed to adequately assess the potential for Saudi deposits to have economic viability. Depending upon the question being addressed and the region being assessed, the method requires knowledge of a variety of disciplines, including economic geology, regional geology, mining engineering, statistics and mineral economics. The economic geologist needs to have familiarity not only with the types of deposits that may occur in the KSA but also knowledge of the types of deposits currently being mined globally and the demands of the commodity markets. Examples of metals for which this is especially important in the Saudi context includes iron, niobium, tantalum, This is even more of a concern when assessing the industrial minerals or to evaluate value chain opportunities that may flow from mineral investments.

1.8 REALIZING THE POTENTIAL

This Mineral Potential Assessment has identified orogenic and disseminated (porphyry-type) gold projects, VMS-type base metal projects, Ni-Cu-PGE projects and the carbonate-hosted zinc-lead-silver projects as those having the greatest chance for success and making a measurable contribution to the national

economy of Saudi Arabia. The base case studies contained in this assessment, which used a 50% confidence level as a predictor, showed that the in-ground value of these deposits totals US $110 Billion using long-term commodity prices supplied to WGM by McKinsey. As stated in this report, WGM believes that both gold and VMS-type base metals potential are underestimated using the EMINERS software required for its analysis, and that evidence in the Saudi context shows that the 10% confidence level may more closely reflect the actual potential that will be realized with long-term, continuing exploration. If that is true, the in-situ value of the identified resources increases to $385 Billion.

The discovery of new mineral deposits is a difficult undertaking, and it is not made any easier by the need for mines to maintain production in the face of challenging commodity prices, such as exist in 2015-2016. In response to this challenge, many companies have ceased exploration or significantly reduced exploration expenditures as a cost-cutting tool. In making this decision, however, mining companies accept the long-term risk to maintaining their very existence in the face of diminishing resources and reserves. The focus can become a matter of concentrating on projects or deposits that are not challenged by metallurgical complexities or by market idiosyncrasies and requirements that place the mineral producer at a competitive disadvantage. While this is not much of a challenge for precious metal producers, it is a major concern for producers of many industrial minerals and specialty metals such as rare earths, tin, tungsten, molybdenum, niobium, tantalum, etc.

Giant ore deposits that can sustain long-lived operations and allow the amortization of exploration, development and capital costs are always a preference for explorers. They can also allow low cost production through bulk-mining methods and economies of scale. Such deposits include porphyry-type copper, copper-gold and copper-molybdenum deposits, porphyry-gold deposits, iron ore-copper-gold (“IOCG”) deposits, sedimentary exhalative (“SEDEX”) deposits, laterite nickel deposits and banded iron formation deposits. Explorers can also focus on smaller high-value deposits that can sustain operations despite commodity cycles such as Mississippi Valley Type and Irish-Type carbonate replacement zinc-lead-silver deposits and volcanogenic massive sulphide deposits. Unfortunately, giant deposits represent less than 1% of all deposits types, and the odds of finding a giant are greatly outweighed by the probability of fining a median-sized deposit.

Just as giant deposits are rare, they can also be extremely difficult to find. There is a presumption in some quarters that porphyry copper deposits are geologically simple yet the reality is that they can be quite complex and well hidden. Nature provides geologists with a vast landscape in which a mineral deposit is minuscule. Company managers prefer deposits that are relatively easy to find, and for this reason many companies do not search for MVT deposits – the sulphides do not respond well to conventional geophysical surveying, yet the opportunities created by a predictable geological environment, geochemistry and a tabular geometry are overlooked. The exploration strategies of large companies favour very large deposits because one measure of success is for the discovery to improve company revenues by at least 10%. However, for every large company with such high standards, there are at least 1,000 junior companies that simply want any discovery! Junior companies are opportunists. They are mobile, high-energy predators that will seize any opportunity. They welcome opportunities to discuss their projects and demonstrate their

success, and unlike many large and secretive companies, junior explorers know they don't have all the answers. They are reliant on external experts and they tend to forge a very symbiotic and co-operative relationship with geological surveys.

Over the past decade, well accredited studies[2] of the minerals industry in mature mining jurisdictions such as Canada, Scandinavia and Australia, have pointed to the close relationship between successful exploration and the availability of a solid geoscience foundation on which exploration programs are planned and executed. The building blocks of this information base are assembled from work carried out by sovereign geological surveys and from the work carried out by the Private Sector which is filed and comes into the public domain. The capacity of both Government and Private Sector to fund this work will vary with economic cycles, but both parties have a vital role in the research and development that sustains the industry overall. It comes as no surprise that regimes such as Canada and Australia, where geoscience and exploration information is readily available, are favoured destinations for investors. Even though excellent work is being done in Russia, for example, lack of access to such information and other barriers are sufficient to divert the flow of investment capital to more favourable destinations.

The trend in exploration over the last few decades is to make use of increasingly accurate, multidisciplinary data in a more holistic and integrated approach involving a very wide skill set. It has become vital to understand the intricate nature of the deposit models on which we base exploration programs; how the deposit type was formed and preserved, and how it can be detected in a variety of terrains. Given the need to explore for more deeply buried deposits, especially in mature exploration areas, understanding the subtle features that constitute an ore-field halo is also vital. Mineral deposits can hide, even close to surface, and the explorer is well advised to treat exploration models with the degree of latitude that they deserve.

The discovery of the Balboa copper deposit in Panama is a case in point for using models with a great degree of latitude, assisted by the development of new technologies. For more than 400 years, western explorers had recognized and exploited the copper deposits in this region of Panama. Balboa is the most westerly of 6 shallowly dipping tabular porphyry copper deposits. It was found by a company looking in an area that had not been explored previously, and using improved ZTEM electromagnetic surveying instrumentation which detected a previously unknown anomaly. The lesson is simple, you can't make a discovery if you are not searching, if the tools are wrong or you stop too soon. All procedures in the exploration tool box are worth considering: geology, prospecting, geochemistry, remote sensing and geophysics. Most deposits have complex signatures and they might well be overlooked if only one type of survey was used.

Deposits have been missed because the associated anomaly did not fit the model. Many discoveries have been made as a result of the misinterpretation of anomalies by those who explored before. Deposits have

[2] Studies by such organizations at the Prospectors and Developers Association of Canada, the Fraser Institute, the Australian Institute for Mining and Metallurgy, the Canadian Institute for Mining and Metallurgy and the Mining association of Canada.

been missed because the anomaly was tested and explained, but the deposit was off-set from the anomaly (e.g. Texasgulf's discovery of the Kidd Creek VMS deposit). Companies have also found mines, and even new deposit types, as a result of follow-up work on an anomaly that did not fit the exploration model. The very last and lowest priority anomaly to be examined was not in an area of sandstone cover and it did not fit the geological model, and yet the quality of the anomaly demanded follow-up. With winter arriving very soon, a team of student geologists was sent to the site and within minutes had discovered boulders of massive pitchblende mineralization.

Exploration must be a sustained effort, and prominent mining areas have faded in importance as result of neglect and the inability of explorers to develop and embrace new models. The Witwatersrand Basin in South Africa sustained the national economy for more than 100 years following the discovery of its gold in 1886 (Phillips, 2014). Production reached a peak of 1,000 tonnes a year during 1970, but has steadily declined since. Gold output has averaged about 20 tonnes a year over the last decade and production will probably end in 2022. The steady decline in production is attributable to exploration failure – no new mine has been discovered since 1951. This fact lies in sharp contrast to the Kirkland Lake gold camp in Canada. After nearly 100 years of mining, and the production of 37 million ounces (1,200 tonnes of gold) from 27 mines in the area, a junior company named Kirkland Lake Gold made an 8-million ounce discovery within the very heart of the former producing area by simply exploring a different geological model.

The effectiveness of a geological model can be measured in how successful companies are when using it. For example, the model for orogenic gold deposits has been substantially refined since the mid-1980s, and it is well known to most exploration geologists. This mineral potential assessment made wide use of the orogenic model to define prospective gold belts in the Kingdom. Ma'aden has been effective in the Mansourah area by deploying its exploration programs along the Nabitah Fault Zone which is a key geological prerequisite for orogenic gold in the KSA. Internationally, exploration companies have enjoyed significant success in exploring along similar structures in areas of Proterozoic and Archean Shield, recognizing that being on or adjacent to such structures is vital to success, and that the chances of success rapidly decrease away from such structures. Other deposits models are also useful tools for exploration, but many require additional inputs before the target can be easily defined. VMS-type models offer a proven approach to the exploration for copper-lead-zinc deposits. However, the effective use of the VMS model requires substantially greater geological and lithogeochemical in-puts than are required for orogenic gold, and geophysical surveying can be an important tool in the delineation of VMS-type targets for drilling. Understanding the nature of the target in all its complications is one of the most important aspects of effective exploration. This understanding guided Kirkland Lake Gold, mentioned previously, and it also guided Kefi Minerals in its recent discovery of the Jibal Qutman gold deposit near Bishah. Explorationists are seriously handicapped if the model is not well understood, or is based on a single "type-location" which is dependent on a geological setting that is unique or even controversial - trying to imagine another Norilsk or Sudbury nickel deposit is extremely difficult.

Mines are discovered by geologists who bring to a project all of the same positive and negative personality characteristics that surface in any commercial enterprise. Exploration success can best be achieved by in

geologists who are optimists. Some might say that success can only be achieved by those for whom the cup is always half-full, never half-empty, but this is too simplistic. Exploration is high-risk endeavor best undertaken by those who are well informed and capable of mitigating risk through the use of staged exploration programs using established industry standard practices. Exploration needs to be managed by realists who are optimistic, but it is no place for those who cannot see beyond risk and the possibility of failure.

Unfortunately, the outcome of many of the exploration projects carried out in the Kingdom have been constrained by factors that may not have been completely in the control of project managers. It is difficult to imagine a set of circumstances that would impel exploration geologists to turn away from so many excellent exploration targets so early in the exploration process. Yet this is what has happened repeatedly during the last five decades. The pages of this Mineral Project Assessment are filled with examples of projects that were abandoned too early. Most of these were gold prospects or VMS-type polymetallic targets or nickel-copper occurrences. In some cases, the exploration of specialty metal prospects has ended too soon, and it is impossible to know whether potential economic viability exists or not. In the case of the rare earth metals, specific prospects require additional exploration while other prospects have no economic potential under any foreseeable market conditions. In the case of porphyry copper mineralization, there is simply too little information at this time to make any meaningful assessment of economic viability, or even if this metallogenic model has any true potential in the Arabian Shield, although evidence suggests that it does. Some projects have been promoted repeatedly for decades because they are viewed as success stories, yet one can only ask the question, 'if they were such great projects, why are they not now in production?'.

Wood (2014) stated that "exploration is a bet that the money invested will create rather than destroy wealth". In citing the exploration success of Newcrest, Wood attributes the company's strong record to four factors:

- strong Board support for "organic growth," i.e., growth through discovery;
- a team of technically strong and creative geologists, focused on discovery;
- a willingness on the part of the team and of the company to accept risk; and,
- necessity – it was clear in mid-1991 that Newcrest had to discover additional ore within the next three years if Newcrest was to survive, and the company's exploration team was given a directive to discover 2 Moz of gold over the next three years.

Wood also emphasized the commitment of senior management to continuity of effort and the importance of persistence. In mid-1992, the company produced 600,000 ounces of gold worth about US $2.4 billion per year and it had a market capitalization of A $152 million. By mid-2007, 15 years later, Newcrest's market capitalization was A $7 billion, and the wealth created by its mineral production increased to more than A $160 billion. Newcrest grew through persistent and well funded efforts of highly skilled autonomous teams of exploration geologists that were dedicated to the task of finding new orebodies. The methods they used were not substantially different from those being used by many other companies, however Newcrest explored for deposits in areas where others had not gone. It developed a strategy for ensuring targets were adequately tested before moving on to newer prospects. The potential for a project to fail must

be not only recognized, but accepted as integral to the exploration process. It is knowing when to move on that avoids what Wood describes as "Gambler's Ruin". Saudi Arabia offers a huge number of under-explored targets that are prime for the approach taken by Newcrest. This strategy is rare in large companies, but it is common in junior and smaller companies. Citadel Resources was the catalyst for action at Jabal Sayid after Ma'aden held the licence for more than 20 years. Kefi Minerals seized the opportunity it recognized at Jibal Qutman and a mine was discovered within a few short years. Both Citadel and Kefi Minerals were new-comers to Saudi Arabia. These events reinforce the need for the Kingdom to find a means to attract junior companies, however the difficulties experienced by many in simply acquiring exploration licences has been a major factor in preventing the activity that is required to generate a vibrant exploration community. Junior companies are predators. They are led by hunters, not managers. In junior companies, creative thinking is encouraged. They have a low tolerance for bureaucratic red tape. Risk-taking is expected.

Successful explorers recognize that exploration is not a science, however, it must be based on science because only the scientific endeavours of organizations like the Saudi Geological Survey can provide the reliable geoscience information on which explorationists can base their decisions. Explorationists are tasked with one simple job – finding a mine. Newcrest recognized the simple fact that it would cease to exist if it did not find new mines. Survival has a way of focusing one's attention. Newcrest's geologists were dedicated to this sole purpose. Project turn-over is vital to achieving these goals. While persistence is important, geologists need to work within a system that requires a prospect to prove itself within a specific period of time or within a specific, structured exploration framework such that on-going pointless investments are avoided. Many successful companies require a project to prove itself within three exploration stages as follows:

1) regional reconnaissance to identify areas within which to focus;
2) detailed exploration programs dedicated to transforming anomalous areas to specific individual targets for drilling; and,
1) diamond core drilling.

If the program does not generate positive results at the end of the third program, the prospect is abandoned. The measure of success, however, must be realistic because it is extremely rare for a project to generate a mine-making discovery or drill hole intersection during the first exploration program. It requires great skill to recognize opportunity even when the analytical data is not as good as one might have expected. It is important that the amount of drilling be proportional to the size or number of targets being tested, and it is vital that such decisions be made by the team leader and not by corporate headquarters or those controlling the company's finances. Newcrest recognized this fact.

Prospectors and junior resource companies usually lack the technical knowledge and financial resources required to develop a prospect into an operating mine. Nevertheless, they have an almost endless capacity to accept risk, and a proven ability to turn significant profits by adding value to early level mineral properties, often by doing no more than generating some interesting results and making larger companies aware of the potential. The potential for such rewards is sufficient to support a multi-billion dollar investment cycle in Canada that is centred on junior explorers.

According to Dietrich, former Manager of Evaluations for Noranda Inc., a major Canadian mining conglomerate, turning an inception-level prospect into an operating mine can be compared to a series of manufacturing steps. However, he differentiates it from manufacturing in that the mobility of capital is higher, the enterprise is much more speculative, risk is higher and product pricing is beyond the control of the operator. Exit costs for investors are negligible and therefore capital flows will quickly reverse should circumstances changes, a fact that many Governments have faced when they changed the rules to the detriment of investors. Within this framework it is therefore necessary to understand what projects will best support the ultimate goal, and to differentiate between those with a low probability for success and those for which the chances are better. All mineral deposits can be characterized by various target valuation models. The earlier that this is done the more likely we will be able to make quantitative decisions about the viability of our project. The physical processes inherent in a valuation model include determining the following major factors:

- if the resource potential is sufficient to support a mine over a reasonable life-span;
- potential cut-off grades and metallurgical challenges;
- mining and processing options and the potential capital and operating costs for each;
- likely market requirements, if any, and potential revenue streams based on commodity price forecasts;
- the impact of local supply, infrastructure and human resource requirements; and,
- the impacts of environmental and societal factors as well as taxes and royalties.

Through the use of some form of a scoping study or preliminary economic assessment to convert technical information into economic terms, the project owners should be able to acquire a vision of the mining operation, and then ask the following simple question:

"Does this mining project resemble other successful mines that exist in comparable jurisdictions?"

The answer should be positive, following which the owner/operator can then proceed with some confidence that a substantial amount of project risk has been eliminated. The sooner this valuation metric is achieved, the better if the company is to avoid pouring money into a project that will ultimately fail. The hurdle that a project must clear depends on the ambitions and requirements of the company. A major company may require a project to add to its revenue stream by at least 10% whereas a small company may simple wish to make a profit. The bar by which projects are measured therefore is relative, not absolute. The same argument can be made for governments seeking to develop their minerals sector. If they wish to be a top tier producer, they must focus on those projects most likely to achieve that goal, and push aside those projects that have little potential for success. This not the same as abandoning those projects because they will continue to exist, and in time they may become economically feasible due to changing market conditions or technological innovations that solve technical challenges. All explorers, whether Private Sector or Government Agencies, must be aware of the downstream commercial hurdles demanded of their projects such that they can focus on a portfolio of mineral properties that have the greatest probability of success.

As clearly stated in this report, the development of Saudi Arabia's mineral potential will require substantial, sustained investments guided by experienced industry professionals. The DMMR and the SGS have vital roles to play, not by trying to do all the exploration recommended in this report, but by providing a stable and efficient regulatory environment, and by building the essential geoscience framework within which private sector investors can participate in the exciting challenge of developing the Kingdom's mineral sector.

2. INTRODUCTION

2.1 STRUCTURE AND GOALS OF THE MINERAL POTENTIAL ASSESSMENT

The Mineral Potential Assessment is a component of the Comprehensive Mining Strategy Project ("**CMSP Project**") being undertaken by the Ministry of Petroleum and Mineral Resources ("**MOP**") in respect to the Mineral Sector in the Kingdom of Saudi Arabia as managed and administered by the Deputy Ministry for Mineral Resources ("**DMMR**"). The minerals industry is supported by a foundation of geoscience knowledge assembled and maintained by the Saudi Geological Survey ("**SGS**").

The Project is designed to examine the long term potential of the Mineral Sector to become a major contributor to the Saudi economy. Based on the Kingdom's mineral endowment, the outcomes of the project are intended to catalogue the mineral occurrences, prospects and deposits of Saudi Arabia to provide an improved information base documenting the potential of key minerals and mineral groups to contribute to the growth of the Saudi workforce and the economy.

Saudi Arabia's mineral potential vests in specific geological formations, and therefore it is geographically constrained to specific sites or belts. Mineral deposits are part of the natural landscape. The mines needed to develop and produce essential mineral products for the Saudi economy and to support our modern way of life cannot be moved. By identifying the likely location of major mineral belts, the Mineral Potential Assessment ("**MPA**") provides guidance to the MOP in respect to future infrastructure requirements to support mineral sector development. Equally important, knowledge of the location of mineral deposits provides essential information to planners in respect to urban development such that conflicting land use strategies can be avoided.

With the knowledge of future discoveries in the minerals sector, educators can examine the human resource requirements needed to support the growing mineral sector, both in respect to exploration and mining operations as well as the job families that derive from mid-stream and down-stream mineral production, including design and fabrication facilities. Beyond the basic value chain relating to mineral sector development, opportunities exist to identify how technology and innovation can be used to improve outcomes in the Saudi Minerals Sector, but this must be based on the knowledge of what mineral commodities are most likely to contribute to the economy, a natural out-flow of the MPA.

The potential growth of the mineral sector, as enunciated in this MPA, demands that government regulators be aware of potential developments such that guidelines can be developed by all concerned branches of the administration to ensure that mineral development is done in a responsible, sustainable manner. This requires a cohesive approach within the Saudi administration to eliminate performance gaps. With full knowledge of what is at stake in terms of economic development, as enunciated in the conclusions of the MPA, regulators must move to eliminate conflicts and overlaps in administrative procedures such that the "process" encourages rather than discourages investment. These centres of concern range from the

monitoring and management of exploration activities, to the design and licensing of mines and down-stream infrastructure, to guidelines for human resource deployment. The sustained investment needed for a vibrant minerals industry also requires information services and investment promotion, and the MPA offers insights into selected commodities that can be used to attract investors.

The proponents of this Project recognize that progress takes time and nothing will be accomplished "over-night". It is the desire of the authors of this MPA that knowledge will allow efficiencies, productivity and administrative procedures to be improved with resulting improvements in investment levels to allow a substantial improvement in the contribution of the Minerals Sector to the Saudi economy.

2.2 PREVIOUS ASSESSMENTS

2.2.1 SUMMARY

There have been several assessments and compilations of the mineral potential of Saudi Arabia. Some have been nation-wide studies, as with the Riofinex study named '**A Review of the Geology, Mineralization and Mineral Resource Potential of the Kingdom of Saudi Arabia**', 2-volume study initially published in 1984 (RF-OF-05-1). In 1986, it was republished as a 3-volume set under the same report reference number. That study was the first comprehensive review of more than 50 years of mineral prospecting, exploration and mining activity in the KSA. More than 2,000 documents were reviewed. Mineral sector work by the Saudi Geological Survey together with the USGS, the BRGM and the various other missions at that time was being transformed from science-focused activities to work that was more heavily weighted on mineral exploration surveys. Yet at the time of that study, no mines were operating in the Kingdom and only 2,208 entries were contained in the Saudi Mineral Occurrence Database System ("**MODS**").

At about the same time as the Riofinex study, Ian Clegg of the DMMR authored a compilation entitled '**A Summarised Compilation of Prospects Drilled by the DMMR and Private Sector 1366-1404 (1936-1984)**'. Although not strictly an assessment, this compilation of nearly 60 drilled targets was a very useful document that formed the basis of many subsequent assessments because it was a go-to document for actual exploration data, including drill hole assays.

Watts, Griffis and McOuat Limited ("**WGM**") was contracted by the DMMR to undertake a major review of exploration and geoscience activity carried out in Saudi Arabia since the earliest days of mineral sector activity. The study was carried out between 1989 and 1992 and resulted in the first complete review of the status, adequacy and effectiveness of previous project work programs. WGM made recommendations for additional exploration for those projects where the initial results were thought to be favourable. In many instances, WGM held projects in high regard that had been previously dismissed by foreign agencies. The

review resulted in the publication of more than 30 reports. One result of the review was the acquisition by Ma'aden of exploration licences covering more than 50,000 square kilometres on which the Bulghah, As Suq, Ad Duyawah, Mansourah, Masarah and Bi'r Tawliah gold deposits were discovered.

During 2001-02, WGM led a consortium of consultants that assessed the exploration potential of key mineral belts and evaluated the ability of the Kingdom to support the exploration required to properly explore and support the development of such mineral deposits that might be discovered. This study was a high-level overview rather than an estimate of potential resources, however it did examine the ability of the Kingdom to provide sufficient trained professionals to support exploration and mine development. The study included a review of existing infrastructure and identified areas where new infrastructure would be needed to support a growing industry. Experts also assessed the mining code and recommended changes to the Mining Law and Regulations to encourage mineral sector investment. Central to the recommendations was the principle that all companies exploring in the Kingdom must be accountable to the same set of rules as up to that time Ma'aden was exempt from work requirements on its licences. Another major recommendation was the privatization of Ma'aden to end its preferred relationship with government, a position that allowed it to act in a manner that unfairly competed with the Private sector. This comprehensive assessment assured the Deputy Ministry for Mineral Resources ("DMMR") that the KSA held tremendous mineral potential and was the catalyst for significant changes to the mining code and to Ma'aden's role in the Kingdom, much as recommended. Within one year, Ma'aden relinquished approximately one third of its exploration licences that it was no longer prepared to explore, and an up-surge in foreign and domestic interest in exploration led to dozens of new licence applications.

In 2008, the BRGM published '**A Summary Guide to the Metallic Mineral Deposits Map of the Arabian Shield, Kingdom of Saudi Arabia**' using the 1:1,000,000 scale map as a base. The document summarized the geology and categorized mineral potential according to nine major deposit types:

6.1. Base- and precious metals related to submarine volcanism (VMS type);
6.2. Cr-Ti-Fe-Ni-Cu (PGE) mineralization related to mafic-ultramafic rocks;
6.3. Sn-W mineralization related to peraluminous post-collisional granite;
6.4. REE-Th-U mineralization related to HFSE enriched granite and syeno-granite;
6.5. Porphyry-type Cu-Mo, Cu-Au and W-Mo mineralization;
6.6. Epithermal gold and base-metal sulfide mineralization;
6.7. Mesothermal gold veins related to faults;
6.8. Sedimentary Pb, Zn, Cu or Ni-Mo mineralization; and,
6.9. Ti-Au-W residual placers.

As a promotional document, this summary was probably of some value to those lacking knowledge of the geology of the KSA and seeking a brief overview, however it did nothing to advance exploration geoscience.

2.2.2 CHANGES TO THE INFORMATION BASE

As of the mid-1980s when the first country-wide mineral assessment was initiated by Riofinex, most of the Arabian Shield had been geologically mapped at 1:100,000 scale. The Phanerozoic rocks adjacent to the Shield had also been mapped, however the geology in large areas of the cover rocks remained poorly defined. This work actually divides into pre-1975 programs that were generally broad regional reconnaissance studies and post 1975 programs that were more systematic in assessing individual mineral occurrences.

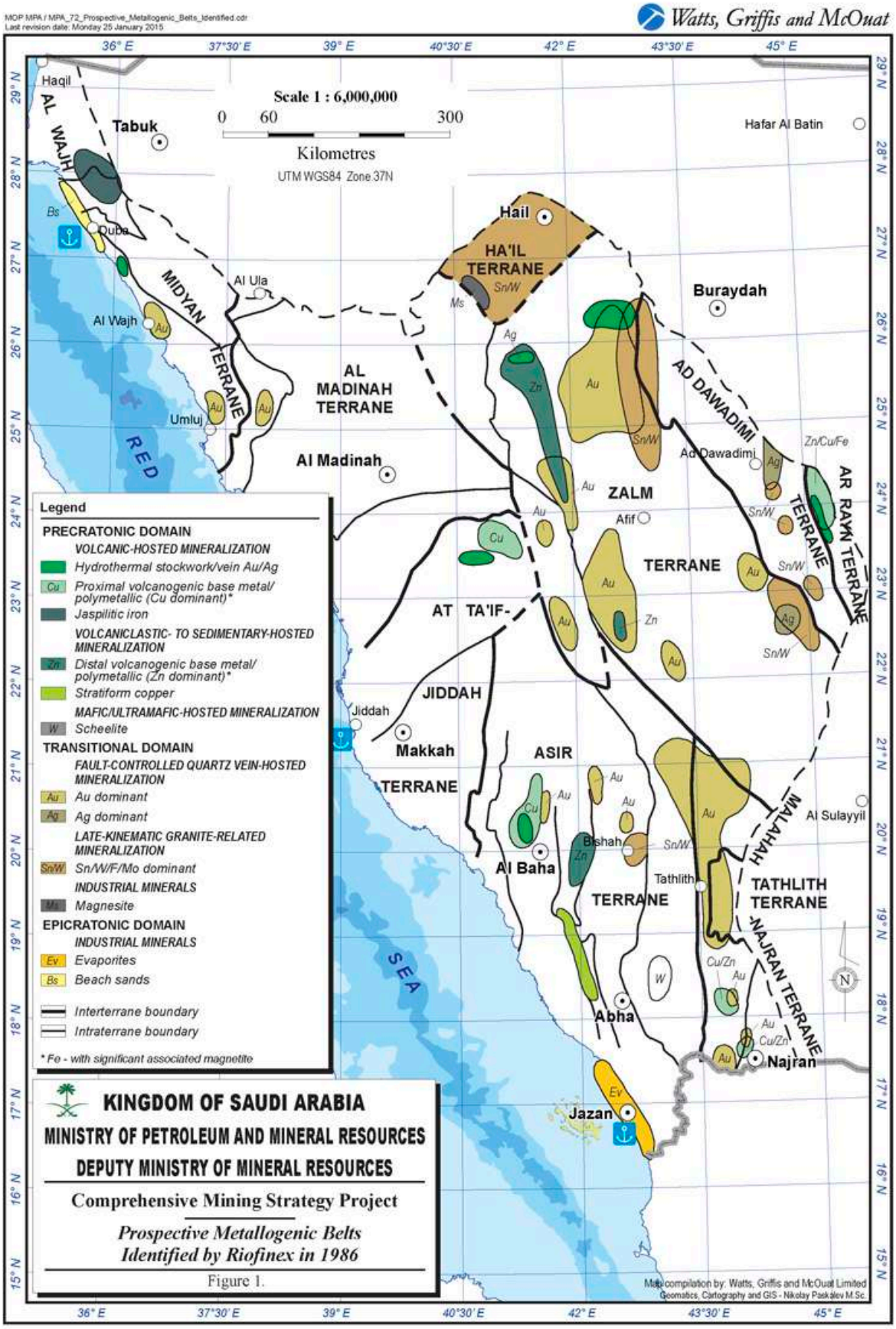
With increased activity during the latter part of the 1980s, the completion of the geological mapping and increased exploration activity resulted in a better understanding of the geological framework of the Arabian Shield and an improved understanding of the relationships between geology and various types of mineral deposits. This understanding benefited in part from global mineral sector activity that allowed old geological models to be challenged and new models developed and proven. This was especially the case in well endowed and active mining countries such as Canada, the United States, Australia, South Africa, Russia, Chile and Brazil. These new and amended models allowed for fundamental improvements in the geoscience information base during the late 1980s and 1990s. These changes are still on-going today, albeit at a slower pace. Improved data quality, from a wide variety of sources such as better equipped analytical laboratories and geophysical survey companies, geochronological labs, remote sensing technologies, on-site (hand-held) analytical devices or mineral scanners and GPS instrumentation have irrevocably altered our information bases and allowed for better interpretation of exploration and geoscience data. When data assimilation and processing is accomplished with the use of a powerful geographic information system ("**GIS**"), the various geoscience disciplines contributing to mineral exploration can be better integrated for more effective mineral sector investment.

2.2.3 OUTCOMES

Prior to the initial study by Riofinex in the mid-1980s, the mineral potential of the Arabian Shield was poorly understood and many important prospects were generally dismissed is being of little economic interest. Riofinex pointed out the fact that a significant amount of data had been collected, but it had not been adequately compiled for purposes of interpretation. Consequently, any mineral potential assessment was handicapped by significant elements of the geological framework that were yet to be developed. Riofinex recognized a series of mineral belts with moderate to high mineral resource potential as shown in Figure 1 and for the first time associated these targets with specific geological settings. The outcome of this was an improved understanding of the factors that were important for deposit formation, and which could be used as exploration vectors in the search for mineral deposits. WGM's 1989-1992 study expanded on this theme by bringing a very wide and varied set of exploration professionals to the assessment of the work completed. Where others identified limited or no potential, WGM identified enormous potential based on its better understanding of the exploration process and the geological framework. While WGM's view was

based on an optimistic outlook, that approach reflected the driving force that separates those who explore and make discoveries from others for whom a prospect is never good enough. Many of Ma'aden's best mines are in areas that were previously dismissed until recommended by WGM (e.g. Al Amar, As Suq, Mansourah-Bi'r Tawilah).

The reinterpretation of the geology of the Arabian Shield by Peter Johnson has provided a unified stratigraphic column whereas before there existed a confusing assortment of naming conventions (taxonomy) with several different names for the same rock unit depending on its location. Harmonization of the nomenclature not only eliminated apparent discontinuities, but it also provided better and simpler alignment of age relationships. These improvements have direct impacts on our understanding of the building blocks that make up the Arabian Shield as well as the nature of mineral events that give rise to economically viable mineral deposits. This again has provided a substantial improvement in the geological framework of the Arabian Shield.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Legend
PRECRATONIC DOMAIN
VOLCANIC-HOSTED MINERALIZATION
Hydrothermal stockwork/vein Au/Ag
Proximal volcanogenic base metal/ polymetallic (Cu dominant)*
Jaspilitic iron
VOLCANICLASTIC- TO SEDIMENTARY-HOSTED MINERALIZATION
Distal volcanogenic base metal/ polymetallic (Zn dominant)*
Stratiform copper
MAFIC/ULTRAMAFIC-HOSTED MINERALIZATION
Scheelite
TRANSITIONAL DOMAIN
FAULT-CONTROLLED QUARTZ VEIN-HOSTED MINERALIZATION
Au dominant
Ag dominant
LATE-KINEMATIC GRANITE-RELATED MINERALIZATION
Sn/W/F/Mo dominant
INDUSTRIAL MINERALS
Magnesite
EPICRATONIC DOMAIN
INDUSTRIAL MINERALS
Evaporites
Beach sands
Interterrane boundary
Intraterrane boundary
* Fe - with significant associated magnetite
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Prospective Metallogenic Belts Identified by Riofinex in 1986
Figure 1.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

2.3 PROCEDURES USED IN THE MINERAL POTENTIAL ASSESSMENT

2.3.1 INVENTORY OF THE INFORMATION BASE

The mineral potential assessment for metallic and non-metallic minerals commenced with a review of the project information base which contained approximately 3,900 files. Many of the files were scanned maps which were given to the review team as separate documents coded to the report from which they were sourced. The project library included 33 files covering WGM's review carried out during 1989-1992 as well as a representative assortment of 864 geological files comprising technical reports, maps and spreadsheets. Other data included 109 files made up of summary documents extracted from Ma'aden's technical reports and studies, and various third party reports including feasibility studies. A total of 91 files were provided concerning geochemical and other data for specific prospects – many of these concerned rare earth metals. Geological, hydrogeological, geophysical, geographic, aeromagnetic and topographic maps comprising 243 documents. The remainder of the information base was composed of reports and data files covering topics relating to other disciplines involved in the Comprehensive Mining Strategy Project such as talent and human resources, infrastructure, mine engineering, mineral processing, government statistics, environmental, health and safety, government policy and investment studies, Saudi standards, technical specifications, service companies, water and hydrology. The information base was summarized in an Excel "Reference File" which gave some information on 3,665 files such as its number, the type and size of the file, the file name, and in some cases the actual name of the report from which the file had been derived.

In order to expedite the review process, WGM quickly reviewed each file to determine its date of publication, title and key technical aspects. The Reference File was supplemented with additional bibliographic information as well as the names of any mineral commodities or prospects mentioned in the file. Each report was allocated to a specific geologist concerned with the review of the subject commodity. This ensured that each review geologist was made aware of the reference material available to him.

In some cases, WGM was aware of technical reports by the SGS or others surveys working in the KSA, such as the BRGM or the USGS, that were absent from the information base. Some of these were in the WGM technical library. When possible, WGM made use of these reports as well as other reports available on the Internet and authored by reputable geoscientists in accredited technical journals such as the African Journal of Earth Science and the Bulletin of the Society of Economic Geologists. WGM also identified reports to the project management group that should be available but were missing from the information base and these were then supplied to the project team.

2.3.2 THE GEOLOGICAL FRAMEWORK OF SAUDI ARABIA

Much of the following information was taken from Johnson and Al-Subhi (2007). Saudi Arabia may be subdivided geologically into two provinces, the Arabian Shield and the Arabian Platform (Figure 2). The Arabian Shield is that part of the Arabian Nubian Shield that was segregated from the Nubian Shield to the west by rifting and extension along the Red Sea. The shield extends south into Yemen, north into Jordan and east into Oman. The rock units and structures of the shield can be traced beneath the Phanerozoic cover rocks by means of magnetic anomalies up to 300 km from the margins of the exposed shield. The Arabian Platform comprises up to 10 km of layered Phanerozoic rocks that were deposited on the Arabian Shield and which extend easterly to the Arabian Gulf, south-easterly to the Arabian Sea and northerly into Syria and Iraq.

The Arabian-Nubian Shield is a composite terrane that is constructed from a number of individual blocks of older crust that converged and amalgamated into a single continuous block of Proterozoic shield. The layered (non-intrusive) rocks that comprise the shield formed at convergent plate boundaries and represent island/magmatic-arc assemblages that formed in a series of subduction-zone environments. These rocks are important hosts to VMS-type base metal deposits. Along the sutures joining these component parts, ophiolites represent younger oceanic-crust that was obducted along the collisional boundaries. Paleoproterozoic rocks exposed in the extreme eastern part of the shield represent continental crust. The Arabian and Nubian Shields are subdivided into a number of tectonic terranes reflecting the pre-amalgamation plates from which the shield was assembled. The exact number of terranes and the locations of terrane boundaries is a matter of some debate. Nine terranes are currently recognized according to Johnson and Al-Subhi.

Following the accretion of the Shield, subsequent relaxation, extension and faulting resulted in post-amalgamation volcanic and sedimentary basins into which late-Proterozoic sedimentary and volcanic rocks were deposited. These volcanic and sedimentary successions that overlie the older terrane-forming volcanic-arcs and plutonic rocks constitute an important tectonic marker in the shield. The resulting unconformities are evidence of crustal accretion, uplift and erosion, followed by subsidence, and they mark the stage in orogeny and crustal growth at which juvenile crustal units (volcanic and magmatic arcs) were sufficiently welded together by convergence, deformation and metamorphism to form youthful continental crust strong enough to support overlying basins. The basins are important as they created a setting for the emplacement of various plutonic rocks with which a variety of mineral deposits is related including porphyry-type gold, granite-hosted Sn-W-Mo deposits and Nb-Ta-REE-Zr deposits in highly evolved granites.

The perimeter of the Arabian Shield in Saudi Arabia defines an area of 727,000 km^2, however the exposed area of Precambrian basement crops out over an area of 441,181 km^2, this being smaller due to extensive areas of alluvial, harrat and Phanerozoic cover. Nevertheless, the Arabian Shield and its extensions into neighbouring countries, is one of the largest exposures of Proterozoic shield anywhere on the earth. The Arabian Shield constitutes a continental crust that is typically 40-45 km thick and is comparable to continental crust globally. Due to up-lift along the Red Sea Rift, the crust thins to less than 15 km at the

contact between the shield and the rift, and thickens to about 50 km at the subduction zone beneath the Zagros Mountains. The age of basement rocks in the shield ranges from late Archean (found in Yemen) to late Neoproterozoic. The oldest rocks in Saudi Arabia are Paleoproterozoic and the oldest in Jordan are about 820 Ma.

In terms of their general lithology the rocks of the Arabian Shield can be divided into:

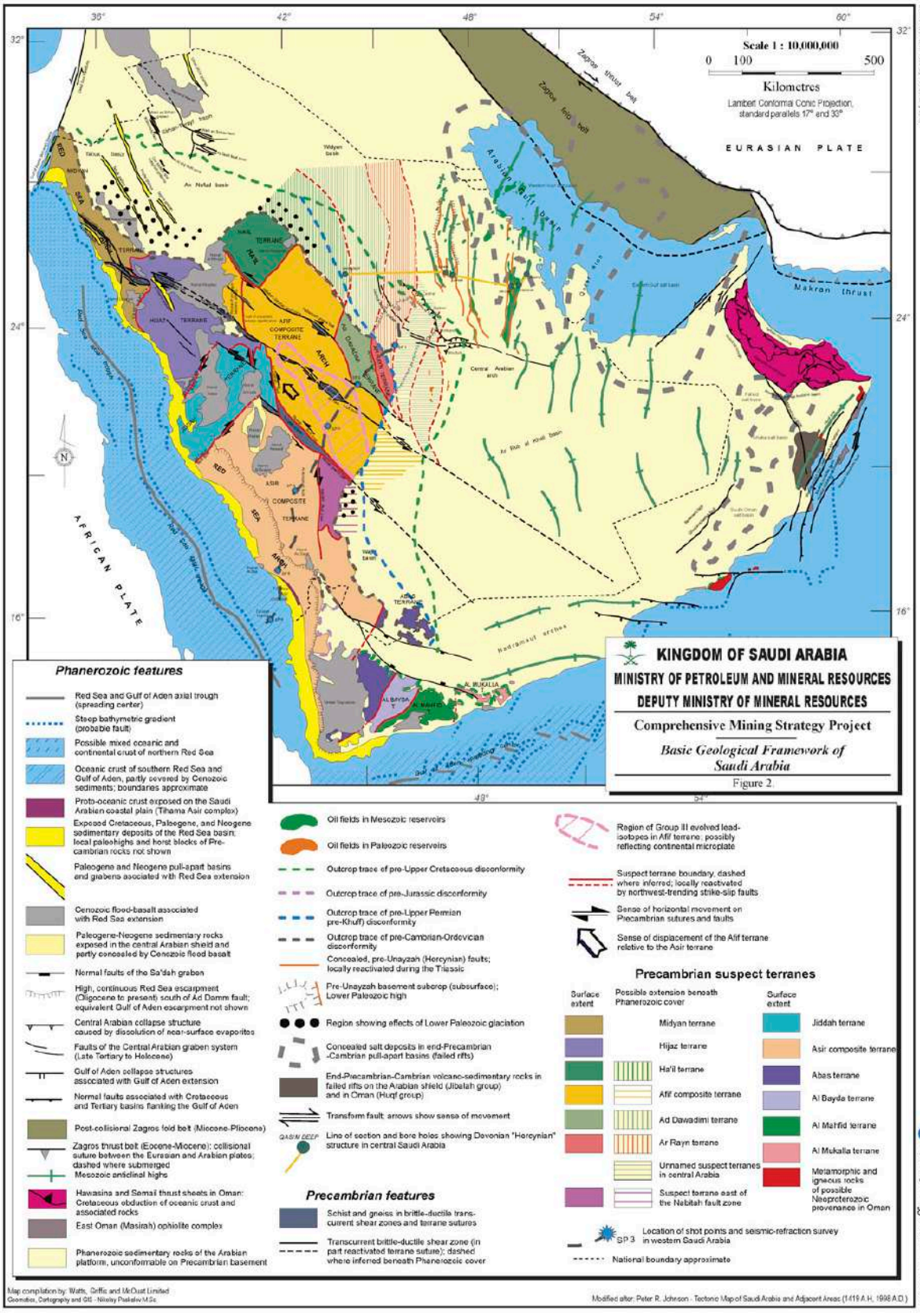
Plutonic Rocks - granite, granodiorite, diorite, and gabbro, and moderately metamorphosed and deformed equivalents;

Layered Rocks - a grouping of rocks in the Saudi geological literature encompassing volcanic, volcaniclastic and sedimentary rocks, and their low-grade metamorphic equivalents; and,

Schist and Gneiss - high-grade metamorphic and strongly deformed rocks, mostly derived from plutonic protoliths, but including some derived from volcanic and sedimentary sources.

The layered and plutonic rocks are widespread, comprising about 47% of the exposed shield. Schist and gneiss tend to concentrate along fault systems like those associated with the Najd faults and along the Nabitah Fault Zone. These structurally affiliated (orogenic) rocks are relatively minor in coverage (5.5%) and tend to crop out as mylonitic gneiss chlorite-rich schists or deformed (foliated) granitoid rocks. Intrusive rocks are abundant and widespread, making up 51 percent of the outcrop area of the shield. They are categorized as (1) granite, monzogranite, syenogranite, alkali-feldspar granite, and alkali granite, (2) granodiorite and tonalite, (3) mostly diorite, (4) syenite and monzonite, (5) gabbro and (6) ultramafic rocks. Overall, granitoids (granite, granodiorite, and tonalite) are the most abundant igneous rock types, comprising 81% of all the intrusive rocks. Ultramafic rocks (peridotite, dunite, harzburgite and their serpentinized equivalents) crop out in isolated, mainly linear belts. Aerially, they are a minor component of the shield (0.73% of the outcrop area of the shield; 1.4% of all intrusive rocks), but are important tectonically as markers of sites of subduction and suturing.

Many of the intrusive rocks in the shield were emplaced during the processes of terrane formation and terrane amalgamation - particularly those of calk-alkaline composition. These are commonly referred to as pre- or syntectonic intrusions. Vast amounts of granitoid rocks were emplaced also following terrane amalgamation and date between 650 Ma and 560 Ma. Generally referred to as "late- to post-tectonic", these of interest because of their association with mesothermal gold-bearing quartz veins, thorium-rare-earth element occurrences, and tin-tungsten mineralization. Late to post-tectonic granite, diorite, gabbro and syenite are also of interest as important sources of ornamental stone due to their massive and less fractured nature in comparison to older intrusions.


Scale 1 : 10,000,000
0 100 500
Kilometres
Lambert Conformal Conic Projection,
standard parallels 17° and 33°
EURASIAN PLATE
AFRICAN PLATE
Zagros fold belt
Zagros thrust belt
Makran thrust
Arabian Gulf basin
Central Arabian arch
Ar Rub' al Khali basin
Hadramaut arches
Red Sea rift
Dead Sea transform
ARABIAN SHIELD
ASIR COMPOSITE TERRANE
HIJAZ TERRANE
AFIF COMPOSITE TERRANE
MAHD TERRANE
HA'IL TERRANE
AD DAWADIMI TERRANE
AR RAYN TERRANE
ABAS TERRANE
JIDDAH TERRANE
AL BAYDA TERRANE
AL MUKALLA TERRANE
AL MAHFID TERRANE
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Basic Geological Framework of Saudi Arabia
Figure 2.
Phanerozoic features
Red Sea and Gulf of Aden axial trough (spreading center)
Steep bathymetric gradient (probable fault)
Possible mixed oceanic and continental crust of northern Red Sea
Oceanic crust of southern Red Sea and Gulf of Aden, partly covered by Cenozoic sediments; boundaries approximate
Proto-oceanic crust exposed on the Saudi Arabian coastal plain (Tihama Asir complex)
Exposed Cretaceous, Paleogene, and Neogene sedimentary deposits of the Red Sea basin; local paleohighs and horst blocks of Precambrian rocks not shown
Paleogene and Neogene pull-apart basins and grabens associated with Red Sea extension
Cenozoic flood-basalt associated with Red Sea extension
Paleogene-Neogene sedimentary rocks exposed in the central Arabian shield and partly concealed by Cenozoic flood basalt
Normal faults of the Sa'dah graben
High, continuous Red Sea escarpment (Oligocene to present) south of Ad Damm fault; equivalent Gulf of Aden escarpment not shown
Central Arabian collapse structure caused by dissolution of near-surface evaporites
Faults of the Central Arabian graben system (Late Tertiary to Holocene)
Gulf of Aden collapse structures associated with Gulf of Aden extension
Normal faults associated with Cretaceous and Tertiary basins flanking the Gulf of Aden
Post-collisional Zagros fold belt (Miocene-Pliocene)
Zagros thrust belt (Eocene-Miocene): collisional suture between the Eurasian and Arabian plates; dashed where submerged
Mesozoic anticlinal highs
Hawasina and Semail thrust sheets in Oman: Cretaceous obduction of oceanic crust and associated rocks
East Oman (Masirah) ophiolite complex
Phanerozoic sedimentary rocks of the Arabian platform, unconformable on Precambrian basement
Oil fields in Mesozoic reservoirs
Oil fields in Paleozoic reservoirs
Outcrop trace of pre-Upper Cretaceous disconformity
Outcrop trace of pre-Jurassic disconformity
Outcrop trace of pre-Upper Permian pre-Khuff) disconformity
Outcrop trace of pre-Cambrian-Ordovician disconformity
Concealed, pre-Unayzah (Hercynian) faults; locally reactivated during the Triassic
Pre-Unayzah basement subcrop (subsurface); Lower Paleozoic high
Region showing effects of Lower Paleozoic glaciation
Concealed salt deposits in end-Precambrian -Cambrian pull-apart basins (failed rifts)
End-Precambrian-Cambrian volcano-sedimentary rocks in failed rifts on the Arabian shield (Jibalah group) and in Oman (Huqf group)
Transform fault; arrows show sense of movement
QASIM DEEP
Line of section and bore holes showing Devonian "Hercynian" structure in central Saudi Arabia
Precambrian features
Schist and gneiss in brittle-ductile transcurrent shear zones and terrane sutures
Transcurrent brittle-ductile shear zone (in part reactivated terrane suture); dashed where inferred beneath Phanerozoic cover
Region of Group III evolved lead-isotopes in Afif terrane; possibly reflecting continental microplate
Suspect terrane boundary, dashed where inferred; locally reactivated by northwest-trending strike-slip faults
Sense of horizontal movement on Precambrian sutures and faults
Sense of displacement of the Afif terrane relative to the Asir terrane
Precambrian suspect terranes
Surface extent
Possible extension beneath Phanerozoic cover
Midyan terrane
Hijaz terrane
Ha'il terrane
Afif composite terrane
Ad Dawadimi terrane
Ar Rayn terrane
Unnamed suspect terranes in central Arabia
Suspect terrane east of the Nabitah fault zone
Surface extent
Jiddah terrane
Asir composite terrane
Abas terrane
Al Bayda terrane
Al Mahfid terrane
Al Mukalla terrane
Metamorphic and igneous rocks of possible Neoproterozoic provenance in Oman
SP 3
Location of shot points and seismic-refraction survey in western Saudi Arabia
National boundary approximate
Map compilation by: Watts, Griffis and McOuat Limited
Modified after: Peter R. Johnson - Tectonic Map of Saudi Arabia and Adjacent Areas (1419 A.H., 1998 A.D.)
Watts, Griffis and McOuat

The classification of the rocks of the shield according to their metamorphic facies is not reliable due to a lack of a single consistent method of determining the metamorphic grade of rocks. Historically, metamorphic grade has been inferred based on general lithological descriptions rather than specific petrographic or mineralogical assessments. Greenschist-facies rocks are found throughout the shield, and this facies is common throughout the volcanic-arc assemblages that make up the amalgamated terranes of the shield. Post-amalgamation layered formations and intrusions typically exhibit very low grade metamorphism or are unmetamorphosed. High grade metamorphism is present along some collisional (suture) zones.

It is thought that Phanerozoic rocks, now most widespread on the Arabian Platform, entirely covered the Precambrian basement for most of the Phanerozoic. Lower Paleozoic siliclastic rocks in contact with the shield have a maximum age of about 530 Ma and are part of an extensive siliclastic blanket deposited throughout the Arabia Peninsula and north-eastern Africa during the Early Paleozoic. Erosion, following uplift on the Central Arabian Arch at the end of the Devonian, locally removed the Lower Paleozoic succession, and Permian rocks come into direct contact with basement rocks along the extreme eastern margin of the shield. Remnants of the one extensive Phanerozoic cover occur as outliers on the shield especially in the northeast and in the extreme south near the Yemen border. The Phanerozoic on the Arabian Platform is important not only for its enormous oil and gas deposits in the Gulf region, but also for important deposits of phosphates and evaporites, as well as commercially insignificant deposits of coal. Anecdotal evidence of high-grade stratabound zinc (+lead?) in the Phanerozoic sequence, possibly near the margin of the shield, has come from various sources connected with ARAMCO but no details have been made available.

The Shield is overlain in the west by a layered Phanerozoic rocks that were deposited along the Red Sea basin in a series of fault-bounded grabens that developed between the divergent craton margins. These rocks are part of the Mesozoic-Cenozoic succession that fills the Red Sea basin, which resulted from extension and rifting between Africa and Arabia. This rifting marks the tectonic origin (isolation) of the Arabian Shield from the Nubian Shield, commencing at about 30 Ma in the Gulf of Aden and approximately 20 Ma in the main part of the Red Sea. Potentially important, carbonate replacement-type zinc-lead-silver deposits are found in limestone formations along the Red Sea coast. Similar deposits, such as Jabali, are found in an extensional basin in Yemen although that basin is Mesozoic in age and the mineralization is Jurassic. The cover rocks along the Red Sea also contain large salt and potash deposits.

Areas of the Shield are also overlain by Tertiary basalt flows (harrats) that are related to the extensional tectonics also associated with the Red Sea opening. These basalt flows have been used as sources for pozzolan and for building materials. Some of the volcanic calderas produce volcanic bombs within which a semi-precious gem, peridot, is exploited in the jewellery trade.

Legends for the geological figures contained in this report are provided in the Appendix.

3. METALLIC MINERAL DEPOSITS

3.1 OROGENIC GOLD – VEIN-TYPE AND DISSEMINATED DEPOSITS

3.1.1 METALLOGENIC MODEL AND EXISTING MINES / MAJOR DEPOSITS

Two major types of gold deposits are recognized in the Kingdom which are characterized by the following geological features:

-i- Mesothermal Deposits (e.g. Mansourah)

- located on or adjacent to regional-scale fault/shear ("deformation") zones typically at or near a major terrane boundary;
- associated with structures that developed during the Nabitah orogeny;
- gold was introduced as soluble complexes in medium temperature (200°-300°C) hydrothermal fluids during regional metamorphism and was deposited when these fluids reacted with the host rocks (a common reaction involves the introduction of gold as a sulphur complex, reaction of the sulphur with iron to create pyrite, fluid destabilization and deposition of gold);
- the host rocks may metavolcanic rocks, intermediate to mafic intrusions, ophiolite (listwaenite) and their altered equivalents;
- silicified and quartz-veined intrusions may occur within the deformation zone;
- widespread and strong carbonate alteration is the best indicator of intense fluid flow surrounding mineralized zones;
- sericite and quartz (silica) alteration may be dominant within mineralized zones, and less commonly green micas such as fuchsite and roscoelite may be present;
- gold is associated with disseminated pyrite and arsenopyrite +/- base metal sulphides; and,
- gold may be fine to coarse grained – many of these occurrences were exploited by ancient miners due to the presence of visible gold.

-ii- Disseminated (Porphyry-Type) Deposits (e.g. Sukhaybarat, Bulghah, Bi'r Tawilah)

- hosted in late Proterozoic granodiorite to tonalite intrusions, especially the Idah Suite (circa 700 Ma);
- mineralization is controlled by fractures and shears;
- deposits are spatially associated with large-scale compressional faults;
- networks of Au-bearing quartz-carbonate veins may be present in steeply dipping shear zones and faults;
- low level, pervasive silicification and carbonate alteration may be present;
- some mineralization may occur in adjacent country rocks, especially where they are sheared;
- gold is associated with disseminated sulphide, predominantly pyrite with lesser chalcopyrite and arsenopyrite, in the groundmass as well as on fracture surfaces; and,
- gold typically occurs as very fine grained disseminations and rarely is visible.

Of the first model, which might best be described as orogenic gold, the existing mines include As Suq and Ad Duwayhi. Mines such as Mahd adh Dhahab may have a structural connection, however these are polymetallic epithermal deposits which are associated with specific centres of volcanic activity, and

therefore have a closer association with VMS-type base metals deposits. Another important source of gold is the Al Amar Mine in which a relatively high-grade, structurally controlled gold system is superimposed on a base metal deposit. This occurrence may have closer metallogenic similarities to Mahd adh Dhahab than to the orogenic deposits. Other deposits of this model that are potential mines include Mansourah, Masarah, Ghadarah and the Kefi Minerals deposit known as Jabal Qutman located east of Bishah. The second disseminated gold setting bears a close resemblance to the porphyry gold model. The existing disseminated mines in Saudi Arabia include Sukhaybarat, which we understand has re-entered production, and Bulghah. Bi'r Tawilah is an example of a gold deposit that will probably be mined at some future date. A summary of the existing gold mines and prominent deposits for the foregoing models is provided in Table 2.

Table 2
Summary of Major Orogenic Gold Deposits in Saudi Arabia

Mine/Deposit	Primary Owner	Deposit Type	Mineral Resources		Mineral Reserves		Notes
			Mt	g Au/t	Mt	g Au/t	
Bulghah Mine	Ma'aden	disseminated	41.85	0.85	--------	--------	during 23 years (1991-2013) production averaged 69,935 oz / year
Sukhaybarat Mine	Ma'aden	disseminated	10.63	1.79	16.73	1.08	throughput of 700,000 tpa to 2024 – current mineral resources do not included mined ore
As Suq Mine	Ma'aden	vein-type	8.6	1.78	--------	--------	major Nabitah-related shear zone; also averages 3.68 g Ag/t
Jabal Qutman	Kefi Minerals	vein-type	28.46	0.80	--------	--------	in sheared and altered rock in or near the Nabitah Zone
Ad Duwayhi Mine	Ma'aden	vein-type	--------	--------	16.8	3.24	hosted in sheared intrusive and volcanosedimentary rocks
Bi'r Tawilah	Ma'aden	disseminated	97.8	0.54	--------	--------	hosted in sheared and hydrothermally altered granodiorite
Humaymah	Ma'aden	vein-type	35.8	0.87	--------	--------	hosted in diorite-tonalite near Ad Dafinah Fault, but associated with NNE-trending shears
Mansourah	Ma'aden	vein-type	35.7	2.66	--------	--------	hosted in altered intrusive and country rocks in the Nabitah shear zone
Masarah	Ma'aden	vein-type	22.3	2.19	--------	--------	as above
Shabah	Ma'aden	vein-type	36.0	1.96	--------	--------	in metasedimentary rocks adjacent to Idah Suite diorite – some similarity to Sukhaybarat
Zalim East	Ma'aden	vein-type	3.98	2.40	--------	--------	hosted in sheared granite to gabbro pluton rocks
Wasemah	Ma'aden	vein-type	29.5	1.38	--------	--------	Mostly vein-type gold mineralization in shears
Umm Naam	Ma'aden	vein-type	32.9	1.25	--------	--------	gold disseminated in altered bodies and vein stockworks
Ghazal	Ma'aden	vein-type	0.7	1.32	--------	--------	large single composite vein system

As can be seen from the foregoing table, the disseminated intrusion-hosted deposits are the largest in respect to tonnage however this gold mineralization is typically lower grade than the vein-type deposits. The physical size and geometry of the disseminated deposits favours open-pit mining whereas only near-surface portions of the vein-type deposits can be mined without resorting to selective underground mining techniques. It is worth noting that many of the disseminated deposits also contain vein stockworks that can be selectively mined at higher grades.

3.1.2 DISTRIBUTION OF DEPOSITS

WGM's initial assessment of the Saudi Mineral Occurrence Database (MODS) identified 827 gold occurrences. Based on the location co-ordinates given, these are found at 722 sites each of which is defined by a one kilometre radius encircling at least one gold occurrence. Doubling the radius results in fewer clusters of gold sites; 666 in total. Of these clusters, 537 were ranked as gold occurrences, 112 were

ranked as gold prospects, 33 were identified as having ancient mines and 3 were ranked as early mining or development stage projects. A single site was identified as a mine, Mahd adh Dhahab, which is not dealt with in this section due to its unique metallogenic character. As is clear from the foregoing numbers, many of the foregoing sites have multiple occurrences within a short distance of each other. This explains the difference between the number of true prospects and the much larger number of less well-defined sites.

Unfortunately, the current version of the MODS does not contain information concerning mineral resources. This information is useful as it provides context, and sites with larger resources are generally better explored, or at least have a greater number of completed drill holes. WGM's filtering of the database reveals that 93 of the 666 sites have been drill tested and that in total, 22 of these include multiple drill-tested targets bringing the total number of drill-tested MODS gold occurrences to 115 or 14% of the total 827 records.

As stated above, WGM's initial filtering of the gold prospects in the MODS resulted in the selection of only those occurrences with mineral resources, or those that had been drilled. This was an important step in the process of defining prospective belts. It is important to differentiate between genuine belts and areas having isolated or only one-of-a-kind gold occurrences because mines tend to be found in areas where occurrences are abundant. Mineral sites that have defined resources are considered to be more desirable because the ability of a site to qualify as resource-bearing indicates greater size and continuity and potentially higher grade than a simple mineral occurrence which might be quite small, and therefore not economically interesting. This pre-selection allowed WGM to reduce the number of sites to be reviewed in detail from the original number of 827 occurrences to 463 sites that were previously drilled and 46 with a historical estimate of mineral resources, although many of these estimates are very small (< 500,000 tonnes) and are based on too few drill holes to comply with any established international reporting standard.

The orogenic vein-type deposits are predominantly found along major fault zones that have a north-trending orientation as distinct from the north-westerly trending Najd Fault system. These gold-bearing structures are related to either the Nabitah Orogeny or they are structures of a similar strike that developed during assembly (suturing together) of the Arabian Shield. It is clear from some of the rocks found along such structures, such as altered ophiolite assemblages, that these structures are very deeply rooted, potentially passing through much of the Earth's crust. In most cases, perhaps all cases, they represent the collisional zones between Proterozoic Terranes that had previously moved independently of each other. These zones are very similar to the great deformation zones in the Canadian Shield, such as the Destor-Porcupine Fault Complex and the Kirkland Lake-Larder Lake Break which have produced 10s of millions of ounces of gold, the only major difference being that the examples in the Arabian Shield are much younger. Nevertheless, they have similar continuity over 100s of kilometres and both are populated by an abundance of gold occurrences.

The disseminated gold deposits in the Kingdom are associated with intermediate plutonic rocks (e.g. granodiorite, diorite, tonalite) that are part of or related to the Idah Suite of intrusions. Although some of these intrusions are proximal to Nabitah structures (e.g. Bi'r Tawilah), most of the intrusions occur in areas with relatively minor or localized faulting. In modern times, Sukhaybarat was the first such mine to be

brought into production, and this was closely followed by Bulghah. These deposits may have some features in common with deposits in the Great Basin of the western United States in that they are predominantly developed in large sedimentary basins. The intrusions at Sukhaybarat and Bulghah were emplaced into the Mardamah Group (Murdama Gp.), a thick sequence (>8,000 m) of predominantly epiclastic sedimentary rocks located in the Afif terrane. These sediments were deposited in a basin more than 600 km long and 120 km wide situated between the Ad Dawadimi greenstone belts to the east and greenstone belts in the Jiddah and Hijaz terranes to the west. As reported by Johnson (2005), these intrusions are a uniquely dated suite with an age of 620-615 Ma that "are a significant control on mesothermal gold mineralization in the region".

3.1.3 PROSPECTIVE MINERAL BELTS AND GOLD OCCURRENCES

3.1.3.1 Al Wajh Belt

Location, Distribution of Occurrences and History

The Al Wajh belt lies east of the Red Sea coast between latitudes 26.13ºN and 25.10º N. The belt and the gold occurrences within it are cut into a northern segment (Table 3) and a southern segment (Table 4) by the E to ESE-striking Ajjaj Shear Zone located at approximately 26º N, and across which there is 25 km or more of sinistral offset. Maqrah Samawah-N (MODS 1424) is the most northerly gold occurrence known and 110 km to the SSE, Shaib Al Mismah (1238) marks the southern end of the northern segment. This section of the belt contains 45 gold occurrences. The southern segment of the belt extends a farther 90 km to the south from the Bi'r Suwayqah (2082) to Al Uwaynid (0435) and contains a total of 19 gold occurrences. In general, the gold occurrences, prospects and ancient mines of the Al Wajh belt have been assessed as having little or no economic interest despite the fact that ancient gold workings are numerous and extensive. In fact, nearly all of the sites have ancient mine shafts, stopes and/or waste dumps. Compared to similar belts in mature exploration areas in Canada, the USA or Australia, very little diamond drilling has been carried out in the Al Wajh Belt. In general, the exploration completed by such groups as the USGS and the BRGM has focused on specific targets and programs have been abandoned if the immediate results were not positive. In most cases, the exploration has not progressed beyond surface sampling, much of which has focused on mine waste dumps. Historical practices involving sample analysis were shown to be inadequate, and systematic geophysical and geochemical studies have had limited application (WGM, 1992a). Much of the historical work did not take into account modern metallogenic models, and the important roles of structure and hydrothermal alteration were overlooked.

Table 3

Name and Location of Gold Occurrences - Northern Segment, Al Wajh Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry *
				Longitude	Latitude			
1424	Maqrah Samawah-N	Silaila	Gold	36.11330600	26.93094400	Duba	VL	dd, v
1422	Maqrah Samawah-E	Marrah	Gold	36.11496000	26.91725000	Duba	VL	dd, v
1415	Wadi Inbiqa	Nabaghah	Gold	36.12613900	26.76972200	Duba	Med	dd, v
6010	Wadi Al Mujayrmah-S	Wadi Al Mujayrmah-S	Gold	36.12741700	26.91277800	Duba	Med	V
3986	Wadi Inbiqa-E	Wadi Unaybik	Gold	36.13458300	26.77952800	Duba	VL	Placer
1423	Maqrah Samawah	Hawawit Area	Gold	36.13663900	26.91961100	Duba	Med	dd, v
6009	Jabal Zufr-W	Jabal Zufr-W	Gold	36.13836100	26.91391700	Duba	Low	V
6005	Jabal Yahmum	Jabal Yahmum	Gold	36.16944400	26.92577800	Duba	Low	V
6006	Jabal Yahmum	Jabal Yahmum	Gold	36.17166700	26.92327800	Duba	Low	V
5109	Jabal Ar Rubayq-E	Wadi Hujail-SE	Gold	36.17966700	27.49263900	Duba	Low	V
6008	Jabal Zufr	Jabal Zufr	Gold	36.18633300	26.88344400	Duba	Low	V
1417	B'irkat Antar	B'irkat Antar	Gold	36.29536100	26.61775000	Al Wajh	Med	dd, v
1418	Jabal Liban-E	Abu An Na'Am	Gold	36.48819400	26.58050000	Al Wajh	Med	dd, v
1242	Dulayat Umm Sidrah	Al Ghibb	Gold	36.51666700	26.20000000	Al Wajh	VL	v
1294	Sharm Haramil	Umm Huwayweetat Ash	Gold	36.56944400	26.25991700	Al Wajh	Med	v
1241	Shaib Fushaygh	Al Mitgabel	Gold	36.57677800	26.25166700	Al Wajh	VL	v
1295	Shaib Fushaygh	Umm Twairat	Gold	36.58497200	26.25197200	Al Wajh	VL	v
1292	An Nahdein	An Nahdein	Gold	36.58819400	26.30958300	Al Wajh	Med	v
4820	Jibal Umm Quryyat-NW1	Umm Al Qurrayyat	Gold	36.58944400	26.24805600	Al Wajh	Undefined	v
1296	B'ir Al Qubbah	Al Qubbah	Gold	36.59186100	26.38933300	Al Wajh	Med	v
4813	Jibal Umm Quryyat-SW2	Umm Al Qurrayyat	Gold	36.59500000	26.21500000	Al Wajh	Med	Undetermined
1293	Umm Huwayweetat	Umm Huwayweetat	Gold	36.59841700	26.23011100	Al Wajh	Very low	v
4812	Jibal Umm Quryyat-SW	Umm Al Qurrayyat	Gold	36.59861100	26.21111100	Al Wajh	Undefined	v
1243	Jibal Umm Quryyat-SW3	Kwar Ash Shamali	Gold	36.60000000	26.21666700	Al Wajh	Very low	v
4811	Jibal Umm Quryyat-SW1	Umm Al Qurrayyat	Gold	36.60166700	26.21250000	Al Wajh	Undefined	v
1239	Wadi Ash Shijnah	Hasheem	Gold	36.60363900	26.21136100	Al Wajh	VL	v
4809	Jibal Umm Quryyat-SW4	Umm Al Qurrayyat	Gold	36.60933300	26.22391700	Al Wajh	Undefined	v
4810	Jibal Umm Quryyat-SW5	Umm Al Qurrayyat	Gold	36.61027800	26.22561100	Al Wajh	Undefined	v
4818	Jibal Umm Quryyat-NW3	Umm Al Qurrayyat	Gold	36.61250000	26.25611100	Al Wajh	Undefined	v
4817	Jibal Umm Quryyat-NW2	Umm Al Qurrayyat	Gold	36.61455600	26.25272200	Al Wajh	Undefined	v
4819	Jibal Umm Quryyat-NW4	Umm Al Qurrayyat	Gold	36.61616700	26.26369400	Al Wajh	Undefined	v
1289	Qalat Az Zurayb	Abu Nafeela	Gold	36.62119400	26.21547200	Al Wajh	Med	v
4808	Jibal Umm Quryyat-N	Umm Al Qurrayyat	Gold	36.62277800	26.23527800	Al Wajh	Undefined	v
4816	Jibal Umm Quryyat-N2	Umm Quryyat	Gold	36.62522200	26.24519400	Al Wajh	Undefined	v
1297	Shaib Fushaygh-W	Ash Shuata	Gold	36.62544400	26.19150000	Al Wajh	Med	v
1288	Jibal Umm Qurayyat	Umm Al Qurrayyat	Gold	36.62577800	26.23080600	Al Wajh	Med	dd, v
4814	Umm Qurayyat-N3	Umm Al Qurrayyat	Gold	36.62777800	26.24972200	Al Wajh	Undefined	v
4815	Jibal Umm Quryyat-N1	Umm Al Qurrayyat	Gold	36.62777800	26.24972200	Al Wajh	Undefined	v
1291	Wadi Al Miyah Central	Abu Nithiara	Gold	36.62911100	26.16977800	Al Wajh	Med	v
1244	Wadi Al Miyah-W	Nasra	Gold	36.66666700	26.23333300	Al Wajh	Very low	v
1290	Khawr Al Arja	Khor Al Arja	Gold	36.68827800	26.16197200	Al Wajh	Med	v
1240	Shaib Al Khawr	Khawr Al Gibli	Gold	36.69313900	26.16166700	Al Wajh	Undefined	v
1247	Ash Shuhaiba	Ash Shuhaiba	Gold	36.71105600	26.09936100	Al Wajh	VL	Undetermined
1238	Shaib Al Mismah	Abu Seirat	Gold	36.73333300	26.12913900	Al Wajh	Med	v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins

Table 4

Name and Location of Gold Occurrences - Southern Segment, Al Wajh Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
2082	B'ir Suwayqah	Suwayqah	Gold	37.2589170	25.8034720	Umm Lajj	VL	dd, veins
0453	Shaib At Tundubiyah	Umm Lajj	Gold	37.3005560	25.4843060	Umm Lajj	VL	uncertain
2083	Shaib Muhayfir	Muhayfir	Gold	37.3096940	25.6893330	Umm Lajj	Med	dd, veins
0454	Shaib An Nusay	Umm Lajj	Gold	37.3113890	25.4747220	Umm Lajj	VL	dd
1283	Jibal At Tundubiyah	Abu Al Marw	Gold	37.3119440	25.4059440	Umm Lajj	VL	v
0442	Jabal Ghurabah-S	Umm Lajj	Gold	37.3194440	25.2219440	Umm Lajj	VL	v
5164	Jibal Muraykhat-N	Jibal Muraykhat-N	Gold	37.3200830	25.8135280	Umm Lajj	Med	veining
0441	Tur Al Hail	Umm Lajj	Gold	37.3223890	25.2307780	Umm Lajj	VL	v
0418	Mutaynat Al Qumayra	Umm Lajj	Gold	37.3363890	25.2155560	Umm Lajj	VL	v
0461	B'ir Al Muqarin	Umm Lajj	Gold	37.3761110	25.1741670	Umm Lajj	VL	v
0460	Jibal Umm Raqabah	Umm Lajj	Gold	37.3780560	25.1652780	Umm Lajj	VL	v
0436	Jibal Al Himam	Al Hammam	Gold	37.3872780	25.4311670	Umm Lajj	Med	dd, veins
0455	Jibal Marakh	Umm Lajj	Gold	37.3939170	25.3591670	Umm Lajj	VL	dd, veins
0457	Wadi Al Ghumyir	Wadi Al Ghumyir	Gold	37.3988890	25.0080560	Umm Lajj	VL	dd, veins
0462	Jibal Marakah-N	Umm Lajj	Gold	37.3990280	25.3605560	Umm Lajj	VL	v
0456	Wadi Al Hail-E	Umm Lajj	Gold	37.4016940	25.2047220	Umm Lajj	VL	dd
0437	Wadi Amq	Umm Lajj	Gold	37.4177780	25.4694440	Umm Lajj	VL	dd, veins
0458	Umm Rihay	Umm Ar Rihi	Gold	37.4401110	25.0936670	Umm Lajj	VL	dd
0435	Al Uwaynid	Al Uwayrid	Gold	37.4442220	25.1134720	Umm Lajj	VL	dd, veins

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins

The low level of exploration carried out to date combined with the mediocre quality of the data produced therefore influence this assessment of the gold potential of the belt.

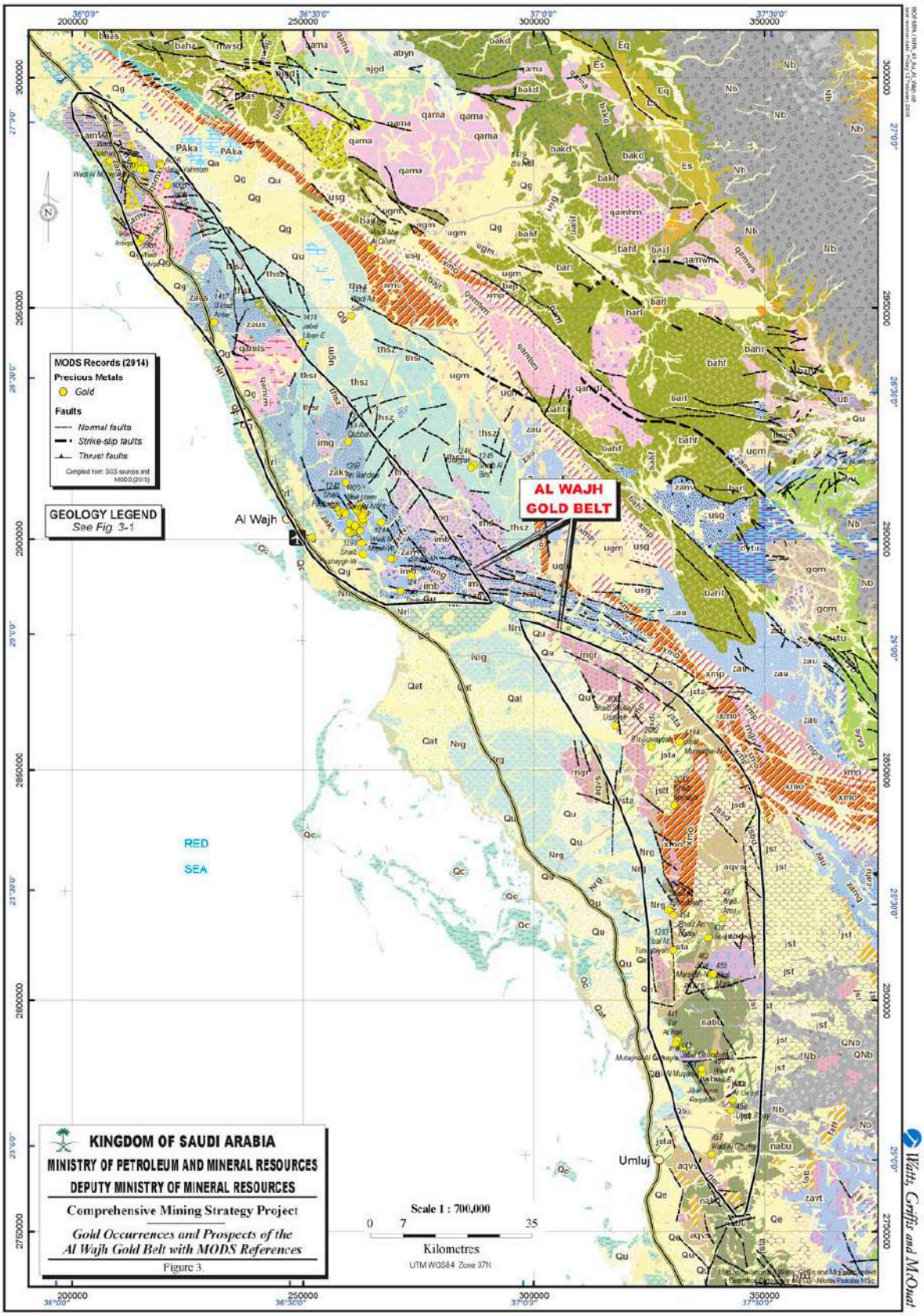
Most of the known gold occurrences in the 200 km long Al Wajh Belt are small with estimated resource tonnages of less than 150,000 t (e.g. Jibal Umm Qurayyat) and with gold grades in the order of 3 g/t to 10 g/t. The associated silver contents are variable but of less importance. None of these resource estimates are compliant with current regulatory standards such as Canada's National Instrument 43-110 or Australia's JORC Code. In addition, they cannot be considered as "final" due to the deficiencies mentioned in the previous section, primarily relating to the amount and the extent of the exploration carried out to date as well as deficiencies in the quality of the work performed. The occurrences that have received the most exploration from past workers include those at the Quryyat area as well as Bi'r Al Qubbah, Qalat Az Zurayb (formerly Abu Nafeela), and Umm Hawaweetat ash Shyna. WGM was informed that work by the SGS at the Al Qubbah prospect was reported in SGS open file report SGS-OF-2007-1 which was not available for this study. The SGS noted similarities between Al Qubbah and the Sukhaybarat gold mine in the Afif Terrane, a deposit that is metallogenically related to the emplacement of an Idah Suite intermediate intrusion. Al Qubbah is hosted in Kibrah Formation shale, limestone and volcanic rocks which are part of the Za'am Group. These strata are intruded by a relatively young (660 Ma) granodiorite of the Imdan

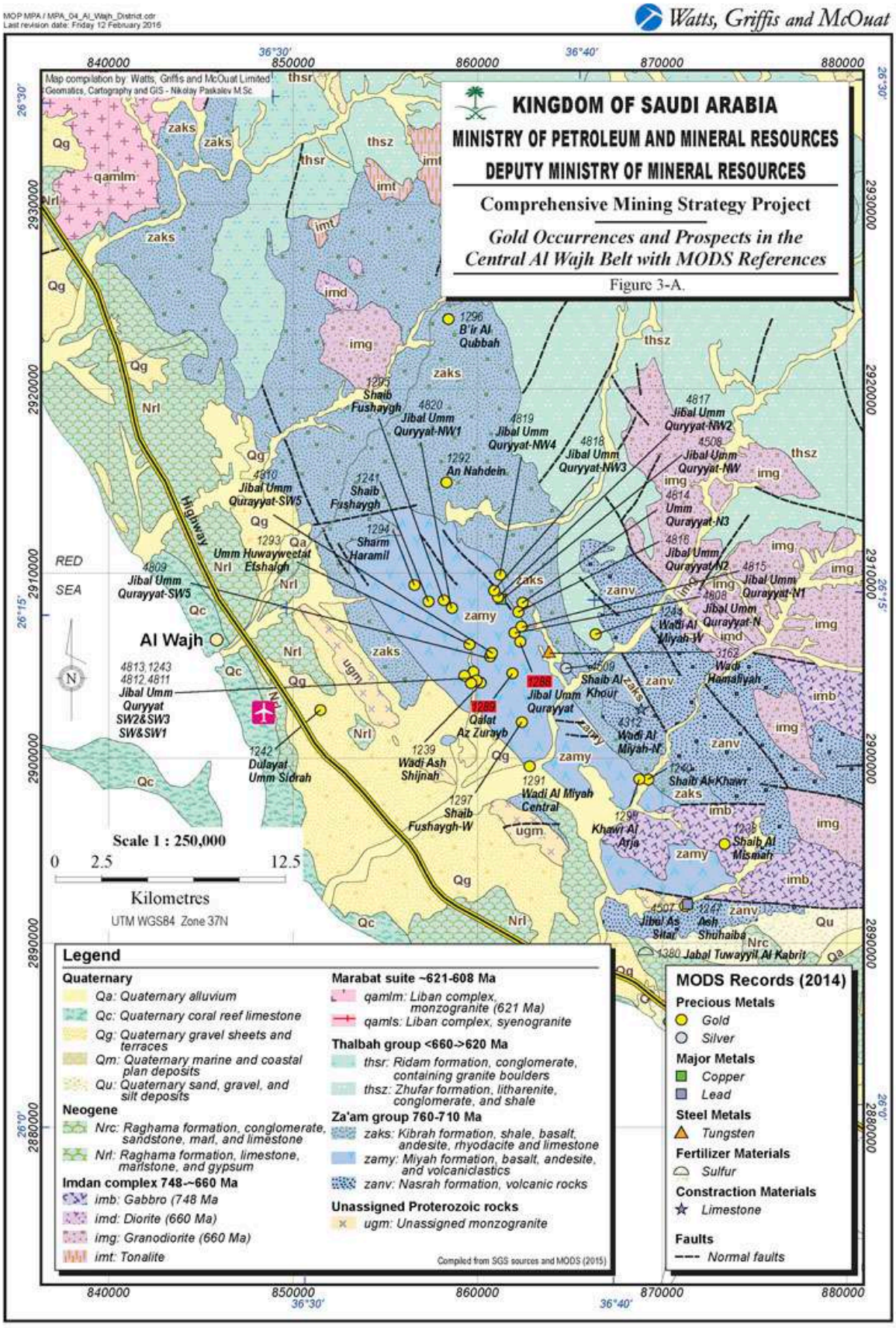
Complex (748-660 Ma) which may be time-equivalent to the Idah Suite. This age was an important period of time during which much of the intrusion-related gold mineralization was formed in the Afif Province.

Most of the occurrences are hosted in mafic to intermediate volcanic and volcaniclastic rocks of the Zaam Group and for the most part gold occurs in quartz veins and in hydrothermally altered schist associated with the NNW-trending shear zones. The host rocks are commonly intruded by rocks of diorite, gabbro and granodiorite composition. Gold occurrences are associated with intrusive rocks which may have acted as heat engines for the circulation of golf-bearing solutions. The NNW-trending shears/structures are older features, probably related to Nabitah tectonics, because they are offset by younger Najd faults. Nabitah structures are an important reflection of orogenic activity that was vital in the genesis of other gold deposits in the Kingdom such as Mansourah and Masarah. In this sense, the metallogenic model for the Al Wajh Belt conforms to existing models for other important Saudi gold deposits and also to the greenstone belt model developed in other parts of the world, notably in Canada and Australia. Many of the world's great gold mining districts are located in similar settings such as the Timmins, Kirkland Lake and Val d'Or gold centres in Canada which have produced gold for more than 100 years. Although the Canadian examples are Archean in age, and therefore may not be perfect comparisons, greenstone belts are some of the world's great metal producers.

The Al Wajh region has been affected by at least two fold events, the first affecting only the Zaam Group and causing low-angle axial surfaces striking east-west. The subsequent event affected all Precambrian layered rocks and resulted in north-plunging axial surfaces that strike NNW and with which the Al Wajh gold belt is parallel. The gold belt is part of a large deformation zone along which movement has taken place over an extended period of time and within which the rocks are schistose and hydrothermally altered (carbonatized, chloritized, silicified, pyritized and sericitized). The southern end of the Al Wajh belt is defined by a major NW-trending, sinistral wrench fault related to the Najd event which offsets the southern continuation of the Al Wajh zone. The zone is offset approximately 50 km to the southeast where it continues to the south beginning with the Suwayqah occurrence (MODS 2082). Over a strike length of approximately 90 km, an additional 19 gold occurrences are located along the belt that passes through the Umm Lajj area (Table 4). Like the 110 km long northern segment of the Al Wajh Belt, most of these sites contain ancient mine workings. South of the town of Umm Lajj, the zone passes off the escarpment marking the edge of the Arabian Shield and is covered by Cenozoic strata on the Red Sea coastal plain.

One of the most prominent shears in the belt is located between Wadi Zurayb and Wadi Arjah, it trends north-northwest along Wadi Hamaliyah and the contact between andesite and basalt on the west and shale on the east. Several gold occurrences appear to be associated with this structure; they include Sharm Haramil (MODS 1294), Umm Al Qurayyat (MODS 1288), Wadi Hamaliyah (MODS 3162 – classified as tungsten), Qalat Az Zurayb (MODS 1289), and Khawr al Arja (MODS 1290) as shown in Figure 3 and detailed in Figure 3A. The widespread occurrence of gold in a geologically favourable environment warrants systematic and intensive follow-up at both the regional and occurrence level.


MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Strike-slip faults
Thrust faults
GEOLOGY LEGEND
See Fig 3-1
AL WAJH
GOLD BELT
Al Wajh
Umluj
RED
SEA
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Gold Occurrences and Prospects of the
Al Wajh Gold Belt with MODS References
Figure 3.
Scale 1 : 700,000
0 7 35
Kilometres
UTM WGS84 Zone 37N
Watts, Griffis and McOuat


Watts, Griffis and McOuat
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Gold Occurrences and Prospects in the Central Al Wajh Belt with MODS References
Figure 3-A.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc
Al Wajh
RED SEA
Highway
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 37N
Legend
Quaternary
Qa: Quaternary alluvium
Qc: Quaternary coral reef limestone
Qg: Quaternary gravel sheets and terraces
Qm: Quaternary marine and coastal plan deposits
Qu: Quaternary sand, gravel, and silt deposits
Neogene
Nrc: Raghama formation, conglomerate, sandstone, marl, and limestone
Nrl: Raghama formation, limestone, marlstone, and gypsum
Imdan complex 748-~660 Ma
imb: Gabbro (748 Ma
imd: Diorite (660 Ma)
img: Granodiorite (660 Ma)
imt: Tonalite
Marabat suite ~621-608 Ma
qamlm: Liban complex, monzogranite (621 Ma)
qamls: Liban complex, syenogranite
Thalbah group <660->620 Ma
thsr: Ridam formation, conglomerate, containing granite boulders
thsz: Zhufar formation, litharenite, conglomerate, and shale
Za'am group 760-710 Ma
zaks: Kibrah formation, shale, basalt, andesite, rhyodacite and limestone
zamy: Miyah formation, basalt, andesite, and volcaniclastics
zanv: Nasrah formation, volcanic rocks
Unassigned Proterozoic rocks
ugm: Unassigned monzogranite
Compiled from SGS sources and MODS (2015)
MODS Records (2014)
Precious Metals
Gold
Silver
Major Metals
Copper
Lead
Steel Metals
Tungsten
Fertilizer Materials
Sulfur
Constraction Materials
Limestone
Faults
Normal faults

Geology

The Umm Urayat ancient mine (MODS 1288), previously known as the Umm al Qurayyat occurrence has been extensively exploited by ancient miners and is the most explored gold deposit in the Al Wajh Belt. The deposit is surrounded by carbonate alteration that extends > 100 m beyond the known gold zone, and mapping this alteration has been shown to be effective in tracing mineralization. Gold mineralization is associated with a quartz-sericite-pyrite halo that generally contains > 100 ppb Au. Previous geological mapping of 90 quartz vein systems in the area resulted in gold values as high as 32,000 ppb. Approximately 20% of the veins contained in excess of 1,000 ppb Au and many of these were not associated with established occurrences recognized in the MODS.

The Wadi Hamaliyah occurrence (MODS 3162) is distinguished by a gold-tungsten-arsenic association. Quartz stockworks occur in meta-andesite flows and tuff host scheelite and gold mineralization. The intrusive felsic porphyries are pyritic especially near the contact aureoles. It has been suggested that porphyry dikes in the north sector of the area are a source of gold. The trace element association in this area is interesting and the occurrence of widespread geochemical anomalies in this part of the Al Wajh Belt warrants follow-up.

The Al Qubbah occurrence, now renamed as the B'ir Al Qubbah gold prospect (MODS 1296), is located 18 km north-northwest of Umm al Qurayyat. It is similar in many respects to the Wadi Hamaliyah occurrence in that gold occurs in quartz stockworks and fractures hosted in a granodiorite-diorite intrusion and in surrounding cherty metasedimentary rocks. Early diamond drilling carried out by the Saudi Arabian Mining Syndicate (SAMS) during the 1970s showed that the diorite stock was pyrite-bearing. Based on its geological work in 2001, the SGS singled out the Al Qubbah prospect for its similarities with the Sukhaybarat deposit (Sahl et al, 2007).

As shown in the foregoing tables, there are many other gold occurrences in the Al Wajh Belt, yet little or no systematic exploration work has been carried out on most of them. In many parts of the world, gold mines are found in structural belts or corridors which are distinguished by a large number of such occurrences. The trend of the Al Wajh Belt, and its north-westerly location in the Arabian Shield suggests that it is associated with Nabitah orogenics which are known elsewhere in the shield for their metallogenic association with gold mines. In addition to gold, there are many other mineral occurrences in this belt, including zinc and copper occurrences, which are commonly associated with structural zones. WGM believes that the Al Wajh Belt probably extends no farther north than the town of Duba, before passing offshore below the Red Sea. No significant gold occurrences are identified north of Duba. However, in the extreme north the Jabal as Sabil gossan (MODS 3325) is hosted in gabbroic and dioritic rocks and contains an unusual green mica mineral identified as roscoelite. This mineral occurs in several world-class epithermal gold deposits, such as Mt. Kare and Porgera in Papua New Guinea, and green micas are associated with world-class mesothermal deposits in the Kirkland Lake mining camp in Canada. WGM previously identified this as an unusual occurrence worthy of additional exploration. The fact that no gold occurrences are identified north of Duba suggest that the area may be under-explored. Certainly, the

general lack of exploration in the area since WGM's review in 1992, offers some proof that explorers, especially Ma'aden (which had early access to the WGM reports) have largely ignored the Al Wajh Belt.

Recommendations

The proposed program for the Al Wajh Belt would commence with a review and compilation phase (e.g., at a scale of 1:5,000-1:10,000) of all available geoscience data for the area shown in Figure 3. The compilation would be carried out in conjunction with specific, short field examinations to confirm the reported locations of the ancient workings and gold occurrences which the authors understand have recently been modified by the SGS using modern GPS technology.

Each prospect should be assessed to determine the extent to which the previous WGM recommendations tendered in 1992 have been implemented. In general, these recommendations remain valid. Today's improved technology and capabilities do not mean that any of the steps previously recommended can be avoided. New concepts have more recently been developed suggesting metallogenic similarities between the Al Qubbah prospect and the Sukhaybarat Mine. This is an important genetic concept that needs to be adequately investigated during on-going exploration.

Any initial work must include orientation studies, for example, cleaning any existing workings or exploration trenches and systematic geochemical resampling of the occurrences. In areas outside but adjacent to specific gold occurrences, the sampling of soils below the desert regolith pavement (to eliminate human contamination effects) might enlarge the area to be targeted for intensive exploration. It is also vital to understand that the ancient miners focused on visible gold, however in many gold deposits, especially those associated with hydrothermal alteration zones, gold mineralization is commonly less than 50 microns in size and well below what is visible to the naked eye. Consequently, many gold-bearing rocks were ignored by ancient miners who saw no evidence of mineralization. For studies that are more regional in character, as should be undertaken for the entire Al Wajh Belt, the use of high quality satellite imagery, such as ASTER, in combination with Landsat data can provide a cost-effective means of extending structures identified as being of interest for gold. At a cost of approximately $100 per scene, ASTER imagery can also be used effectively to highlight alteration zones associated with various types of gold mineralization, especially that associated with altered intrusions and large quartz stockwork zones (e.g. Bulghah). On a more basic level, satellite imagery is useful for mapping potentially favourable gold structures, gossans, alteration zones, and major lithological changes.

In any prospect area, wadi-sediment and heavy mineral sampling at a minimum density of 5 samples per square kilometre is recommended. Samples should be taken in the alluvial sediment beneath the sandy eolian surface layer. Both the fine fraction of the sediments (e.g., minus 63 micrometers) and the total heavy mineral component should be tested for Au (by minimum 30-gram fire assay), base metals, and other indicator elements commonly associated with gold such as Ag, As, Sb, Te, Mo, Cu, Co, Zn and Pb. The effectiveness of the ultra-fine fraction (-200#) wadi-sediment for gold exploration in the low-relief pediplain

environment of Saudi Arabia was demonstrated by Salpeteur and Sabir (1989) as a means of eliminating affects associated with wind-blown sand. Higher relief areas typically lack this ultra-fine fraction but are also less affected by wind-blown material, and use of more conventional size fractions can be made, for example the -80 # fraction.

Given that even the best exploration geology, remote sensing and geochemical data reflects surface conditions, the difficulty in drilling targets commonly lies in the uncertainly that the subsurface presents. To avoid costly "prospecting with a diamond drill", additional detailed exploration is necessary to define and refine the location and geometry of targets for drilling. Geophysical surveying has the potential to add to this third dimension, however gold is typically unresponsive to geophysical testing, and therefore such surveying can only detect geological features with which gold may be associated. Geophysical responses should be evaluated within the overall geological and geochemical context as applied to the deposit model, and should be used only as one of the vectors for selecting drill targets. Some of these survey types are discussed as follows:

Magnetometer Surveying

Gold is nonmagnetic and very rarely associated with or hosted by magnetic rocks. Magnetometer surveying, which is relatively inexpensive, can add to our understanding of magnetic bodies in the subsurface including the location of lithological contacts and the geometry of intrusive bodies that may be associated with the mineralizing process – these may be targets. The Bi'r Tawilah deposit, located in the central part of the Shield along the Nabitah Fault Zone, is a porphyry-type gold deposit hosted in an intermediate (diorite-granodiorite) composition intrusion. The Sukhaybarat and Bulghah mines are situated, at least partially, in sheared and stockworked dioritic plutons.

Electromagnetic ("EM") Surveying

Gold is highly conductive of electricity however its low concentration in deposits means that it is unresponsive to EM surveying. Nevertheless, gold deposits are commonly hosted within major structures which <u>are</u> responsive to EM surveys. The EM response may be attributable to the presence of graphite in the structure, clay alteration along the structure or simply the ionic effects of water within the sheared rocks. Response variances across such structure may also demonstrate that the rocks are substantially different on each side of the EM conductor, and this can be a favourable geological factor for gold mineralization. EM responses may be useful in determining the orientation of drill holes once targeted zones are identified. Exploration technology has produced many advances in EM surveying, for both airborne and ground surveying, with rather large attendant cost differentials. Consultation with a survey provider and an independent geophysical consultant is strongly advised during the decision-making process to ensure that the equipment selected and the survey design is appropriate for the local circumstances.

Induced Polarization ("IP") Surveying

IP surveying is probably the survey method of choice for gold because there is no other geophysical survey that can produce data to be modelled in 3D in the same manner. IP surveying

typically consists of two components, chargeability and resistivity, which are measured at the same time. The geological setting of the gold prospects in the Al Wajh Belt, especially the sheared character of the gold-bearing structure and the contrast between country rocks and mineralized zones (shear/deformation zones), indicates that induced polarization-resistivity (IP-resistivity) surveying would be a useful means of defining drill targets at depth. The quartz or silica commonly injected into a shear will cause distinctively high resistivities than in the more conductive schists that occur along such structural zones. Any disseminated sulphide in the zone will provide an anomalous chargeability affect, and targets will be defined by a combination of high resistivity and high chargeability for frequency domain equipment. Other phase domain and time domain equipment is also permissive.

EM-surveying is relatively expensive compared to magnetometer surveying, and may only be useful in determining the location of a major structure when it is hidden below surficial deposits. In general, if the locations of the target structure is known with some degree of certainty, then IP surveying may be a better approach that offers superior target resolution. Within most target areas, the primary need will be to ensure penetration well beyond 150 m as in some cases this volume has already been tested by reconnaissance drilling. Surveying through this area will provide valuable response data from the gold-bearing zone for modelling purposes.

WGM recommends using a dipole-dipole array with an ‘a’ spacing of 50 m for readings at n=1 to at least n=6. If a suitable generator is available, readings might even be possible to n=10 as the overburden is typically thin and non-conductive except in wadi floors. Arrays such as these are time-consuming to deploy, however, with the zone well defined by geological mapping, the survey should be able to concentrate on a relatively short profile length of approximately 800 to 1,000 m. Larger arrays for 3D IP surveying are also permissive for surveying large areas and acquiring data to a greater depth however these surveys tend to be expensive.

Surveying to depths of 200 m to 300 m will require a transmitter with sufficient power to produce clean data at such depths. While this equipment is readily available in North America, the equipment commonly used in Saudi Arabia is not of the same caliber. WGM’s review of several previous surveys carried out in the Kingdom have identified problems, at times severe, with noise caused by the choice of electrodes used (typically stainless steel stakes). Copper-sulphate pots or wire mesh electrodes typically produce superior signal to noise ratios. Care should obviously be taken in selecting an operator a qualified sub-contractor.

Reconnaissance diamond drilling of targeted zones should only be undertaken following the compilation of all survey and other data such that a complete model for the target can be assembled. Areas of identified gold mineralization should be systematically drill-tested with a minimum budget of 5,000 m of core drilling per target. If more than one mineralized structure is identified in a given target area, then each should receive a similar budget. All drilling must incorporate conventional QA/QC protocols in accordance with JORC or NI 43-101 standards and guidelines. All assays of the drill core must be accomplished using the

fire assay method, preferably on an assay charge of 50 g. WGM understands that this service is available from Al Amri Laboratories in Jeddah for a small surcharge in addition to the cost of using a 30-gram charge.

References

Sahl, M.S.A. and the SGS, 2007, **Selected Prospects in the Arabian Shield: Comments on Geology and Geochemistry, and Recommendations for Further Work**, Saudi Geological Survey Open-File Report, SGS-OF-2007-1, 31 pages.

3.1.3.2 The Al Maraysi Gold Belt

Location, Distribution of Occurrences and History

The area was originally explored by the DGMR during the late 1960s and 1970s as a result of the discovery of widespread ancient copper mine workings. The mineralization at Al Maraysi, formerly Al Marasia (MODS 0413) and at Al Maraysi-S, formerly Al Maraysi-SE Prospect (4923) were subsequently designated as gold prospects and this fact appears to have refocused the exploration model. Jabal Samran, originally classified as a copper prospect, has also been re-classified as a gold prospect with associated copper, however, the mineralization is associated with a felsic volcanic sequence located several kilometres from the margin of the Al Maraysi structural zone, and its metallogenic affinity is volcanogenic rather than orogenic. The gossan at Abu Shahab, formerly Abu Shaiab (MODS 1254) has been included in the prospective targets because it is associated with strong alteration on one of the major lineaments.

The gold prospects (Table 5) are situated along a strong NE-trending structural lineament which is composed of several parallel features within a zone 5-6 kilometres in width. The gold belt is located near the western margin of the exposed Arabian Shield in the At Taif-Jeddah Terrane and it probably extends into the Red Sea Rift below Cenozoic cover rocks (Figure 4). On the shield, it can be traced over a distance of approximately 63 km.

At the main Al Maraysi prospect, a centre of ancient mining activity in the area, bedrock samples collected during early exploration work contained up to 3.1 g Au/t, 1.2% Zn, 0.48% Cu and 0.3% Pb. In 1967, two very shallow diamond drill holes were completed to depths of 30 m and 80 m respectively. The first hole intersected 19.2 g Au/t over 3.5 m and 13.7 g/t over 1.8 m. In addition, an 8.55 m section of altered rock contained 9.52 g Au/t and 31.49 g Ag/t. The second hole, drilled below the first, failed to intersect any significant mineralization, however, the BRGM has indicated that the second hole may have been drilled down-dip and failed to intersect the gold-bearing zone. Based on the extremely encouraging results of the first drill hole, the USGS reassessed the area and recommended geophysical surveying to delineate additional targets for drilling. Eight years later, in 1975, ground magnetometer, Turam, IP and seismic surveys were completed over the gold-bearing zone, and IP anomalies were detected. Additional

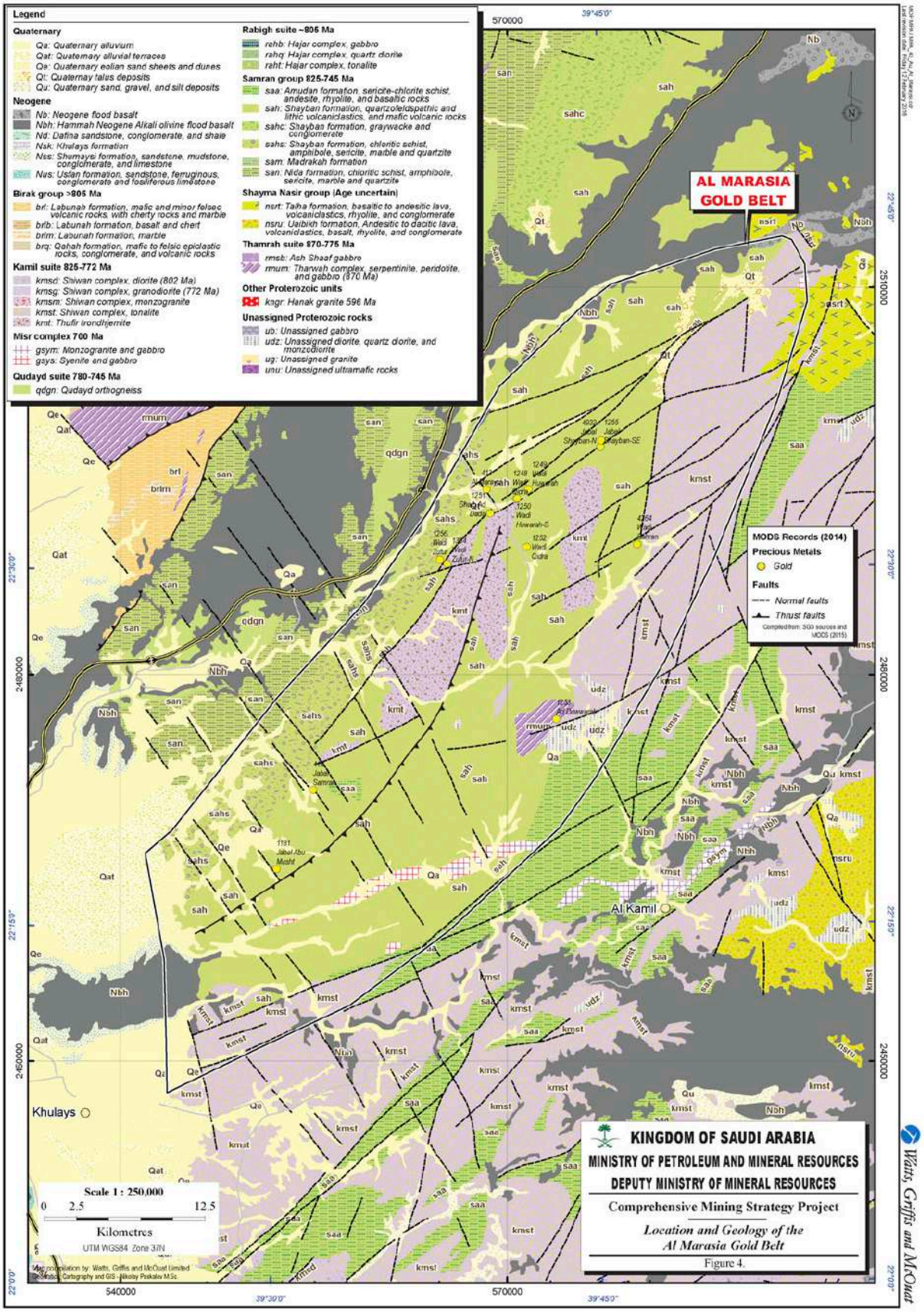
geophysics was recommended to trace the anomalies. Follow-up exploration work included 22 trenches totaling 739 m, but these generally failed to find additional mineralization. During 1978, mineralogical studies were done by Australian Ore and Minerals Ltd.

Table 5
Name and Location of Gold Occurrences - Al Maraysi Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry *
				Longitude	Latitude			
1258	Jabal Shayban-NE1	Matober	Au, Cu	39.7653890	22.5982500	Al Abyar	Med	dd, v
4932	Jabal Shayban-N	Jabal Shayban	Au	39.7519720	22.5879720	Al Abyar	VL	dd, v
1255	Jabal Shayban-SE	Umm Sani	Au, Cu	39.7513610	22.5835560	Al Abyar	VL	v
1249	Wadi Huwarah	Maxifa	Au, Cu	39.6967500	22.5542780	Al Abyar	undefined	v
0413	Al Maraysi	Al Marasia	Au, Ag, Cu, Zn	39.6650280	22.5541390	Al Abyar	Med	dd, v
1254	Abu Shahab	Abu Shiaab	Gossan	39.6438890	22.5345000	Al Abyar	Med	gossan
4923	Al Maraysi S	Al Maraysi SE	Au, Cu	39.6438890	22.5345000	Al Abyar	VL	chlorite schist
4932	Jabal Baydan	Jabal Baydan	Au, Cu	39.7358330	22.5336110	Al Abyar	VL	dd
1250	Wadi Huwarah-S	Brumah	Au, Cu	39.6883610	22.5478060	Al Abyar	undefined	uncertain
1248	Wadi Qidra	Wadi Jidrah-N	Au, Cu	39.6874440	22.5471670	Al Abyar	undefined	v
1251	Shaib Ad Dada	Jibalah	Au, Cu	39.6679170	22.5373890	Al Abyar	VL	dd, v
4264	Wadi Bahran	Wadi Bahran	Au	39.7786110	22.5152780	Al Abyar	VL	v
1252	Wadi Qidra	Wadi Jidrah	Au, Cu, Zn	39.6952500	22.5137780	Al Abyar	VL	v
1256	Wadi Zufur	Wadi Thufer	Au, Zn, Cu, Ag	39.6296670	22.5051110	Al Abyar	VL	lenses
1384	Wadi Zufur-N	Wadi Thufer	Au, Zn, Cu	39.6352780	22.5022220	Al Abyar	undefined	lenses
1253	Ad Duwwarah	Ad Dawara	Au, Cu, Zn	39.7169440	22.3933330	Dhubaya-Jumah	Low	uncertain
1181	Jabal Abu Musht	Abu Umm Shut	Au, Cu	39.5056940	22.2889440	Thuwal	Med	v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins

In 1984, the Al Maraysi Belt was covered by airborne EM-magnetometer surveys which detected a conductor associated with a magnetic low about 1 km west of Al Maraysi. Ground follow-up EM surveying outlined a conductor which was tested by three percussion holes – disseminated pyrite was present in the samples but assay values were low. During 1988-89, the BRGM completed a restudy of the Samran-Shayban Belt for its gold potential, with site visits to Abu Shahab, Al Maraysi, Jabal Shayban, Wadi Bahran, Jabal Shayban-SE, Matober and Wadi al Bahair. Over a 10-day period, 1,012 samples were collected from 40 occurrences and prospects, however the work was terminated early for unknown reasons. The sites included copper prospects that are regarded as being outside of the structural zone favourable for gold, for example Wadi Shajiyah (4926, 4927), Jabal Baydan (4933), Wadi Saq (1257). The study also included copper prospects within the Al Maraysi Gold Belt including Jabal al Hamra (4934), Wadi ash Shatban (4924), the Hamar Zone (Hamar - 0412) and Wutaileh (0669). Half of the samples were from Shayban (277) and Al Hamra (219). The samples tested for gold were not fire assayed, however the siliceous samples were digested in HF and gold content was measured using AAS.


Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qt: Quaternay talus deposits
Qu: Quaternary sand, gravel, and silt deposits
Neogene
Nb: Neogene flood basalt
Nbh: Hammah Neogene Alkali olivine flood basalt
Nd: Dafina sandstone, conglomerate, and shale
Nsk: Khulays formation
Nss: Shumaysi formation, sandstone, mudstone, conglomerate, and limestone
Nus: Usfan formation, sandstone, ferruginous, conglomerate and fossiliferous limestone
Birak group >805 Ma
brl: Labunah formation, mafic and minor felsec volcanic rocks, with cherty rocks and marbie
brlb: Labunah formation, basalt and chert
brlm: Labunah formation, marble
brq: Qahah formation, mafic to felsic epiclastic rocks, conglomerate, and volcanic rocks
Kamil suite 825-772 Ma
kmsd: Shiwan complex, diorite (802 Ma)
kmsg: Shiwan complex, granodiorite (772 Ma)
kmsm: Shiwan complex, monzogranite
kmst: Shiwan complex, tonalite
kmt: Thufir irondtjernite
Misr complex 700 Ma
gsym: Monzogranite and gabbro
gsys: Syenite and gabbro
Qudayd suite 780-745 Ma
qdgn: Qudayd orthogneiss
Rabigh suite ~806 Ma
rehb: Hajar complex, gabbro
rahq: Hajar complex, quartz diorite
raht: Hajar complex, tonalite
Samran group 825-745 Ma
saa: Amudan formation, sericite-chlorite schist, andesite, rhyolite, and basaltic rocks
sah: Shayban formation, quartzofeldspathic and lithic volcaniclastics, and mafic volcanic rocks
sahc: Shayban formation, graywacke and conglomerate
sahs: Shayban formation, chloritic schist, amphibole, sericite, marble and quartzite
sam: Madrakah formation
san: Nida formation, chloritic schist, amphibole, sericite, marble and quartzite
Shayma Nasir group (Age uncertain)
nsrt: Taiha formation, basaltic to andesitic lava, volcaniclastics, rhyolite, and conglomerate
nsru: Uaibkh formation, Andesitic to dacitic lava, volcaniclastics, basalt, rhyolite, and conglomerate
Thamrah suite 870-775 Ma
rmsb: Ash Shaaf gabbro
rmum: Tharwah complex, serpentinite, peridotite, and gabbro (870 Ma)
Other Proterozoic units
kngr: Hanak granite 596 Ma
Unassigned Proterozoic rocks
ub: Unassigned gabbro
udz: Unassigned diorite, quartz diorite, and monzodiorite
ug: Unassigned granite
uru: Unassigned ultramafic rocks
AL MARASIA GOLD BELT
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Al Kamil
Khulays
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 37N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Location and Geology of the Al Marasia Gold Belt
Figure 4.
Watts, Griffis and McOuat

The Al Marasia occurrence and the Hamar occurrence (0412), located on the licence 9 km to the southwest, both associated with gossans, contained gold values of 1-12 g/t and 1-6.7 g/t, respectively. Al Marasia was estimated to contain a small uneconomic resource of 24,200 t averaging 6.2 g Au/t and 19.2 g Ag/t to a depth of 20 m.

Follow-up exploration was carried out by the BRGM at Al Maraysi as part of its regional program that included detailed mapping, structural studies and geophysical surveying (SP, IP, mise-a-la-masse, gravity and magnetometer) followed by the drilling of a total of 30 holes (4,614.9 m) on selected prospects: 11 at Al Maraysia, 11 at Wadi al Shatban, 4 at Hamar, 3 at Abu Shahab and 1 hole at Al Maraysi South. The resources at Al Marasia were re-estimated to contain 500,000 to 800,000 tonnes at less than 5% Cu. With a clear focus on base metal potential, the BRGM classified the Al Marasia, Wadi ash Shatban, Hamar and Abu Shiaab prospects as being stratiform exhalative VMS-type deposits. Gold enrichment in the gossans was noted and a possible link to late shearing was tendered, but largely ignored.

The definition of the Jabal Baydan deposit was mostly predicated on its zinc content. The BRGM estimated that it contained 500,000 to 700,000 tonnes of mineralization based on 11 percussion and 26 diamond drill holes completed up to 1996. With an average grade of approximately 16-17% Zn and 1.5-2.5 g Au/t, the deposit is hosted in the uppermost (latest) volcanic unit associated with rhyolitic volcanism which predates the deposition of epiclastic rocks. The black graphitic shale host rocks overlie rhyolitic quartz eye tuff indicating the probability of deposition from exhalative fluids, consistent with a VMS model, however these fluids do not normally contain significant amounts of gold. Drill hole BA-CO10 intersected 15.65 m of black shale averaging 4.7 g Au/t in addition to elevated zinc, copper and silver contents. WGM believes it is likely that gold mineralization was due to activity relating to a subsequent mineralizing system. The black shale acted as a chemically favourable host rock. This later mineralizing event may be related to orogenic activity or late volcanic (epithermal) activity.

Ctiadel acquired the Jabal Shayban prospect under an exploration licence in approximately 2006, referred to as the company's "Wadi Shugea Project". Reverse circulation drilling programs were carried out during 2007 and 2008. During the second program, typical higher grading intersections included drill hole SH052RC which encountered 41 m averaging 22.75 g Au/t beginning at surface, and hole SH049RC which cut 28 m averaging 14.17 g Au/t in attenuated lenses which plunge steeply south along the west-dipping Shayban Shear Zone. More typically, hole SH056RC intersected 4 m averaging 1.96 g Au/t. Mineralization was traced over a strike length in excess of 550 m and was estimated in 1999 to contain in excess of 250,000 equivalent ounces of gold when all mineral credits are combined. Through a series of take-overs, the project is now operated by Bariq which is 70% owned by Vertex Group (Middle East) WLL of Bahrain. Over 70 drill holes were completed by the end of 2014, however Bariq has not released recent exploration information to the public.

For many of the prospects in the belt, the BRGM failed to do systematic exploration, with the work being a superficial examination supplemented by only a few samples. Less than 10 samples were usually collected and in many cases the total is fewer than 5 (e.g., Wadi Qidra, Abu Shahab, Jabal Shayban-SE, Jabal

Shayban-NE1 and Ad Duwwarah. In 1991 the BRGM recommended limited core drilling of selected targets (Jabal Shayban, Al Hamra and Wadi al Lusub South), but it is uncertain if this work was ever completed (Coumoul et al, 1991).

Geology

The Al Maraysi Gold Belt is located within what has been called the Samran fold-thrust belt by Johnson (1998). Situated on the northern margin of the Jiddah Terrane, the rocks are composed volcanic, volcaniclastic and intrusive rocks which are deformed by tight-to-isoclinal, subvertical shear zones, and high- to low-angle reverse faults. Al Maraysi Gold Belt identified by WGM includes the Hamar Shear Zone referred to by Johnson as well as the Samran-Shayban Shear Zone 5-6 km to the southeast. The two shear zones probably merge to the northeast. They are parallel to the Bi'r Umq Suture which represents the line of closure between the Hijaz Terrane to the north and the Jiddah Terrane to the south, a structural feature that extends into East Africa as the Nakasib Suture. In a manner similar to the gold-bearing Nabitah structures, some of the reverse (thrust) faults in this area contain bodies of serpentinite (probably ophiolite) which indicate that these fault zones structures are very deeply rooted as might be expected. Collectively, it is this intense structural deformation to which the gold potential is attributed. Johnson's analysis of the tectonic history classifies these structures as syn-metamorphic which precisely matches the metallogenic model for orogenic gold. The brittle-ductile strain and hydrothermal alteration seen along these structures supports the circulation of high-temperature metamorphogenic fluids of the kind typically associated with such gold deposits. The structural corridor, within which the Maraysi Gold Belt occurs, crosses the Red Sea and reoccurs exactly along strike in the Haya Terrane of Sudan and Eritrea where a number of gold deposits have been identified. These structures may be of similar age to the Nabitah, and it is certain that they are significantly older than Najd fault zones since the belt terminates in the northeast against the Ad Dafinah-Ruwah Fault Zone.

The mineralization intersected at Shayban occurs within south-plunging, west-dipping boudinaged bodies aligned along the Shayban Shear Zone where it cuts across weakly metamorphosed felsic to intermediate volcaniclastic rocks including marble and chert intruded by diorite plutons. In the vicinity of ancient mine workings, the host rocks are strongly altered and gossanous. The gold-bearing bodies, measuring up to 150 m long by 70 m wide and 30 m thick, are strongly veined and sulphide bearing. The process that introduced gold-telluride mineralization was a late stage metallogenic event along the shear zone that overprinted pre-existing VMS-type massive sulphide mineralization in a manner similar to the gold system at the Al Amar Mine. Grades are quite variable within the mineralized lodes indicating the presence of nuggety, irregularly distributed grains of gold.

Mineralization at Al Maraysi is represented on surface by well-developed, copper-stained (limonite-hematite) gossan in an outcrop of chlorite and sericite schists and phyllite. These are the metamorphic equivalents of the meta-lapilli tuff, quartz-crystal phyllic tuff and quartz-eye porphyry from which they were derived. The mineralization occurs in a number of bodies that are tabular, parallel to the local NE-striking

(020°) foliation and shallowly to moderately dipping to the northwest. Coumoul and others report the assays in Table 6, averaging 3.9 g Au/t and 10.27 g Ag/t across 15 m in a body of foliated gossan sampled during the BRGM's assessment of the precious metals potential of the Samran-Shayban belt.

Table 6
Continuous Channel Sample Assay Results, Al Maraysi Gossan

Sample Number	Gold (g/t)	Silver (g/t)
SMR 1001	0.16	1.27
SMR 1002	0.42	1.49
SMR 1003	1.20	9.20
SMR 1004	0.65	1.96
SMR 1005	6.90	17.62
SMR 1006	0.88	4.69
SMR 1007	6.42	11.35
SMR 1008	2.42	3.57
SMR 1009	0.22	0.65
SMR 1010	0.94	<0.50
SMR 1011	1.38	0.65
SMR 1012	0.37	<0.50
SMR 1013	0.47	<0.50
SMR 1014	5.08	15.19
SMR 1015	5.88	40.65
SMR 1016	2.68	42.79
SMR 1017	12.20	29.32
SMR 1018	1.53	10.87
SMR 1019	0.26	1.33
SMR 1020	3.86	1.52

Note: BRGM did not report sample lengths or intervals – not all samples are equal. On average, lower grade sample are narrower than higher grade samples.

Some later shearing at Al Maraysi, which is essentially an S2 foliation, occurs at 150°-160°, probably as a result of a Najd over-print. Quartz in the shears is typically brecciated and traces of galena are noted. At one locality, gossan is well developed on a body of massive siliceous to cherty rock. The surrounding rocks are chlorite schist and chlorite-sericite schist which show a strong crenulation cleavage.

At Abu Shahab, the structural zone represented by chlorite schist, sericite schist and hematized schist is more than 100 m wide with quartz veins up to 20 cm thick. The strongest foliation is oriented at 020° / 60°-70°W. The quartz veins in many locations are strongly brecciated and the BRGM reports a gossan measuring 40 m by 300 m. Traces of gold were reported from a single surface sample.

At Hamar, post-metamorphic (possibly axial-planar) faulting occurs which is sub-parallel to the foliation in chlorite schist, sericite schist and quartz-sericite schist. Quartz veining is strong locally. The schist contains minor amounts of malachite does not appear to be spatially associated with vein formation. The prevalent strike of the foliation is 020°-030°. Gossans outcrop along a 600 m long, 50 m wide shear zone and the two drill holes previously showed irregular gold values as high as 2.06 g/t. Despite the gold values, the gold potential of the prospect was ignored and subsequent work used a variety of geophysical techniques to test for base metals.

Like in many other areas of the belt, high gold values reported at the Jabal Abu Musht (formerly Abu umm Shut) copper occurrence have largely been ignored in favour of its potential for base metals. The chloritized, silicified and sericitized felsic tuffs suggest potential for gold. Samples taken from pillars in ancient workings assayed as high as 48 g Au/t and 1.45% Cu. Gold values as high as 6.17 g/t occur in wadi sediments. Repeated sampling of mine workings has confirmed the high gold contents in the area. WGM concludes that the Al Maraysi Gold Belt is associated with a structural zone that extends along a wider belt of felsic and mafic volcanic rocks that is also highly prospective for volcanogenic base metal (VMS-type) deposits related to felsic volcanic centres. The gold mineralization resulted from hydrothermal fluids that penetrated along structural conduits (faults, shears, deformation zones) and the level of mineralization varies from prospect to prospect depending on the physical and chemical properties of the host rocks with which the fluids interacted. In some instances, the structural zones cut across felsic volcanic rocks containing copper and other base metals. In most, if not all cases, the focus has been on exploring the base metal potential.

Recommendations

The focus on base metals and the general lack of a systematic approach to gold exploration in this area using proper analytical techniques suggests that there may be potential that has been routinely overlooked. The area certainly contains an unusual cluster of copper occurrences as well, clearly signaling potential for stratabound base metals if the BRGM`s assessment is correct. Sufficient exploration has been done in the area to provide a good basic database of geophysical, geological and geochemical data. Yet even when the potential for gold was clear, the BRGM's reassessment in the late 80s was focussed on base metals. Its reassessment for precious metals in 1991 focused solely on major base metals prospects which had elevated gold contents, and surprisingly Al Marasia was dismissed as having "no individual economic interest" (Coumoul et al) despite the values shown in Table 6. This gold belt needs to be re-evaluated with a focus on orogenic gold, not on base metals. This is not intended to ignore the obvious base metal potential, but rather to look at the belt through a different lens. This new approach will require a focus on structural conduits likely to be associated with mesothermal gold rather than the stratigraphic controls known to be of importance for VMS-type deposits.

At Al Maraysi, the original drill hole completed in 1967 indicated strong gold mineralization in an area also containing copper. These results have not been duplicated in subsequent work. Although it is not unusual for drilling programs for gold to encounter set-backs, the results of the follow-up work seem to have had an excessively strong influence on the subsequent exploration of the area. It itself, the first intersection of 10.27 g Ag/t across 15 m is a **remarkable** result. Greater follow-up interest should have been generated, and the subsequent work should have involved diamond drilling. The continuing use of percussion drilling, a technology totally unsuitable for gold exploration, and the reliance on gold analyses of uncertain precision is a statement on the times when gold prices were relatively low compared to those that exist today. The target area for gold should be redefined based on the previous results and a clear geological model predicated on exploration for structurally controlled gold mineralization. A systematic IP survey should be

carried out define the target zone in 3D space prior to drilling, and an initial program of 3,000 m of diamond drilling should be completed focusing on IP chargeability anomalies.

The foregoing approach should be replicated on each of the gold prospects with IP profiles carried out perpendicular to the structural zones that host gold mineralization. Profiles should be on no more than a 100 m spacing. Each target should receive an initial provision of 2,000 to 3,000 m of diamond core drilling depending on the size of the target zone. If more than one target zone is present, then the budget should be increased proportionately.

As an indication of potential in the Al Maraysi Gold Belt, the ancient Mesaana Mine which occurs nearby at Jabal Samran contains quartz and quartz-carbonate veins which are axial-planar with the foliation and are gold-bearing with values as high as 31.74 g/t. Some veins up to 1.3 m in width are reported to contain consistent gold contents of approximately 6.2 g/t. Hydrothermal alteration is destructive and masks original minerals and textures. Although the mineralization is not likely orogenic, and may have an epithermal character, the area warrants additional exploration because the previous work has focused on base metals - gold values are seldom reported and the available reports do not make useful mention of analytical techniques for gold by which the reader can assess the validity of the results.

References

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Johnson, P.R., 1998, **The Structural Geology of the Samran-Shayban Area, Kingdom of Saudi Arabia**, USGS-TR-98-2 (Ir-947), a technical report for the Ministry of Petroleum and Mineral Resources, Deputy Ministry for Mineral Resources, Jeddah, Kingdom of Saudi Arabia, 45 pages, 1 Appendix.

3.1.3.3 Ash Shakhtaliyat Gold Belt

Location, Distribution of Occurrences and History

The Ash Shakhtaliyat Gold Belt comprises a series of gold prospects and occurrences that are located in the Eastern Shield in the Afif Terrane along a NNW-trending structural lineament. In detail, the structural zone is composed of several parallel lineaments that are up to 10 km apart. The lineament is dislocated in several areas by relatively younger, northwesterly trending Najd Faults. Left lateral off-sets of as much as 10 km are seen in several locations. A large section of the lineament is also buried by Cenozoic lavas belonging to Harrat Kishb. Most of the gold occurrences are found in the southern segment of the lineament, located south of the harrat. Only a few gold occurrences, including the important Bari occurrence, have been identified in the northern segment of the lineament that extends north from Harrat

Kishb, and this area can only be described as under-explored. The zone extends SSE to the Bi'r Nimi area, a distance of approximately 225 km. Details for these prospects are summarized in Table 7, in which the prospects are geographically sorted from north to south. The location of the belt and its general geological setting is shown in Figure 5.

The most advanced prospect in the northern part of the belt is the Al Bari gold-silver-zinc prospect (MODS 0452). Ancient mines are clustered in a group of more than 132 individual workings along a series of subparallel, easterly-striking shear zones which have been traced over strike length of 1,400 m in a zone about 1,000 m wide. The initial work in the area was during 1954 by SAM and commenced with the analysis of three samples taken from ancient mine dumps. These carried as much as 9.26 g Au/t, 3.25 g Ag/t and 0.3% Cu. Ten years later, the USGS surveyed the site and collected additional dump and soil geochemical samples. One diamond drill hole was completed south of the ancient mine's village but the results of this hole are unknown. Exploration continued under the management of the BRGM consisting of reconnaissance-scale geochemical sampling at a density of 1 sample/km^2, additional dump, slag and bedrock channel sampling. Dump samples contained a maximum of 8 g Au/t, 37 g Ag/t, 2.35% Pb and 1.3% Zn. Channel samples across mineralized sections carried lower values (Cassard and Gelot, 1987). During 1968, the Bari region was mapped geologically at 1:100,000 scale. During the 1973-74, more detailed mapping at 1:50,000 and 1:10,000 was carried out at the Bari Prospect, and soil geochemical sampling on a 200 m x 200 m grid was completed over a 20 km^2 area. Several low-level Pb and Zn anomalies were found. During the 1980s, 1:5,000-scale geological mapping was completed and 455 rock chip, grab, dump and channel samples were analyzed for Au and Ag by AA, as well as for an indicator element suite by ICP. Sample lengths were typically one metre except in alteration zones where 50 cm samples were collected. Anomalous gold contents extended up to 3 m from fracture zones which were shown to be the conduits for mineralizing fluids. Because pyrite and pyrrhotite are widespread at Bari, follow-up IP, mise-a-la-masse and VLF-EM surveys were used to trace mineralized zones which were reflected by shallow and deep IP-indicated conductors striking easterly across the Bari prospect.

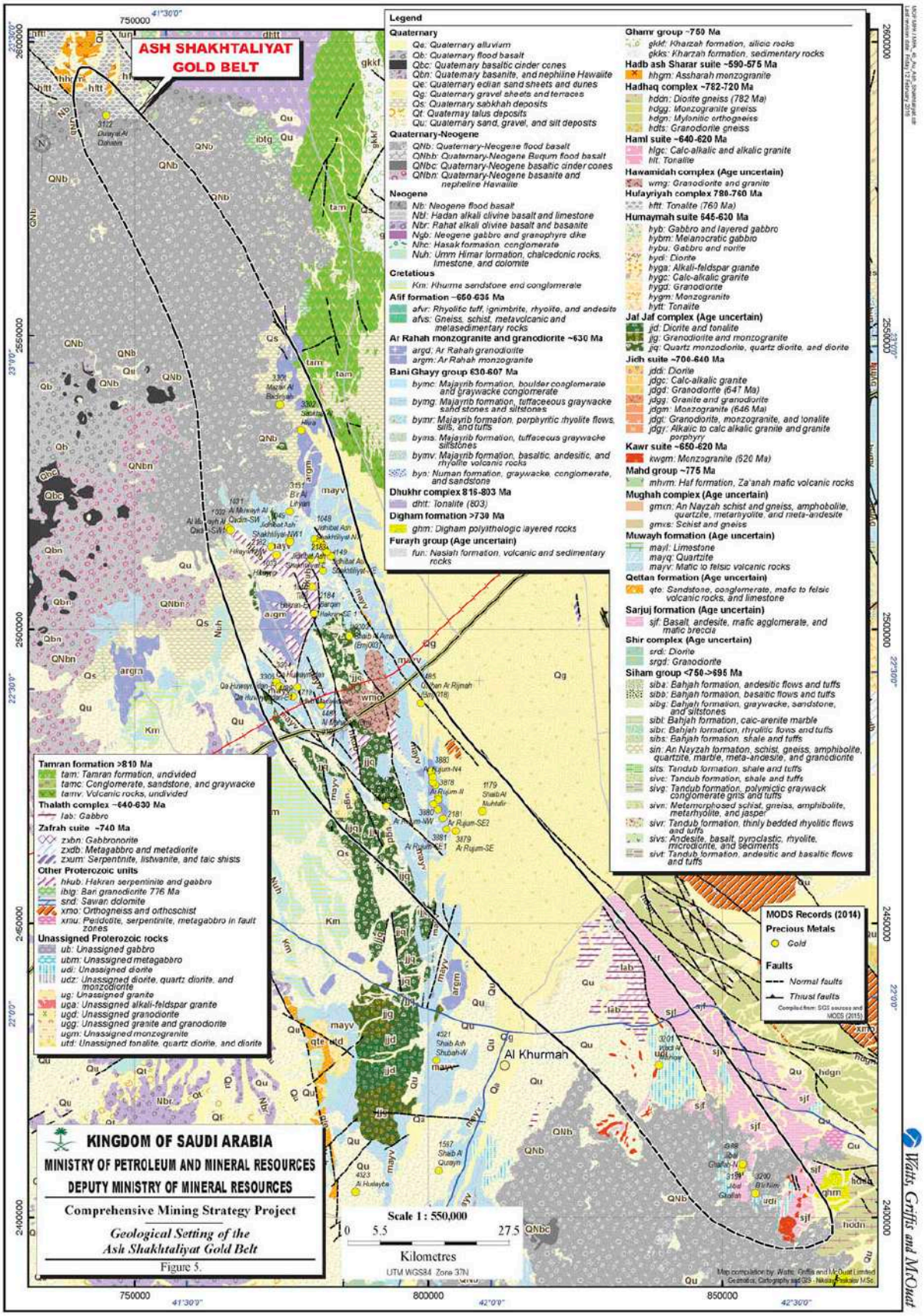
The BRGM carried out three programs of shallow percussion drilling at Bari (32 holes and 3,319.85 m) which were compromised by equipment problems. In four holes, a total of 236.55 m were drilled with coring equipment. Typical intersections included:

- 1.0 m averaging 3.8 g Au/t, 60 g Ag/t and 1.3% Pb (Old Village Area)
- 5.0 m averaging 1.6 g Au/t, 74 g Ag/t, 0.7% Zn and 0.5% Pb (Old Village Area)
- 3.0 m averaging 1.0 g Au/t, 13.8 g Ag/t, 0.34% Zn and 0.42% Pb (Trench 12)
- 39.0 m averaging 7.3 g Au/t, 12.9 g Ag/t and 1.2% Zn (Trench 13)
- 84.0 m averaging 6.8 g Au/t and 5.1 g Ag/t (Trench 13)
- 3.0 m averaging 0.05 g Au/t, 3.0 g Ag/t and >2% Zn (P-20 Area)

Table 7
Name and Location of Gold Occurrences - Southern Segment, Ash Shakhtaliyat Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry *
				Longitude	Latitude			
3132	Dulayat Al Qahatim	Jadib Al Qahtanah	Gold	41.3976670	23.3787780	Zalm	Low	v
0452	Al Bari	Bari	Gold	41.1688060	23.3515280	Zalm	Med	dd, v
3301	Mazari Al Badiriyah	Oum Naagoum	Gold	41.6776390	22.9294170	Zalm	VL	v
3302	Sabkhat Al Hiwa	Al Hazeim	Gold	41.7124440	22.8893330	Zalm	VL	v
3151	B'ir Al Lihyan	B'ir El Hiyan	Gold	41.6913610	22.7649170	Zalm	VL	v
1032	Al Muwayh Al Qadim-SW1	Al Muwayh Al Qadim-SW1	Gold	41.5924170	22.7381670	Zalm	VL	v
1044	Jidhibat Ash Shakhtiliyat-NW2	Jabal Graidan-N	Gold	41.7315560	22.7221110	Zalm	VL	v
1029	Jidhibat Ash Shakhtiliyat-NW3	Ash Shakhtaliat	Gold	41.6901670	22.7217220	Zalm	Med	v
1045	Jidhibat Ash Shakhtiliyat-N1	Ash Shakhtaliat	Gold	41.7411670	22.7187500	Zalm	Med	v
1049	Jidhibat Ash Shakhtiliyat-NW1	Ash Shakhtaliyah Prospect	Gold	41.6905280	22.7183060	Zalm	Med	v
1048	Jidhibat Ash Shakhtiliyat-NW	Ash Shakhtaliat	Gold	41.7339720	22.7130830	Zalm	Med	v
2182	Hikayrin-NW	Jabal Hkayrin	Gold	41.6592500	22.7117500	Zalm	Med	dd, v
1046	Jidhibat Ash Shakhtiliyat-N	Ash Shakhtaliat	Gold	41.7464170	22.7114440	Zalm	Med	v
1047	Jidhibat Ash Shakhtiliyat-SE	Ash Shakhtaliat	Gold	41.7488610	22.7035830	Zalm	Med	v
4149	Jidhibat Ash Shakhtiliyat-NE	Ash Shakhtaliyah Main	Gold	41.7510000	22.7018060	Zalm	Med	v
2183	Jidhibat Ash Shakhtiliyat-E	Ash Shakhtaliyah	Gold	41.7578610	22.6955280	Zalm	VL	v
1042	Tilal Hakran-NE1	Jabal Hakran-NE	Gold	41.7239720	22.6920000	Zalm	VL	v
1043	Jidhibat Ash Shakhtiliyat	Ash Shakhtaliat	Gold	41.7424170	22.6908330	Zalm	VL	v
1041	Tilal Hakran-E	Jabal Hakran-E	Gold	41.7441670	22.6738890	Zalm	VL	uncertain
1040	Tilal Hakran-E	Jabal Hakran-E	Gold	41.7263890	22.6488890	Zalm	VL	uncertain
2184	Barqan Hakran-SE 1	Jabal Hakran-SE	Gold	41.7288890	22.6078890	Zalm	Med	dd
3303	Shaib Al Ayrah (Bmj003)	Shaib Al Ayrah (Bmj003)	Gold	41.7858330	22.5733890	Zalm	VL	uncertain
3304	Qa Huwaymidan	Houimedan-W	Gold	41.6638610	22.5043890	Zalm	VL	v
3305	Qa Huwaymidan-E	Houimedan-E	Gold	41.6690280	22.4976940	Zalm	VL	dd, v
4489	Qa Huwaymidan-E1	Ar Rjum	Gold	41.6987780	22.4963610	Zalm	VL	dd, v
4719	Jidhib Masawdaah	Jidhib Masawdaah	Gold	41.6900280	22.4819170	Zalm	Low	undetermined
4485	Qulban Ar Rijmah (Bmj 018)	Qulban Ar Rijmah	Gold	41.9019440	22.4680560	New Wuwayh	Med	dd, v
4486	Al Mahazah (Bmj 019)	Al Mahazah (Bmj 019)	Gold	41.7376110	22.4675560	New Wuwayh	VL	v
3202	Ar Rujum-N5	Al Muwayh-E-SE	Gold	41.9166670	22.3627780	New Wuwayh	Med	dd, v
3883	Ar Rujum-N4	Ar Rjum	Gold	41.9194440	22.3541670	New Wuwayh	Med	dd, v
3882	Ar Rujum-N3	Ar Rjum	Gold	41.9194440	22.3458330	New Wuwayh	Med	dd, v
3876	Ar Rujum-N2	Ar Rjum	Gold	41.9236110	22.3416670	New Wuwayh	VL	V
3877	Ar Rujum-N1	Ar Rjum	Gold	41.9277780	22.3236110	New Wuwayh	VL	dd, v
3878	Ar Rujum-N	Ar Rjum	Gold	41.9277780	22.3194440	New Wuwayh	VL	dd, v
3880	Ar Rujum-NW	Ar Rjum	Gold	41.9194440	22.3125000	New Wuwayh	Med	dd, v
2179	Rijm Al Muwayh	Ar Rjum	Gold	41.8416670	22.3111110	New Wuwayh	Med	dd, v
2180	Ar Rujum	Ar Rjum	Gold	41.9263890	22.3041670	New Wuwayh	Med	dd, v
1179	Shaib Al Muhtafir	Rigum Senayfrah	Gold	42.0000000	22.3000000	New Wuwayh	VL	dd, v
2181	Ar Rujum-SE2	Ar Rjum	Gold	41.9347220	22.2902780	New Wuwayh	Med	dd, v
3881	Ar Rujum-SE1	Ar Rjum	Gold	41.9402780	22.2736110	New Wuwayh	Med	dd, v
3879	Ar Rujum-SE	Ar Rjum	Gold	41.9555560	22.2708330	New Wuwayh	Med	dd, v
4521	Shaib Ash Shubah-W	Wadi Al Shoabah	Gold	41.9165830	21.9190000	Al Khurma	VL	uncertain
3201	Wadi Al Mishqar	Wadi Al Mishqar	Gold	42.2826940	21.9046110	Al Khurma	VL	dd, v
4388	Jibal Ghallah-N	B'ir Nami-N	Gold	42.4166670	21.7500000	Al Khurma	VL	V
3199	Jibal Ghallah	B'ir Nami	Gold	42.4145830	21.7429170	Al Khurma	VL	dd, v
3200	B'ir Nimi	B'ir Nimi	Gold	42.4369440	21.7050000	Al Khurma	VL	dd, v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins


ASH SHAKHTALIYAT GOLD BELT
Legend
Quaternary
Qe: Quaternary alluvium
Qb: Quaternary flood basalt
Qbc: Quaternary basaltic cinder cones
Qbn: Quaternary basanite, and nephiline Hawaiite
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qf: Quaternary talus deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood baselt
QNbb: Quaternary-Neogene Buqum flood basalt
QNbc: Quaternary-Neogene basaltic cinder cones
QNbn: Quaternary-Neogene basanite and nephelinre Hawaiite
Neogene
Nb: Neogene flood basalt
Nbl: Hadan alkali olivine basalt and limestone
Nbr: Rahat alkali olivine basalt and basanite
Ngb: Neogene gabbro and granophyre dike
Nhc: Hasak formation, conglomerate
Nuh: Umm Himar formation, chalcedonic rocks, limestone, and dolomite
Cretatious
Km: Khurma sandstone and conglomerate
Afif formation ~650-635 Ma
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
afvs: Gneiss, schist, metavolcanic and melasedimentary rocks
Ar Rahah monzogranite and granodiorite ~630 Ma
argd: Ar Rahah granodiorite
argm: Ar Rahah monzogranite
Bani Ghayy group 630-607 Ma
bymc: Majayrib formation, boulder conglomerate and graywacke conglomerate
bymg: Majayrib formation, tuffaceous graywacke sand stones and siltstones
bymr: Majayrib formation, porphyritic rhyolite flows, sills, and tuffs
byms: Majayrib formation, tuffaceous graywacke siltstones
bymv: Majayrib formation, basaltic, andesitic, and rhyolite volcanic rocks
byn: Numan formation, graywacke, conglomerate, and sandstone
Dhukhr complex 815-803 Ma
dhlt: Tonalite (803)
Digham formation >730 Ma
ghm: Digham polyithologic layered rocks
Furayh group (Age uncertain)
fun: Nasiah formation, volcanic and sedimentary rocks
Ghamr group ~750 Ma
gkkf: Kharzah formation, silicic rocks
gkks: Kharzah formation, sedimentary rocks
Hadb ash Sharar suite ~590-575 Ma
hhgm: Assharah monzogranite
Hadhaq complex ~782-720 Ma
hddn: Diorite gneiss (782 Ma)
hdgg: Monzogranite gneiss
hdgn: Mylonitic orthogneiss
hdts: Granodorite gneiss
Haml suite ~640-620 Ma
hlgc: Calc-alkalic and alkalic granite
hlt: Tonalite
Hawamidah complex (Age uncertain)
wmg: Granodiorite and granite
Hufayriyah complex 780-760 Ma
hftt: Tonalite (760 Ma)
Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hybm: Melanocratic gabbro
hybu: Gabbro and norite
hyd: Diorite
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygm: Monzogranite
hytt: Tonalite
Jaf Jaf complex (Age uncertain)
jd: Diorite and tonalite
jg: Granodiorite and monzogranite
jq: Quartz monzodiorite, quartz diorite, and diorite
Jidh suite ~700-640 Ma
jdd: Diorite
jdgc: Calc-alkalic granite
jdgd: Granodorite (647 Ma)
jdgg: Granite and granodiorite
jdgm: Monzogranite (646 Ma)
jdgt: Granodiorite, monzogranite, and tonalite
jdgy: Alkalic to calc alkalic granite and granite porphyry
Kawr suite ~650-620 Ma
kwgm: Monzogranite (620 Ma)
Mahd group ~775 Ma
mhvm: Haf formation, Za'anah mafic volcanic rocks
Mughah complex (Age uncertain)
gmxn: An Nayzah schist and gneiss, amphibolite, quartzite, metarhyolite, and meta-andesite
gmxs: Schist and gneiss
Muwayh formation (Age uncertain)
mayl: Limestone
mayq: Quartzite
mayv: Matic to felsic volcanic rocks
Qettan formation (Age uncertain)
qte: Sandstone, conglomerate, matic to felsic volcanic rocks, and limestone
Sarjuj formation (Age uncertain)
sjf: Basalt, andesite, matic agglomerate, and matic breccia
Shir complex (Age uncertain)
srd: Diorite
srgd: Granodiorite
Siham group <750->695 Ma
siba: Bahjah formation, andesitic flows and tuffs
sibb: Bahjah formation, basaltic flows and tuffs
sibg: Bahjah formation, graywacke, sandstone, and siltstones
sibl: Bahjah formation, calc-arenite marble
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, meta-andesite, and granodiorite
sits: Tandub formation, shale and tuffs
sivc: Tandub formation, shale and tuffs
sivg: Tandub formation, polymictic graywack conglomerate grits and tuffs
sivn: Metermorphosed schist, greiss, amphibolite, metarhyolite, and jasper
sivr: Tandub formation, thinly bedded rhyolitic flows and tuffs
sivs: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
sivt: Tandub formation, andesitic and basaltic flows and tuffs
Tamran formation >810 Ma
tam: Tamran formation, undivided
tamc: Conglomerate, sandstone, and graywacke
tamv: Volcanic rocks, undivided
Thalath complex ~640-630 Ma
lab: Gabbro
Zafrah suite ~740 Ma
zxbn: Gabbronorite
zxdb: Metagabbro and metadiorite
zxum: Serpentinite, listwanite, and talc shists
Other Proterozoic units
hkub: Hakran serpentinite and gabbro
ibtg: Bari granodiorite 776 Ma
srd: Sawan dolomite
xmo: Orthogneiss and orthoschist
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
udi: Unassigned diorite
udz: Unassigned diorite, quartz diorite, and monzodiorite
ug: Unassigned granite
uga: Unassigned alkali-feldspar granite
ugd: Unassigned granodiorite
ugg: Unassigned granite and granodiorite
ugm: Unassigned monzogranite
utd: Unassigned tonalite, quartz diorite, and diorite
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Al Khurmah
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Ash Shakhtaliyat Gold Belt
Figure 5.
Scale 1 : 550,000
0 5.5 27.5
Kilometres
UTM WGS84 Zone 37N
Watts, Griffis and McOuat

Although hole P-10 intersected an 84 m section that carried 6.75 g Au/t and 5.1 g Ag/t, including a 48-metre interval averaging 10.15 g Au/t, follow-up drilling in this area failed to extend the zone. The geophysical surveying detected strong conductors estimated at more than 100 m below surface, somewhat at or beyond the drilling rigs capabilities at the time. WGM believes that Ma'aden has carried out exploration at Bari since the BRGM work ceased in the 1990s, however none of this work is available to WGM for review during the study.

In respect to gold prospects, the focal point of the southern segment of the Ash Shakhtaliyat Belt includes Jidhibat Ash Shakhtiliyat-NW3 (MODS 1029), Jidhibat Ash Shakhtiliyat (1043) and other Jidhibat Ash Shakhtiliyat area prospects (1044-1049) as well as satellite occurrences at Jidhibat Ash Shakhtiliyat-E (2183) and Jidhibat Ash Shakhtiliyat-NE (4149). Many of these were formerly referred to simply as Ash Shakhtaliat. The gold prospects are located in the Eastern Shield in the Afif Terrane along a NNW-trending structural lineament. In detail, the structural zone is composed of several parallel lineaments that are up to 10 km apart. The southern end of the lineament is located very near the village of Al Khurma at the intersection of highways 265, 275 and 3920. The gold occurrence named Shaib Ash Shubah-W (4521) is found in the area near a N-striking structure.

Exploration at the Shakhtaliyah prospect commenced with the BRGM's recognition of ancient gold workings in 1977 during 1:100,000 scale quadrangle mapping. During 1981, the BRGM completed reconnaissance geological mapping of the area and four trenches were excavated. This was immediately followed by 20 percussion holes totalling 2,030 m which produced many gold intersections exceeding 5 g/t over a strike length of more than two kilometres. Reconnaissance exploration continued in the surrounding region and detailed exploration was carried out at Shakhtaliyah comprising 1:20,000 scale geological mapping, soil geochemistry, ground geophysics and the excavation of 10 additional trenches as well as drilling 30 percussion holes and 11 diamond cored holes in 1982 and another 30 percussion holes in 1984. The drilling was very shallow, totalling only 1247 m in 1982 and 2415 m in 1984. Based on the results of this drilling, three targets areas at Shakhtaliyah were estimated to contain a resource of 1.7 Mt averaging 4.8 g Au/t. Further studies by the BRGM in 1985 included an additional 33 percussion holes averaging 49.7 m in length and six cored holes averaging 58.33 m in length. A new resource estimate for two zones was completed indicating a resource of 739,400 tonnes above 100 m averaging 5.2 g Au/t, and an open-pit mining plan was envisioned. However, some preliminary metallurgical tests were completed indicating a potential for problematic gold recoveries of only 30-50%, and consequently, the prospect was down-graded and the BRGM ceased exploration.

Pincock, Allen and Holt completed a preliminary estimation of the "underground gold resources" using a higher gold cut-off grade of 3 g/t, and re-estimated the resources as 480,000 tonnes averaging 12.5 g Au/t. As a result of this more favourable outlook, the BRGM resumed exploration during late 1990, and continued into the following year. The prospect was topographically surveyed using a 25 m by 25 m grid. Four additional trenches totalling 579 m were mechanically excavated in an E-W direction for structural studies (not for sampling). Detailed surface mapping was completed, including detailed mapping of targets nearby. Some samples were collected for geochemical and petrographic study. Additional drilling was also

completed with the goal of defining mineralized bodies with a minimum thickness of 5 m, a horizontal strike of 300 m or more and totalling 2 million tonnes at an average gold grade of 12-16 g/t. In total, the BRGM completed 5 diamond drill holes totalling 1,568 m and analysed 1,881 samples for gold in Jeddah and 173 samples were fire assayed for gold in Australia. The shear zone was described as an anastomosing network of mylonitic bands up to several metres thick and with a combined thickness of up to 250 m. The drilling traced the structure to a depth of more than 300 m. Each of the diamond drill holes intersected multiple narrow zones of gold mineralization ranging from approximately 50 cm to 6.6 m. A sample of some of the intersections follows (from Roubichou and others, 1991):

Hole	From (m)	To (m)	Width (m)	Grade (g Au/t)
C018	37.00	38.30	1.30	7.73
same	53.50	53.70	0.20	7.38
same	68.00	69.00	1.00	4.38
C019	81.50	88.10	6.60	2.37
same	143.20	145.65	2.45	11.16
same	158.50	159.50	1.00	5.75
C020	34.65	38.15	3.5	4.76
C021	154.50	155.70	1.20	1.05
same	207.10	208.30	1.20	2.03
same	386.40	387.30	0.90	1.07
C022	9.10	10.20	1.10	1.30
same	171.80	172.60	0.80	2.49

Two types of gold mineralization were recognized, both being synchronous with shearing however the gold was not predominantly contained in quartz as may have been though previously. Mineralization was associated with hydrothermal alteration related to ductile shearing which gave way to brittle-ductile shearing and then several phases of brittle deformation including mylonitization and faulting. The first type of mineralization, with grades as high as 18 g Au/t, was associated with chlorite-pyrite alteration adjacent to quartz stockworks and extending up to a few decimetres away from the veins. The second type was more irregular in grade and associated with breccia zones and associated quartz, sericite and pyrite – typical gold contents were less than 5 g/t over widths of 2-8 m. Some enrichment to levels of approximately 10 g Au/t was recognized where the host shear zone cut trondjhemite dikes and the resulting breccia was altered and mineralized. Despite the random nature by which the gold-bearing shear zones was tested, the BRGM was clearly disappointed in the results and recommended that exploration efforts focus on other prospects due to the irregular character of the mineralization. The BRGM concluded that there was no economic potential in the mineralized shear between 100 and 400 m from surface.

The Humaydan West (Houmidan) Prospect is located in an area of north-south trending ancient workings. The area contains quartz veins and stringer zones that are thought to be part of a Nabitah orogenic zone. Altered sheared and foliated metavolcanic rocks from mine dumps were assayed and gave significant gold assays. An RC drilling program was recently completed (27 holes for 2,640 m) successfully. The size of the zone was then investigated by a follow-up soil sampling program using a 200 m profile spacing and 50 m stations on each control line.

The Ar Rhum (Rjum) prospect area, including area of the Al Muwayh and Hurfrah occurrences (MODS 3202 and 4485) through which this lineament passes, is situated approximately 35 km north of Al Khurma. Farther north is the cluster of gold occurrences at Ash Shakhtaliah, including Bi'r Al Hiyan (3151). North of this, additional gold occurrences are associated with a parallel structure that extends along the eastern margin of Harrat Kishb. These additional occurrences include Al Hazm (3302) and Umm Naagoum (MODS 3301). About 130 km NNW of Al Khurma, the farthest end of the structural zone passes under Harrat Kishb.

Geology

At Al Bari, variable degrees of gold, silver, zinc and lead mineralization are fracture related within a suite of calc-alkaline plutonic rocks including diorite, granodiorite and quartz diorite (Coulombeau and others, 1977). Gold mineralization is localized in conjugate fracture and shear systems which are ENE to E-striking and ESE-striking. Hydrothermal alteration (silicification, bleaching) is pervasive along fracture margins penetrating a metre or more into the surrounding rock, even where the amount of introduced quartz is minor. Fractures and alteration are equally developed in all lithologies. Two principal areas of mineralization are recognized in the Old Village area and in the area around Trench-13. Channel samples from these areas have assayed as high as 6.5 g Au/t, 36.9 g Ag/t, 3.2% Zn, 1.1% Pb and 0.28% Cu (Cassard and Gelot, 1987). A third extensive area of alteration is situated one kilometre north of the Old Village area - it contains two conductors with an aggregate east-west extent of 2.5 km.

The ancient mine sites at Ash Shakhtiliyat were first identified on a USGS geological map in 1962. As described in the foregoing section, they are aligned on a major NNW-trending structural lineament (deformation zone) that is quartz-veined and strongly altered and pyritized. The country rocks are Hulayfah Group metavolcanic rocks which are intruded by dioritic dikes. Gold-bearing veins are concentrated within and adjacent to deformed diorite intrusions. Ancient workings in the main prospect area are situated along a linear zone that is 2,500 m long. The BRGM is credited with the discovery and initial mapping of the ancient workings in 1977 when initial reconnaissance grab sampling was completed. During the next 4 years, detailed mapping, trenching and magnetometer surveying focused on MODS sites 1045-1048. A 20-hole (2,030 m) program of percussion drilling was completed in 1981. Although percussion drilling is known to be a poor exploration technique, especially for gold, two zones were outlined that the BRGM estimated to contain 3.0 Mt at 5.5 g Au/t. During 1982-84, soil geochemical surveying, IP and VLF-EM surveys were completed, and a program of 11 diamond drill holes (1,247 m) tested deeper parts of the mineralized zone. A total of 30 new percussion holes in 1982 and a further 30 percussion holes in 1984 (2,415 m) filled in gaps between previous intersections. A geologically based resource estimate was completed amounting to 1.7 Mt averaging 4.8 g Au/t in three lenses. The disparity between the two BRGM estimates was never explained.

During 1984-85, the BRGM completed 6 shallow diamond cored holes (350 m) and 33 additional percussion holes (1,639 m) on the main Ash Shakhtiliyat prospect and adjacent zones. Cyanide leach tests were carried out on a bulk sample. Based on its new drilling, the BRGM re-estimated the resources to total

739,400 t grading 5.2 g Au/t to a depth of 100 m. Again the decrease in resources from 3.0 Mt initially to 1.7 Mt and then to 0.739 Mt was never adequately explained. In 1986, the consulting firm Pincock, Allen and Holt estimated the gold resources to a depth of 100 m to be 480,000 t averaging 12.5 g Au/t using a 3 g/t cut-off. In 1990 the BRGM studied the geology and concluded that additional resources were needed to support a development decision, and 3 deeper diamond cored holes totaling 874 m were drilled. The BRGM then concluded that the gold-bearing zones were too irregularly mineralized to be of economic significance, and the importance of the zones was down-graded in favour of other gold prospects such as Jabal Hakran South and Zalm (Roubichou et al, 1991). Work was suspended until Ma'aden acquired the licence in the early 1990s. Ma'aden's early annual reports do not report the nature of exploration programs being done and do not report exploration results. There are general references to Ma'aden completing geophysical surveys in the mid 1990s with disappointing results, and it is highly doubtful that the company has carried out any follow-up surveying in the last 15-20 years. Ma'aden has never reported a mineral resource for Ash Shakhtaliyah. After 2011, resource estimates were reported for some projects, however after 2012, the reporting of resources that were not compliant with the JORC Code ceased as Ma'aden moved towards international standards in its reporting. It's refusal to report on the results of exploration work unfortunately means that the current status of this metallogenic belt is unknown since most of the gold belt is located on Ma'aden's licence, especially its Ash Shakhtaliyah and Ar Rjum (Rujum) licences.

The Ar Rujum gold occurrences (MODS 2179, 2180, 3202, 3879, 3880, 4486 and 4489) have been extensively explored during the period 1995 through at least 2010. The mineralization at Ar Rujum has been subdivided into three deposits: Wasemah, Umm Naam and Ghazal – these names are not found in the MODS database and the precise relation to existing MODS records is uncertain although all are in the area generically referred to as Ar Rujum. Ma'aden has not routinely reported on exploration results however the MODS database indicates that the work at Ar Rujum has included ground magnetometer and IP surveying. An SRK report in November 2007 indicates that Ma'aden planned to complete 24,000 m of drilling that year on deposits at Ar Rujum. Ma'aden's exploration has been relatively comprehensive, although the early drilling was mostly percussion drilling and therefore of unreliable quality. Based on subsequent RC and diamond drilling, the company produced an estimate of Inferred Mineral Resources for the project during 2007 which totalled 35.89 Mt averaging 1.9 g Au/t, thus making it one of Ma'aden's largest gold resources at that time.

One prospect, previously referred to as Umm Naam (corresponding to MODS 3380), was being drilled at the time of a WGM site visit during 2008. Although subsequent statements in Ma'aden's 2012 annual report indicate that these resources were not JORC compliant, a comparison of these resources with other resources estimated at that time show that bringing historical estimates into compliance has not resulted in significant losses of either tonnage or grade. For example, Mansourah's historical measured-indicated and inferred gold resources were estimated at 18.1 Mt averaging 2.4 g/t and 3.6 Mt at 2.0 g/t. Its current JORC compliant resources are estimated at 26.4 Mt at 2.83 g/t and 9.3 Mt averaging 2.16 g/t, respectively. Clearly additional exploration at Mansourah supported and enlarged the previous deposit. Consequently, although the above-mentioned Ar Rujum resources are non-compliant, WGM accepts them as being a reasonable approximation of the gold resource classified as Inferred Resources at the time. In its 2014 annual report,

Ma'adan subdivides the resources, classified as Indicated and Inferred, into two deposits, the first named Waseemah and the second named Umm Naam. These are reported as:

Deposit	Inferred Resources *		Indicated Resources *		Global Resources		Comments
	Tonnes	Grade	Tonnes	Grade	Tonnes	Grade	
Wasemah	2.8	1.20	25.3	1.44	28.1 Mt	1.42 g/t	Uncertain MODS association.
Umm Naam	0.8	1.1	32.9	1.25	33.7 Mt	1.25 g/t	Probably MODS 3880 - Ar Rujum-NW

* Inferred and Indicated Resources are reported as JORC compliant.

The Wasemah deposit is hosted on a regionally extensive the same or a related NNW-trending shear zone which extends through the Ash Shakhtiliyat area. Within the deformation zone, mineralization occurs as a series of elongated or lens-like bodies which dip eastwards at 45° to 70°. They are up to 40 m wide, in excess of 100 m long and extend at least 100 m down dip. Mineralisation is associated with quartz veins and is hosted in sheared and altered diorite-granodiorite. Very fine grained gold occurs within and adjacent to pyrite, which occurs in amounts of 1-10%, and goethite. Minor amounts of chalcopyrite (<1%) may be present as well as traces of chalcocite, covellite, sphalerite and molybdenite. Average gold contents vary from 1.5 g Au/t to 5.5 g Au/t. Mineralisation occurs over a strike length of at least 950 m. Umm Naam is geologically similar to Wasemah, consisting of numerous gold-bearing sub-parallel E-dipping shears which crosscut diorite, mafic volcanics and quartz-feldspar porphyry units. Mineralisation occurs along all shear structures. The highest grades and widest sections occur where shears cut diorite units, which is a common feature of many orogenic gold deposits, not only in Saudi Arabia, where intermediate intrusions are major hosts to mineralization. The Ghazal Prospect was an ancient gold mine. It is characterised by an outcropping quartz vein that is hosted in tuff and occasional diorites. The vein has a strike of at least 400 m and gold is associated with its more highly sheared sections.

Recommendations

Coulombeau and others (1977) developed a negative view concerning the potential of Bari. This was based on non-systematic exploration and very little evidence. Since 1977, exploration work on the Bari prospect has been more methodical, and the channel sampling techniques were well planned and carried out. In doing this review, WGM is drawn to the fact that the Bari prospect was essentially explored with percussion drills that were incapable of testing the geology at the depth of the main geophysical anomalies. This failing, combined with the unsuitability of percussion drills for gold exploration, poses a great challenge in assessing the exploration results. It is clear that the results to date have the potential to under-report gold contents. The inability of the drill to extend gold-bearing zones, and to return comparable results may be more related to equipment than geology. Combined with the BRGM's failure to use fire assaying for gold, the exploration of Bari faced many head-winds. Some holes that did not intersect mineralization were drilled down-dip. The continuity and substantial length of the sulfide mineralization in the northern conductor suggests that stratabound exhalite sulfides may be present. In this context, the Bari gold

prospect should potentially be explored as a combined orogenic gold-VMS-base metals target similar to Al Amar. In any case, the Bari prospect and especially the northern conductor zone, deserves additional exploration in the form of detailed geophysical surveying (IP and EM) and diamond drilling. WGM believes that Ma'aden has carried out exploration at Bari since the BRGM work ceased in the 1990s, however none of this work is available to WGM for review during the study. Ma'aden relinquished the licence sometime after 2004 and it was acquired by Citadel. Through a series of take-overs, the project is now operated by Bariq which is 70% owned by Vertex Group (Middle East) WLL of Bahrain. Bariq has not released recent exploration information to the public.

Much of the Ash Shakhtiliyat area was initially explored by the BRGM which has completed reasonably well designed and executed geological and geochemical exploration programs. One major failing of the BRGM is its reliance on percussion drilling which experience in many parts of the world has shown to be a very poor choice when exploring for gold. Some of the BRGM's assaying techniques, particularly its MIBK extraction, were not appropriate for gold, especially refractory gold. In its 1992 study, WGM was critical of the BRGM for the use of these techniques and for failing to recognize significant gold potential in many areas of the Arabian Shield. The validity of the BRGM's conclusions must be assessed in this context. If 480,000 t averaging 12.5 g Au/t exists to a depth of only 100 m at Ash Shakhtiliyat, then this is a highly significant result from an exploration perspective, yet the BRGM was disappointed. Its deeper drill was far too widely scattered to reliably evaluate the depth potential of the zone. If this zone continued to 1,000 m it would carry 4.8 Mt of ore containing 1.75 million ounces (Moz) of gold – this is a resource that exceeds the total life-time production of many Canadian gold mines. If the BRGM's final estimate is used (739,400 t grading 5.2 g Au/t) and extended to 1,000 m, the resources would total 7.4 million tonnes or 1.12 Moz. Clearly a significant amount of additional drilling is warranted at Ash Shakhtiliyat probably extending to several hundred holes (approximately 50,000 m of core drilling). An attempt should be made to identify the main controlling shears and focus efforts on systematically expanding higher grading zones where these shears intersect more favourable host rocks (trondjhemite?). In such mesothermal deposits, it is not uncommon for the grade and thickness of mineralization to be controlled by the physical and chemical characteristics of the host rock as these influence permeability and the reactions that occur between the host rock and gold-bearing hydrothermal fluids.

In the Kingdom as a whole, relatively little use is made of ground geophysical surveying as a fundamental exploration technique. This has changed somewhat since 2008 when WGM recommended that Ma'aden make greater use of geophysical surveying and the company established a department for such surveying. Nevertheless, relatively little use of ground geophysics such as magnetometer and IP surveying is made in Saudi Arabia compared to that of western companies where virtually every project would have some magnetometer, VLF and IP coverage. Good outcrop exposure in many areas allows for visual examinations of bedrock and zones considered to be prospective for gold. However the areas examined tend to be found where ancient workings are identified, and the exploration has not moved significantly away from such workings. The potential for the main structures to be buried nearby under alluvium is also a distinct possibility. Geophysical surveys in the past tended to cease in the mid 1990s after disappointing results on the Ash Shakhtaliyah licences. WGM is uncertain to what extend Ma'aden is using systematic IP

surveying to model potential gold-bearing structures between known prospects and deposits, however this should be a first priority approach using profiles normal to the strike of the structures on 100 m spacings.

As of 2008/09, only about 15-20% of the favourable exploration area along the Ash Shakhtiliyat gold belt was covered by detailed airborne geophysical surveys. The percentage of coverage of key target areas may be slightly higher at approximately 25%. While airborne surveying will not detect gold deposits directly, airborne magnetometer surveying will differentiate between rock types that are important factors when assessing exploration potential. An important facet of modern systematic exploration is effectively unavailable to exploration planners in this area[3]. This lack can be compensated for through surface geophysical surveying on profile lines across structural zones know to be gold bearing. Magnetometer surveying on the ground surface can be useful in delineating lithological contacts, for example between greenstones and intermediate plutonic rocks such as tonalite and diorite (which may be preferentially mineralized). VLF surveys can detect young fault zones that are filled with water. Although these may not be gold-bearing, they may represent structures that offset mineralized zones. Surface magnetometer and VLF surveying are relatively inexpensive and there is no good reason not to carry out such surveys as part of a comprehensive exploration program long before any plan to drill.

Significant extensions of the gold-bearing structural zones (shears/deformation zone) exist between the Ar Rujum and Ash Shakhtiliyat areas. In both, gold mineralization is associated with disseminated sulphides, predominantly pyrite. Magnetometer and VLF surveying can be used to trace the important structures thought to have potential for gold. Given the common association between gold and disseminated pyrite, however, IP is the geophysical tool of choice for tracing such zones and detecting anomalies that represent targets for drilling. The resistivity component of such surveys can be used to model rock formations and the chargeability component can be used to indicate zones that carry anomalous amounts of pyrite. Importantly, IP provides data that can be modelled in three dimensions thus providing important data at depth, commonly below the deepest levels currently drilled. Care must be taken to ensure that proper QA/QC protocols are in place to maximize the quality of the data collected. In the Nabitah Gold Belt, the IP surveying by the SGS at Umm Matierah carried out during the period 1995-1997 resulted in noisy chargeability and resistivity data that substantially degraded the value of the survey. Despite this, anomalies were detected that coincided with some of the mineralized zones. Better equipment, better field practices and more than reconnaissance-level surveying would have overcome many of the short-comings of this work, but it cannot be claimed that IP surveying failed to detect the gold-bearing zone.

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[3] The moderate level of detail of airborne geophysical data, typically involving profile separations averaging 200 m (or more) effectively limits the usefulness of the geophysical information. While such profile spacings may be suitable for regional-scale geological mapping, they are much less useful for exploring mineral belts. The usefulness of such data for gold exploration is compromised by: (1) the generally narrow geometry of gold-bearing zones; and (2) gold mineralization may not be associated with features than have magnetic responses. Gold deposits may be spatially related to a pluton with a distinctive magnetic signature, and this may be useful as a general guide to the location of potential mineralization. The only recent example of a modern survey that is known to WGM is a test magnetometer-spectrometer survey flown by Ma'aden during 2007 over a portion of the Nabitah Deformation Zone to determine whether the zone, and intrusions within it, could be adequately traced below alluvium. The survey demonstrated conclusively that meaningful data could be collected. In light of Canadian experience, this outcome was not surprising yet it was a game-changing event for Ma'aden.

Following the comprehensive surveying of the Ash Shakhtiliyat gold belt, all anomalies should be followed up by in-fill surveying at half of the profile spacing first used. Electrode ("a") spacings can be varied to provide greater detail at shallower depths or increased to provide greater depth penetration. Electrode arrays can be varied depending on the level of detail wanted and the rate of coverage deemed to be acceptable. WGM favours dipole-dipole arrays which provide symmetrical data over vertical anomalies, and the geological interpretation is relatively simplified. The paramount concern should always be getting current into bedrock, and appropriate sized generators must be used that are matched to the IP transmitter. Once detailed, IP anomalies require testing with a diamond core drill.

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3.1.3.4 The Ghuzayyilat-Zalim Gold Belt

Location, Distribution of Occurrences and History

This belt, like the As Siham - Az Zeraib Gold Belt, is a loosely aligned series of 60 gold occurrences aligned along a 170-kilometre long, NNW (340°) structural trend (the Ad Dafinah fault zone) parallel to and 60-70 km west of the Bi'r Tawilah - Mansourah Segment of the Nabitah Gold Belt. The belt is located immediately south of the Ar Rika Fault Zone, a Najd structure which may separate and offset this belt from similar structures to the north. The gold belt is cut off at its southern end by the Ruwah Fault Zone (Figure 6).

The northern part of the belt is marked by two major gold occurrences: Shuqayra Jiza, (MODS 0285) formerly known as Jabal Geza, and Jidhib Ghuzayyilat (3073) formerly known as Jadib Ghuzayyil. Shuqayra Jiza is a somewhat isolated single site whereas Jidhib Ghuzayyilat comprises a large cluster of

30 gold occurrences each having its own MODS record. At the main Ghuzayyil prospect (MODS 1630-1632), ancient gold mines are developed on a series of subparallel quartz-bearing shear zones within a tonalite granodiorite host. Other gold prospects include Shaib abu Kharit (3133) located 10 km to the north, and 26 occurrences in the immediate Ghuzayyilat area including MODS 0284, 0285, 3161, 3163, and 3072-3093, inclusive. A summary of the MODS indices in the gold belt is given in Table 8.

Table 8
Name and Location of Gold Occurrences – Jidhib Ghuzayyilat-Zalim Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
3133	Shaib Abu Kharit	Wadi Abu Khurayt	Gold	41.6732780	23.8558330	Zalim	Undefined	v
3076	Jidhib Ghuzayyilat-NW6	Jadib Ghuzayyil-N	Gold	41.6669440	23.7691670	Zalim	Undefined	dd, v
1632	Jidhib Ghuzayyilat-NW	Jadib Guzzayyil	Gold	41.6505560	23.7661110	Zalim	Undefined	dd, v network
3074	Jidhib Ghuzayyilat-NW4	Jadib Ghuzayyil	Gold	41.6547220	23.7611110	Zalim	Undefined	dd, v network
3075	Jidhib Ghuzayyilat-NW5	Jadib Ghuzayyil Ne	Gold	41.6799720	23.7604720	Zalim	Undefined	dd, v
3164	Jidhib Ghuzayyilat-NE	Jadib Ghuzayyil-E	Gold	41.7169440	23.7591670	Zalim	Undefined	dd, v
3073	Jidhib Ghuzayyilat	Jadib Ghuzayyil	Gold	41.6527780	23.7575000	Zalim	Undefined	dd, v
3077	Jidhib Ghuzayyilat-NW2	Jadib Ghuzayyil	Gold	41.6644440	23.7555560	Zalim	Undefined	dd, v
3072	Jidhib Ghuzayyilat-NW1	Jadib Ghuzayyil	Gold	41.6558330	23.7547220	Zalim	Undefined	dd, v network
3078	Jidhib Ghuzayyilat-SW12	Jadib Ghuzayyil	Gold	41.6632220	23.7465560	Zalim	Undefined	dd, v
3163	Jidhib Ghuzayyilat-SE7	Jadib Ghuzayyil-E	Gold	41.6989720	23.7445280	Zalim	Undefined	dd, v network
3079	Jidhib Ghuzayyilat-SE	Jadib Ghuzayyil	Gold	41.6613890	23.7436110	Zalim	Undefined	dd, v
3090	Jidhib Ghuzayyilat-SW11	Jadib Ghuzayyil	Gold	41.6782780	23.7417500	Zalim	Undefined	dd, v
0284	Jidhib Ghuzayyilat-SW9	Jadib Guzzayyil	Gold	41.6458330	23.7411110	Zalim	Med	dd, v
3080	Jidhib Ghuzayyilat-SW10	Jadib Ghuzayyil	Gold	41.6511110	23.7392780	Zalim	Undefined	dd, v
3081	Jidhib Ghuzayyilat-SW8	Jadib Ghuzayyil	Gold	41.6402780	23.7341670	Zalim	Undefined	dd, v
3082	Jidhib Ghuzayyilat-SE5	Jadib Ghuzayyil SW	Gold	41.7136110	23.7308330	Zalim	Low	dd, v network
3091	Jidhib Ghuzayyilat-SW7	Jadib Ghuzayyil Middle	Gold	41.6601390	23.7304440	Zalim	Undefined	dd, v network
3089	Jidhib Ghuzayyilat-SE6	Jadib Ghuzayyil	Gold	41.6864440	23.7301390	Zalim	Undefined	dd, v
3083	Jidhib Ghuzayyilat-SE4	Jadib Ghuzayyil	Gold	41.6953890	23.7228610	Zalim	Low	dd, v network
3088	Jidhib Ghuzayyilat-SE3	Jadib Ghuzayyil-SE	Gold	41.6858330	23.7227780	Zalim	Undefined	dd, v network
1631	Jidhib Ghuzayyilat-SW5	Jadib Guzzayyil	Gold	41.6825000	23.7219440	Zalim	Undefined	dd, v network
3092	Jidhib Ghuzayyilat-SW6	Jadib Ghuzayyil SW	Gold	41.6659720	23.7219170	Zalim	Undefined	dd, v
3093	Jidhib Ghuzayyilat-SE2	Jadib Ghuzayyil SE	Gold	41.7135280	23.7217500	Zalim	Undefined	dd, v network
3086	Jidhib Ghuzayyilat-SW3	Jadib Ghuzayyil-SE	Gold	41.6719440	23.7188890	Zalim	Undefined	dd, v
1630	Jidhib Ghuzayyilat-SW4	Jadib Guzzayyil	Gold	41.6714440	23.7171390	Zalim	VL	dd, v
3087	Jidhib Ghuzayyilat-SE1	Jadib Ghuzayyil	Gold	41.6823890	23.7160830	Zalim	Undefined	dd, v
3085	Jidhib Ghuzayyilat-SW2	Jadib Ghuzayyil-SE	Gold	41.6833330	23.7105560	Zalim	VL	dd, v
0285	Shuqayra Jiza	Jabal Geza	Gold	41.8888610	23.7094440	Zalim	Med	dd, v
3084	Jidhib Ghuzayyilat-SW1	Jadib Ghuzayyil-SE	Gold	41.6805000	23.7020280	Zalim	Undefined	dd, v network
2107	Burqan Hubayrin-SE6	Jabal Al Hibr-E	Gold	42.1440830	23.6977220	Zalim	VL	v
0918	Burqan Hubayrin-SE8	Jabal Al Hibr-E	Gold	42.1529170	23.6967220	Zalim	Med	dd, v
2009	Burqan Hubayrin-SE7	Jabal Al Hibr-E	Gold	42.1666670	23.6958330	Zalim	Undefined	dd, v
2106	Burqan Hubayrin-SE3	Jabal Al Hibr-E	Gold	42.1379720	23.6955280	Zalim	VL	v
0917	Burqan Hubayrin-SE4	Jabal Al Hibr-E	Gold	42.1441390	23.6946110	Zalim	Med	dd, v
0916	Burqan Hubayrin-SE2	Jabal Al Hibr-E	Gold	42.1506110	23.6879440	Zalim	Med	dd, v
0919	Burqan Hubayrin-SE9	Jabal Al Hibr-E	Gold	42.1590560	23.6874440	Zalim	Low	v
0915	Burqan Hubayrin-SE1	Jabal Al Hibr-SE	Gold	42.1437220	23.6776670	Zalim	Med	uncertain

Table 8
Name and Location of Gold Occurrences – Jidhib Ghuzayyilat-Zalim Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
0910	Burqan Hubayrin-SE	Jabal Al Hibr-SE	Gold	42.1447220	23.6761110	Zalim	Med	dd, v
0914	Burqan Hubayrin-SW4	Jabal Al Hibr-SE	Gold	42.1387220	23.6686390	Zalim	Med	v
0913	Burqan Hubayrin-SW3	Jabal Al Hibr-SE	Gold	42.1323330	23.6682780	Zalim	Med	v
3134	Dulayat Umm Qubur	Kurum Umm Al Qubur	Gold	41.7158060	23.6329440	Zalim	Med	v
4336	Dulayat Umm Qubur	Khurum Umm Al Qubur 2	Gold	41.7280560	23.6225000	Zalim	Undefined	v
0288	Qa Miqarr An Naam	Mangar An Na'Am-SE	Gold	41.9602780	23.5951390	Zalim	Med	dd, v
0286	Jabal Khurb	Jabal Khorb	Gold	41.9020000	23.5921390	Zalim	Low	dd, v
0909	Qa Wahib-SW	Jabal Al Hibr-SE-SW	Gold	42.0014170	23.5753330	Zalim	VL	dd, v
0911	Qa Wahib-SW2	Jabal Al Hibr-SE-SW	Gold	42.0203060	23.5665280	Zalim	VL	dd, v
0912	Qa Wahib-SW1	Jabal Al Hibr-SE-SW	Gold	42.0100280	23.5444440	Zalim	VL	dd, uncertain
1627	Qa Miqarr An Naam	Jabal Mugherah-E	Gold	41.9719440	23.5441670	Zalim	Undefined	dd, v
0498	Abar As Suhilah-N	Wadi Suhaylah	Gold	42.5067780	23.4320830	Zalim	Undefined	v
0483	Wadi Mishqar Ash Shuwatin	Wadi Al Mashqar	Gold	42.4804440	23.3864170	Zalim	Undefined	uncertain
0287	Al Mughayra	Jabal Mugherah-E	Gold	41.9797220	23.5188890	Zalim	Low	dd, v
0363	Al Mughayra	Mugherah-E	Gold	41.9837220	23.4748610	Zalim	Med	dd, v
1027	Abar Hadaf	North Zalim	Gold	42.1375280	22.9595000	Zalim	VL	dd, v
1028	Awraynibah	Jabal Zalim-SW	Gold-Silver	42.1448330	22.7809440	Zalim	VL	dd, v
1025	Burqan Zalm-W	Jaba Zalm-SE Ib25	Gold	42.2271940	22.7761670	Zalim	VL	dd, v
1024	Burqan Zalm	Jabal Zalm-SE	Gold	42.2335830	22.7754720	Zalim	VL	dd, v
1020	Sabkhat Buhayran	Zalim-SE Higway N° 4	Gold	42.1967500	22.7301390	Zalim	High	dd, v
3884	Shaib Ash Shuaybah	Ouest Zalim	Gold	42.0914170	22.7189170	Zalim	VL	v
1178	Sabkhat Buhayran	Wet	Gold	42.2537780	22.6858610	Zalim	Med	v

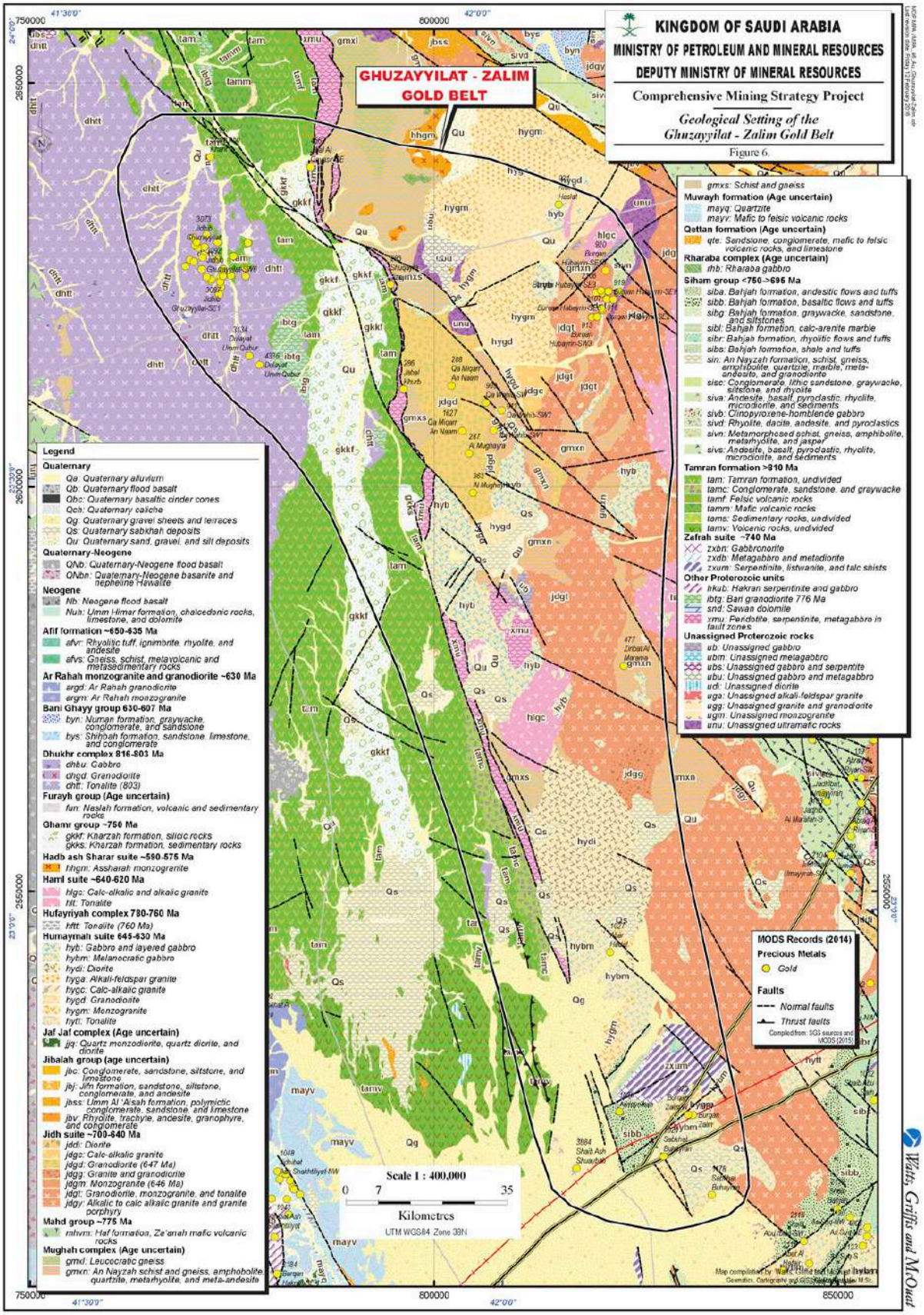
NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = vein

Exploration programs by BRGM in the Ghuzayyilat area consisted of mapping, sampling, trenching, soil sampling and drilling. Six samples averaging 7.5 g Au/t were taken by the USGS in 1954 as part of an assessment of ancient gold prospects. The BRGM commenced 1:100,000 scale geological mapping of the area in 1966 and produced 1:10,000 scale maps of the prospect. Samples collected at that time averaged 5.7 g Au/t and 5.2 g Ag/t. In the early 1980s, an 80 km^2 area around the prospect including 42 ancient workings was mapped at a scale of 1:20,000 scale. The workings were surveyed and mapped in detail at 1:5,000 scale and 345 samples were assayed for gold and silver. Assays from 113 grab samples of red ferruginous quartz from the veins average 7.5 g Au/t, and 132 dump samples produced an arithmetic average gold content of 3.73 g/t. Fifty-one trenches totalling 1,034 m were excavated on the gold-bearing veins and mapped at 1:50 scale. A total of 857 samples were collected from 27 of the trenches, and an additional 112 bulk samples were taken for further analysis. A soil geochemical survey was carried out over a 25 km^2 area using profile lines with a 100-metre and 400-metre spacing resulting in 3,375 sample sites from which coarse fraction and fine fractions were analysed for gold and a multi-element ICP analysis. Seventeen shallow combined percussion/diamond drill holes totalling 1,174 m were completed to test the mineralized zones below the ancient workings. The work has generally shown that the gold-bearing quartz vein systems strike north-westerly and dip 60° NE. The veins are surrounded by a pyritic, potassic alteration halo. The results of drilling were thought to be disappointing at the time. Most vein structures pinched out between 30 and 60 m from surface. Within the oxidized zone, hole PI7 intersected a 1-metre interval that carried 13.88 g Au/t, however most samples carried less than the average seen in surface samples. Assays within pyritized core below the oxidized zone were generally less than 1.0 g/t Au (Cassard and Salpeteur, 1985).

The Shuqayra Jiza prospect was tested by 20 diamond drill holes which showed that mineralization occurs with discontinuous quartz veins in a 200 m wide shear zone over a strike of approximately 3 km. Few of the specific results are reported.

South of the Ghuzayyilat area, a second cluster of 14 gold occurrences is found in the Burqan Hubayrin area (MODS 0909-0919, 2009, 2106 and 2107), formerly known as the Jabal al Hibr area. The Jabal Al Mughayra prospects (MODS 0287 and 0363) are situated at the southern end of this cluster. There is nothing in the literature available for this study that can be used as a guide to this area.

The Zalim area is located up to 20 km west of the structural corridor that hosts the As Suq deposit. Seven gold prospects are located in the Zalim area that are likely controlled by the same set of structures as that in the Jabal Ghuzayyil farther to the north. The main Zalim gold prospect, now known as Sabkhat Buhayran (MODS 1020), saw a brief period of mining in 1950, producing 300 ounces of gold, but was closed in 1952 when the ore was exhausted. The prospects were examined and sampled by the BRGM and Riofinex during the early and mid-1980s. Riofinex concluded that the mineralization warranted additional exploration however WGM has no record of any additional work being done. The SGS has referred to work by the BRGM reported in BRGM-TR-99-15, author unknown, comprising 57 trenches totalling 4,768 m, 51 shallow cored drill holes totalling 3,752.2 m and 38 very shallow reverse circulation drill holes totalling 1,985 m. According to the SGS, this work supported a resource estimate for Zalim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MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Ghuzayyilat - Zalim Gold Belt
Figure 6.
GHUZAYYILAT - ZALIM GOLD BELT
Legend
Quaternary
Qa: Quaternary alluvium
Qb: Quaternary flood basalt
Qbc: Quaternary basaltic cinder cones
Qca: Quaternary calcrete
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
QNbn: Quaternary-Neogene basanite and nepheline hawaiite
Neogene
Nb: Neogene flood basalt
Nuh: Umm Himar formation, chalcedonic rocks, limestone, and dolomite
Afif formation ~650-635 Ma
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
afvs: Gneiss, schist, metavolcanic and metasedimentary rocks
Ar Rahah monzogranite and granodiorite ~630 Ma
argd: Ar Rahah granodiorite
argm: Ar Rahah monzogranite
Bani Ghayy group 630-607 Ma
byn: Numan formation, graywacke, conglomerate, and sandstone
bys: Shihbah formation, sandstone, limestone, and conglomerate
Dhukhr complex 816-803 Ma
dhbu: Gabbro
dhgd: Granodiorite
dhtt: Tonalite (803)
Furayh group (Age uncertain)
fun: Naslah formation, volcanic and sedimentary rocks
Ghamr group ~750 Ma
gkkf: Kharzah formation, silicic rocks
gkks: Kharzah formation, sedimentary rocks
Hadb ash Sharar suite ~590-575 Ma
hhgm: Asshariah monzogranite
Haml suite ~640-620 Ma
hlgc: Calc-alkalic and alkalic granite
hlt: Tonalite
Hufayriyah complex 780-760 Ma
hftt: Tonalite (760 Ma)
Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hybm: Melanocratic gabbro
hydi: Diorite
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygm: Monzogranite
hytt: Tonalite
Jaf Jaf complex (Age uncertain)
jjq: Quartz monzodiorite, quartz diorite, and diorite
Jibalah group (age uncertain)
jbc: Conglomerate, sandstone, siltstone, and limestone
jbj: Jifn formation, sandstone, siltstone, conglomerate, and andesite
jbss: Umm Al 'Alsah formation, polymictic conglomerate, sandstone, and limestone
jbv: Rhyolite, trachyte, andesite, granophyre, and conglomerate
Jidh suite ~700-640 Ma
jdd: Diorite
jdgs: Calc-alkalic granite
jdgd: Granodiorite (647 Ma)
jdgg: Granite and granodiorite
jdgm: Monzogranite (646 Ma)
jdgt: Granodiorite, monzogranite, and tonalite
jdgy: Alkalic to calc alkalic granite and granite porphyry
Mahd group ~775 Ma
mhvm: Haf formation, Ze'amah mafic volcanic rocks
Mughah complex (Age uncertain)
gmxl: Leucocratic gneiss
gmxn: An Nayzah schist and gneiss, amphibolite, quartzite, metarhyolite, and meta-andesite
gmxs: Schist and gneiss
Muwayh formation (Age uncertain)
mayg: Quartzite
mayv: Mafic to felsic volcanic rocks
Qattan formation (Age uncertain)
qte: Sandstone, conglomerate, mafic to felsic volcanic rocks, and limestone
Rharaba complex (Age uncertain)
rhb: Rharaba gabbro
Siham group <750->695 Ma
siba: Bahjah formation, andesitic flows and tuffs
sibb: Bahjah formation, basaltic flows and tuffs
sibg: Bahjah formation, graywacke, sandstone, and siltstones
sibl: Bahjah formation, calc-arenite marble
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, meta-andesite, and granodiorite
sisc: Conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
siva: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
sivb: Clinopyroxene-hornblende gabbro
sivd: Rhyolite, dacite, andesite, and pyroclastics
sivn: Metamorphosed schist, gneiss, amphibolite, metarhyolite, and jasper
sivs: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
Tamran formation >810 Ma
tam: Tamran formation, undivided
tamc: Conglomerate, sandstone, and graywacke
tamf: Felsic volcanic rocks
tamm: Mafic volcanic rocks
tams: Sedimentary rocks, undivided
tamv: Volcanic rocks, undivided
Zafrah suite ~740 Ma
zxbn: Gabbronorite
zxdb: Metagabbro and metadiorite
zxum: Serpentinite, listwanite, and talc shists
Other Proterozoic units
hkub: Hakran serpentinite and gabbro
ibtg: Bani granodiorite 776 Ma
snd: Sawan dolomite
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
ubs: Unassigned gabbro and serpentite
ubu: Unassigned gabbro and metagabbro
ud: Unassigned diorite
uga: Unassigned alkali-feldspar granite
ugg: Unassigned granite and granodiorite
ugm: Unassigned monzogranite
unu: Unassigned ultramafic rocks
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Compiled from: SGS sources and MODS (2015)
Scale 1 : 400,000
0 7 35
Kilometres
UTM WGS84 Zone 38N
Watts, Griffis and McOuat

that amounted to 7.8 Mt to a depth of 100 m with an average grade of 2.63 g Au/t including a slightly higher grading central core of 4.85 Mt grading 2.73 g Au/t. This resource would be based on angled diamond drill holes with an average length of 74 m supplemented with RC holes averaging 52 m. It is doubtful that this estimate would comply with present international standards for estimating mineral resources.

Other prospects in the belt include Abar Hadaf (1027), Awraynibah (1028), Burqan Zalm W (1025) and Burqan Zalm (1024), both formerly part of Zalim, and Shaib Ash Shuaybah (3884) as well as the Sabkhat Buhayran prospect (1178), formerly known as Wet. At the main Gold is present in quartz veins containing minor sphalerite, galena, pyrite, and arsenopyrite hosted by a granite-granophyre complex. Surface grab sampling in 1980 resulted in an assay of 640 g Au/t and 100 g Ag/t indicating a potential for bonanza grades! The BRGM reported that no follow-up work was completed on the deposits as of the mid-1980s (Viland, 1986). Given that the geological setting is very similar to that of the As Suq Mine, WGM recommended additional exploration following its review in 1992.

Geology

Gold at Shuqayra Jiza is spatially associated with the Ad Dafinah structure, a major system of 340°-trending faults which extend southerly from the Najd fault near As Safra. These faults parallel a similar system of faults that mark the western boundary of the Afif Terrane about 50 km to the west. The gold mineralization occurs in discontinuous quartz veins within a 200 m wide shear zone over a strike of approximately 3 km. The Ad Dafinah structure is a thrust at this location, and is marked by bodies of listwaenite up to 50 m thick. The best mineralized section is up to 10 m in width, rich in disseminated pyrite and contains strong silicification and sericite alteration. The host rock is reportedly a sheared felsic metavolcanic rock, however in this setting deformation and alteration tend to be highly destructive in respect to original textures and mineral phases.

The Jidhib Ghuzayyilat gold prospect comprises a series of subparallel quartz-bearing shear zones cutting tonalite-granodiorite. The vein-structures strike 320-330° and dip 60° E within a pyritic, potassium alteration halo. The veins contain variable amounts of pyrite, chalcopyrite, sphalerite, galena, and arsenopyrite and are enveloped by a chlorite-sericite alteration halo. Pyrite is very common within a chlorite-sericite alteration envelope and has a sympathetic spatial relationship to gold. Subordinate chalcopyrite, sphalerite, galena, and arsenopyrite have been noted within the vein systems. Assays from 113 grab samples of red ferruginous quartz from the veins averaged 7.5 g Au/t. Assays from 132 dump samples averaged 3.73 g Au/t.

WGM understands that Ma'aden has continued its prospecting and geochemical exploration programs in the region surrounding Shuqayra Jiza and Jidhib Ghuzayyilat over the past 10-20 years however no information is available relating to specific results of that work.

Assays as high as 3.6 g Au/t were reported from a northerly striking listwaenite-bearing shear zone at Sabkhat Manjur.

At the historical Zalim Mine, now known as Sabkhat Buhayran, gold is hosted in quartz veins with minor sphalerite, galena, pyrite, and arsenopyrite which fill shear zones within a small granite-diorite intrusion that was emplaced into volcanosedimentary rocks. From the shallow BRGM work, it is clear that a potentially large bulk-minable deposit may be present.

Recommendations

Given the fact that the As Suq Mine is close to the Ghuzayyilat-Zalim Gold Belt, it is somewhat surprising that the clusters of gold occurrences in this area have not received persistent systematic exploration. The three major clusters of occurrences in the Jidhib Ghuzayyilat, Burqan Hubayrin (Hibr) and Zalim areas warrant much more exploration than has been completed to date. This exploration should investigate the potential; for a single mineralized NNW-trending structure in this area. If such a shear (deformation) zone existed, it would be of similar age as the Nabitah Fault Zone to the east. Exploration could be initiated by working outwards from known mineralized zones using IP geophysical surveying augmented with magnetometer surveying to trace mineralized zones and lithological contrasts. IP anomalies consisting of high chargeability and high resistivity should be tested with a diamond core drill.

In the main Jidhib Ghuzayyilat prospect, the veins pinch out at depth and that values from sub-surface samples are much lower from these taken at surface. The BRGM proved that gold is concentrated in quartz vein systems with minor amounts of pyrite and base metal sulfides. Although the work carried out to date appears to be comprehensive, the percussion drilling did not adequately explain the pinch out of the vein systems nor the discrepancy in grades between surface and fresh rock. The structures should have good lateral and down-dip continuity. Given the presence of gold in pyrite, a potassium alteration halo and irregular gold values in trenches, further exploration is warranted. In addition, not all of the vein systems on the prospect were fully explored. Many prospects are found in the area, and the work to date has apparently focused only on the main prospect area as no additional information is available for prospects in the surrounding area. Additional work is required to solve those problems, to thoroughly explore all veins, and to search for new vein systems.

The mineralization outlined at Zalim is clear evidence of a large near-surface deposit that may have open pitable, bulk-tonnage mining potential. Although the previous work was not available for detailed review, it is clear that additional drilling is needed to delineate this deposit in accordance with current Best Practices standards and to test below the current base of drilling, estimated to be no more than 100 m from surface.

The presence of Bonanza grades for both gold and silver in the Zalim area is clear evidence that additional exploration is needed, however, given the presence of coarse and irregularly distributed gold, caution must be used in using exploration techniques that are not prone to misrepresenting precious metal contents.

Percussion and RC drilling must be avoided as the samples produced, when assayed, have great potential to over-state or understate metal contents. Diamond drilling combined with fire assaying of 50 gram charges is the only acceptable technique of exploring such mineralization. If the mineralization can be shown to be non-refractory, bottle-roll cyanide leaching of over-sized metallurgical samples is an acceptable means of reliably testing gold and silver grades and extractability on kilogram-sized samples.

Cassard, D. and Salpeteur, I., 1985, **Mineral Exploration of the Jadib Ghuzayyil Gold Prospect Area**: Saudi Arabian Deputy Ministry for Mineral Resources Open-File Report BRGM-OF-05-16, 140 pages.

WGM, 1992, **Extent, Status and Adequacy of Mineral Exploration in the Eastern Arabian Shield**, a confidential report by Watts, Griffis and McOuat Limited for the Ministry of Petroleum and Mineral Resources, Directorate General of Mineral resources, WGM-CR-11-12, 330 pages.

3.1.3.5 The As Siham – Az Zeraib Gold Belt

Location, Distribution of Occurrences and History

The As Siham – Az Zeraib Gold Belt is a loosely aligned series of 60 gold occurrences (Table 9) aligned along a 200-kilometre long, NNW trend parallel to and 20-30 km west of the Bi'r Tawilah - Mansourah Segment of the Nabitah Gold Belt. To a casual observer, the two belts might be thought of a single zone that is favourable for gold, however the scarcity of gold prospects between the two belts indicates that they are separate zones. Whereas the gold belt on the main Nabitah Fault Zone is associated with a major suture zone, the structure controlling these occurrences, including the As Suq deposit, appears to be less well defined in a regional sense. The gold belt is framed by two Najd faults, being cut off on its southern end by the Ruwah Fault Zone and in the north by the Ar Rika Fault Zone (Figure 7). These two faults also delimit the ends of the Bi'r Tawilah – Mansourah belt.

Near the northern end of the belt, Riofinex carried out a mapping and sampling program in 1985 which included portions of the As Siham area including the Wadi Mishqar Ash Shuwatin (formerly Harriah) prospects (MODS 0112 and 0113). The work included some trenching and channel sampling of the wall at 5 m intervals (Aspinal, 1986). At Al Khuwaymat (0116), 6.8 km to the west, Riofinex carried out a mixed program of rotary percussion and mixed-mode (percussion and core) drilling in 1985 resulting in nine holes being completed. Aspinal (1986) reported a 1.5 m intersection in a cored drill hole at Al Khuwaymat which assayed 45.3 g Au/t.

Table 9
Name and Location of Gold Occurrences – As Siham-Az Zeraib Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
0903	Wadi As Silimat	Wadi Al Hazarah	Gold	42.3954170	23.6793610	Zalim	Med	Veins
0904	Wadi Surur-S2	Wadi Al Hazarah	Gold	42.3912780	23.5402220	Zalim	Med	dd, veins
0498	Abar As Suhilah-N	Wadi Suhaylah	Gold-Nickel	42.5067780	23.4320830	Zalim	Undefined	v
0483	Wadi Mishqar Ash Shuwatin	Wadi Al Mashqar	Gold-Copper	42.4804440	23.3864170	Zalim	Undefined	uncertain
0112	Wadi Mishqar Ash Shuwatin	Harriah	Gold-Silver	42.4161390	23.3416940	Zalim	Low	dd, v
0116	Alkhuwaymat	Quwaymah	Gold-Silver	42.3447500	23.3326390	Zalim	Med	dd, v
0113	Dib Umm Kharit	Harriah	Gold-Silver	42.4096940	23.3247500	Zalim	Low	dd, v
0118	Dib Umm Kharit-S	Harriah	Gold-Silver	42.4035000	23.3198330	Zalim	Med	dd, v
0480	Shaib Umm Gharas	Wadi Al Numar	Gold-Zinc	42.3746670	23.3169720	Zalim	Low	dd, v
0477	Ziribat Al Marama	Al Atrur	Gold-Lead	42.1617780	23.2788060	Zalim	Low	dd, v
0117	Shiab Al Maliyah Ash Shamali	As Siham	Gold-Silver	42.3855560	23.2408060	Zalim	Med	dd, v
0478	Wadi Al Maliyah-W	Wadi Ma'Liyah	Gold-Copper	42.3871390	23.2283060	Zalim	Undefined	dd, v
0115	Shaib Al Maliyah Al Janubi	As Siham	Gold-Silver	42.3854440	23.2229170	Zalim	Med	dd, v
0114	Jadhib Al Marafah	Bu Arck Ar Ra'Yan	Gold-Silver	42.3872220	23.1912500	Zalim	Med	dd, v
0423	Jadhib Al Marafah-E	As Siham Area	Gold-Silver	42.4618610	23.1895830	Zalim	Undefined	v
0479	Abraq Ar Riyan	Jabal Abraq Humayrah	Gold-Lead	42.4452220	23.1479440	Zalim	Med	dd, v
0119	Abraq Ar Riyan-SW	Bu Arck Ra'Yan-SE	Gold	42.4336390	23.1479440	Zalim	Med	dd, v
2103	Jadhib Al Marafah-S	La Ism Leha	Gold	42.3987500	23.1318330	Zalim	Undefined	dd, v
0662	Jadhibat Umayyirah	As Siham Area	Gold-Silver	42.4035000	23.1221670	Zalim	Undefined	dd, v
2105	Abraq Ar Riyan-S	Jabal Abraq Humayrah	Gold	42.4445830	23.1194440	Zalim	Undefined	dd, v
2102	Jadhibat Umayyirah	Sabkhah Al Manjur	Gold	42.4347220	23.0944440	Zalim	Undefined	dd, v
0481	Jadhibat Umayyirah-S	Sabkhah Al Manjur	Gold-Zinc	42.4314170	23.0832500	Zalim	Med	dd, v
2104	Jadhibat Umayyrah-SW	Sabkhah Al Manjur	Gold	42.4069720	23.0621670	Zalim	Undefined	dd, v
0489	Sabkhat Juman-NE	Al Uzaylah	Gold-Nickel	42.5019170	23.0543890	Zalim	Undefined	dd, v
0482	Sabkhat Juman-W	Sabkhah Al Manjur	Gold-Copper	42.4297220	23.0412220	Zalim	Low	dd, v
1019	Al Himar-N1	Al Himar-N1	Gold-Silver	42.4656390	22.9323890	Zalim	VL	v
1018	Al Himar-NW2	Al Himar-NW2	Gold-Silver	42.4230560	22.9190830	Zalim	VL	dd, v
1022	Al Himar-NW3	Al Himar-NW3	Gold-Silver	42.4501670	22.9181670	Zalim	Low	dd, v
1011	Al Himar-N	Al Himar-N	Gold	42.4693610	22.9165560	Zalim	Med	dd, v
1016	Al Himar-NW1	Al Himar-NW1	Gold-Silver	42.4132500	22.9045000	Zalim	VL	v
1017	Al Himar-NW	Al Himar-NW	Gold-Silver	42.4279440	22.8994720	Zalim	VL	v
1008	Al Himar	Al Himar	Gold	42.4745560	22.8955830	Zalim	VL	dd, v
1010	Al Himar-SW3	Al Himar-SW3	Gold-Silver	42.4718060	22.8930000	Zalim	Med	dd, v
1009	Al Himar-SW	Al Himar-SW	Gold-Silver	42.4626940	22.8806670	Zalim	VL	dd, v
1924	Al Himar-SW1	Al Himar-SW1	Gold	42.4638890	22.8800280	Zalim	VL	dd, v
1619	Shaib Al Hufayyirah	Al Himar	Gold	42.4687220	22.8078890	Zalim	Med	dd, v
1012	Shaib Abu Sarh	Al Hmar	Gold	42.4515560	22.7879170	Zalim	VL	dd, v
1918	Shaib Al Jiwanni	As Suq-N	Gold	42.4638610	22.7012780	Zalim	VL	dd, v
2119	Shaib Bahjah	As Suq-W Area	Gold	42.4047780	22.6676110	Zalim	Med	dd, v
4258	Abal Al Lamisah	Jabal Lamisah	Gold	42.5495280	22.6581390	Zalim	VL	dd, v
4389	Abal Al Lamisah	Jabal Lamisah	Gold	42.5495280	22.6581390	Zalim	VL	dd, v, stwks
2120	As Suq-NW	As Suq-NW	Gold	42.4196110	22.6577220	Zalim	Med	dd, v
4006	As Suq-NE	As Suq-NE	Gold	42.4401670	22.6456110	Zalim	Med	lenses
1177	As Suq	As Suq	Gold	42.4394720	22.6356940	Zalim	Med	v
2122	Shaib Zaraib Nasir-NW	As Suq Area	Gold	42.4677220	22.6335000	Zalim	Med	dd, v

Table 9
Name and Location of Gold Occurrences – As Siham-Az Zeraib Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
2118	Shaib Abu Iblan-SW	As Suq-W Area	Gold	42.3635830	22.6319720	Zalim	Med	dd, v
2123	As Suq-S	As Suq-S	Gold-Silver	42.4341390	22.6254170	Zalim	Med	dd, v
2121	Shaib Zaraib Nasir	As Suq Area	Gold	42.4851940	22.6099440	Zalim	VL	dd, v
2117	Shaib Abu Iblan	As Suq-W Area	Gold	42.3693060	22.6069170	Zalim	Med	dd, v
2116	Abar Al Hafair	Al Haffirah	Gold	42.3374720	22.5996940	Zalim	Med	dd, v
2115	Shaib Al Lamisah-NE	Sha'lb Lamisah	Gold	42.5302500	22.5961110	Zalim	Med	dd, v
4493	Zaraib As Suq	Haffirah	Gold	42.3765830	22.5768330	Zalim	Med	v
4498	Zaraib As Suq-E	Haffirah	Gold	42.4037220	22.5766390	Zalim	Med	v
4494	Zaraib As Suq-SE1	Haffirah	Gold	42.4028060	22.5740560	Zalim	Med	v
4496	Abar Al Hafair-SE1	Haffirah	Gold	42.3500830	22.5736670	Zalim	Med	v
4497	Abar Al Hafair-SE	Haffirah	Gold	42.3626670	22.5691670	Zalim	Med	v
4495	Zaraib As Suq-SE	Haffirah	Gold	42.3936110	22.5326940	Zalim	Med	v
0424	Jabal Ghurrab	Jabal Ghurrab	Gold	42.3989170	22.4426940	Zalim	VL	dd, v
2124	Jabal Ghurrab-SE	Jabal Ghurrab-SE	Gold	42.4076110	22.4263060	Zalim	VL	dd, v
2690	Zaraib At Tal	Azzeraib	Gold	42.5560000	22.3049170	Zalim	Med	lenses, v

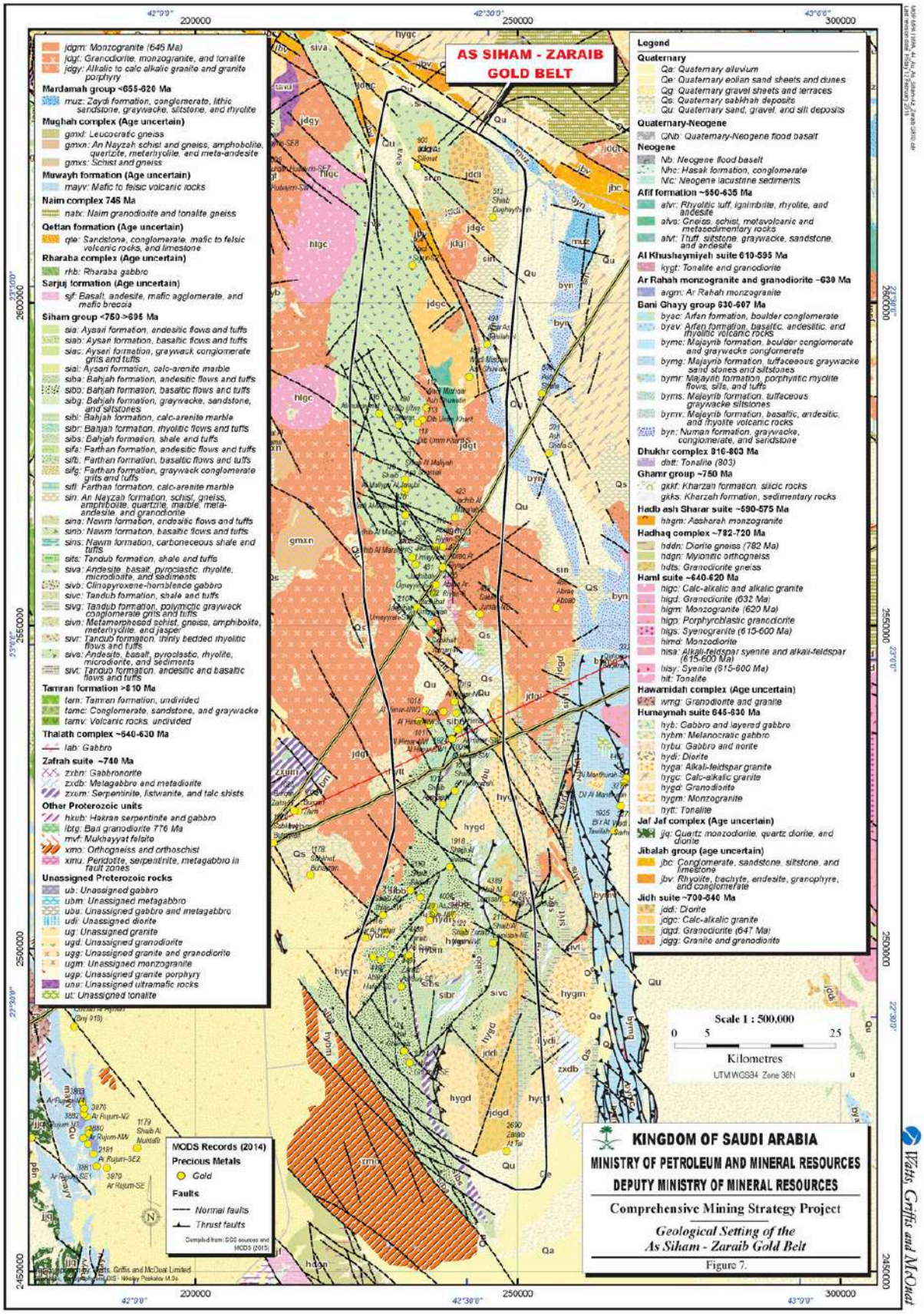
NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins; stwks = stockworks

Three gold prospects near the northern end of the belt, Wadi Mishqar Ash Shuwatin, Dib Umm Kharit and Dib Umm Kharit South were formerly known as simply as the Harriyah occurrences (MODS 0112, 0113 and 0118, respectively). The prospects are located about 65 km north-northeast of Zalim. Ancient workings were first discovered by Schaffner in this area during the early 1950s. Arabian Geophysical and Surveying Company carried out an electromagnetic survey to investigate all the ancient working in the As Siham Quadrangle, however the results of this work were not available for study by WGM. During regional geological mapping of the Afif Quadrangle in the late 1970s, the BRGM observed the presence of 25 ancient workings scattered over a 1.5 km by 5 km area in the Kharit/Harriyah area (Letalenet, 1979). Most of the samples taken by the BRGM assayed less than 9 g Au/t and less than 60 g Ag/t. Al Khuwaymat (MODS 0116), formerly known as Quwaymah and located in the same general area, contained 25 small en-echelon trenches that produced assays in the range of 3-5 g Au/t. Riofinex subsequently completed 18 very shallow rotary percussion holes with total length 479.50 m at Dib Umm Kharit south (Aspinall, 1986). The average gold grade ranged between trace levels and 2.6 g Au/t with 0.2 to 7.4 g Ag/t. Soil samples collected at that time (97 total) were analyzed for three major elements gold, silver and arsenic and gave values of 0.1-6.8 g Au/t, <0.2-11 g Ag/t and 30-500 ppm As. During 2011, the SGS reportedly carried out a reconnaissance exploration program in the area which comprised 80 bedrock channel samples: 37 samples at Umm Kharite North (0113) giving an average gold grade of 2.4 g/t (maximum 15 g Au/t) and 3.05 g Ag/t (maximum 12.93 g Ag/t); and 43 samples at Umm Kharite South (0118), giving an average gold content of 0.62 g/t (maximum of 3.88 g Au/t) and 1.65 g Ag/t (maximum 10.65 g Ag/t). The SGS reportedly has a report in progress on this work which includes a 1:2,000 scale detailed geological map.

The Shaib Al Maliyah Al Janubi and Shiab Al Maliyah Ash Shamali (formerly As Siham) gold prospects (0115 and 0117) are about 20 km south of Wadi Mishqar Ash Shuwatin. The ancient mine workings focused on quartz veins that were first explored in the mid 1950's, and were geophysically surveyed in the late 1960s. Regional mapping by the BRGM from 1974-77 located and assessed all of the known prospects. Continuing work after that resulted in mapping at a more detailed 1:50,000 scale and additional sampling, following which 37 percussion holes (total 2,000 m) were drilled to test the main veins and geophysical anomalies. One percussion hole returned 22.5 g Au/t over 6.0 m. Following this, Riofinex resampled the major prospects during 1977-80 and completed a program of 500 m of trenching and 626 auger holes (avg. 2.34 m) in 1981 (Gaukroger and Morfett, 1982). The auger holes were spaced at 20 m intervals along lines 600 to 800 m apart. The auger cuttings were analyzed for Au, Ag, Cu, Pb, Zn, As, Ni, and Co however; no significant gold values were detected. During 1985, Riofinex expanded their mapping, trenching, and sampling program to nearby prospects, including 5 holes at Jadhib Al Marafah (0114 – formerly Abu Arck Ar Rayan). No significant results were reported in the Shaib Al Maliyah area although one hole of the nine drilled at Al Khuwaymat (0116), formerly known as Al Quwaymah, intersected 1.5 m which assayed 45.3 g Au/t. Further work within this area was recommended.

The 12 areas of gold workings at Al Himar (MODS 1008-12, 1016-19, 1022, 1619 and 1924) are centered about 30 km NE of Zalim and comprise a series of gold-bearing quartz lenses and veins. Two have recently been renamed: Shaib al Hufayyirah (1619) and Shaib abu Sarh (1012). The ancient mines are distributed over an area measuring approximately 15 km along strike and 5-6 km across the local structural trend. The BRGM and Riofinex carried out reconnaissance level exploration of the area in the late 1970s and collected grab samples of ancient workings. Eighteen samples of vein quartz from the main workings averaged 4.5 g Au/t. It is interesting that samples of wall rock were also mineralized and averaged 1.7 g Au/t. No follow-up work was completed (Gaukroger and Morfett, 1982).

The As Suq gold prospects comprise four central areas of ancient workings (MODS 1177, 4006, 2120 and 2123) and six surrounding prospects: Shaib Bahjah (2119), Shaib Zaraib Nasir NW (2122), Shaib Zaraib Nasir (2121), Shaib al Jiwanni (1918), Shaib abu Iblan (2117) and Shaib abu Iblan SW (2118). The various prospects cover an area measuring approximately 14 km by 11 km, all within about 8 km of the As Suq Mine (1177). Gold mineralization occurs in quartz veins and stockworks and is spatially associated with silicified and pyritized shear zones. Ancient workings focused on the quartz veins. Modern exploration in the area began in 1950 when the Saudi Arabian Mining Syndicate (SAMS) put down a decline on the As Suq main prospect to a depth of 50 m below surface. Mining ceased in 1952 and the Ministry sampled dumps and ancient workings the following year however only partial records are available from Gaukroger and Morfett (1982). One estimate stated that 1,600 t of dump material was present averaging 8.5 g Au/t. The BRGM carried out sampling in 1979-80 demonstrating that that vein quartz assayed 2.0 g Au/t and Riofinex carried out follow-up sampling of 1,180 m of trenches across the vein systems during 1981-82. Riofinex also completed three geophysical orientation surveys composed


AS SIHAM - ZARAIB GOLD BELT
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Neogene
Nb: Neogene flood basalt
Nhc: Hasak formation, conglomerate
Nlc: Neogene lacustrine sediments
Afif formation ~650-635 Ma
Al Khusheymiyah suite 610-595 Ma
Ar Rahah monzogranite and granodiorite ~630 Ma
Bani Ghayy group 630-607 Ma
Dhukhr complex 816-803 Ma
Ghamr group ~750 Ma
Hadb ash Sharar suite ~590-575 Ma
Hadhaq complex ~782-720 Ma
Haml suite ~640-620 Ma
Hawarnidah complex (Age uncertain)
Humaymah suite 645-630 Ma
Jaf Jaf complex (Age uncertain)
Jibalah group (age uncertain)
Jidh suite ~700-640 Ma
Mardamah group ~655-626 Ma
Mughah complex (Age uncertain)
Muwayh formation (Age uncertain)
Naim complex 746 Ma
Qattan formation (Age uncertain)
Rharaba complex (Age uncertain)
Sarjuj formation (Age uncertain)
Siham group <750->695 Ma
Tamran formation >810 Ma
Thalath complex ~640-630 Ma
Zafrah suite ~740 Ma
Other Proterozoic units
Unassigned Proterozoic rocks
Scale 1 : 500,000
0 5 25
Kilometres
UTM WGS84 Zone 38N
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the As Siham - Zaraib Gold Belt
Figure 7.
Watts, Griffis and McOuat

of magnetometer, IP and SP to determine if possible hidden extensions to the known mineralized zones could be detected. With the best trench cutting 2.5 g Au/t over 11.5 m. A 2-metre thick vein in this section assayed 7.5 g Au/t. Veins were shown to be somewhat irregular and discontinuous. Gold was generally absent or very weakly distributed in the wallrocks. The BRGM recommended no further work (Gaukroger and Morfett).

The main Shaib Lamisah prospect is located about 9.5 km SE of the As Suq Mine. The name is also applied to Abal al Lamisah (MODS 4258, 4389) which are duplicated MODS records located 7 km to the NE, both records with the same co-ordinates. Two important base metal occurrences are also present in the area, the main Shaib al Lamisah copper-zinc deposit (2095) located 2.5 km to the SW where a resource in excess of 1.40 Mt at 1.7% Cu, 1.9% Zn, and 9.0 g Ag/t has been identified (Elsass, Breton, and others, 1983) and the Shaib al Lamisah N prospect (2178) located 3.8 km to the NW. The gold potential of the area stands apart from the base metal potential and is related to north-trending structures in the area. Very little information is available on the Shaib Lamisah gold prospects. The area was initially explored in 1981 during regional airborne geophysical surveying by Geoterrex that involved INPUT, magnetometer and radiometric surveying. With the detection of conductive anomalies, follow-up exploration focused on base metals. During 1982, the BRGM trenched and sampled gossans, and drill-tested several anomalies with 8 diamond drill holes totalling 1,704 m and 36 shallow percussion holes (2,855 m) at the main copper showing. Very little if any work was carried out subsequently on the gold prospects despite their proximity to As Suq.

Near the southern end of the gold belt, the six gold occurrences in the Abar Al Hafair area (MODS 2116), formerly known as Al Haffirah, span an area measuring approximately 5 km by 5 km. The occurrences include Zaraib as Suq (MODS 4493), Zaraib as Suq E (4498), Zaraib as Suq SE (4495), Zaraib as Suq SE1 (4494), Abar al Hafair SE (4497) and Abar al Hafair SE1 (4496). At The BRGM carried out some mapping and sampling of the veins and Riofinex undertook a program of trenching and sampling in 1981.

At the southern end of the gold belt, the Zaraib At Tal area, formerly known as Azzeraib, contains three gold prospects: the main prospect area at Zaraib At Tal (MODS 2690), Jabal Ghurrab (0424) and Jabal Ghurrab SE (2124). These are located about 65 km SE of Zalim. Eleven pyritic quartz vein zones with a total length of 4,000 m have been sampled and seven were assessed in detail by the BRGM during 1981-82 through a program of 1:25,000 scale geological mapping, trenching, sampling, drilling and geophysical surveying. The work by the BRGM focused on seven of the veins. Eight diamond drill holes totalling 783 m were completed to test vein zones 1, 2 and 3. Percussion drilling, with coring of some mineralized sections, totalled 1,567 m in 21 holes to test zones 1, 2, 3, and 10. Ground electromagnetic (VLF-EM) and magnetometer surveys were completed on profiles with a 50-m separation over a 500 m by 2,000 m area in 1984. The parallel veins/shears had good VLF-EM responses, and 10 percussion holes (731 m) were drilled to explore some of the VLF conductors and to test the down-dip longitudinal extension of zones 1, 2 and 3. Mineral resources for the number 1 vein zone have been estimated at 140,000 t at an average grade of 5.4 g Au/t to a depth of 120 m (Viland, 1986).

Geology

Gold mineralization in the belt occurs in the western part of the Afif Terrane and is associated with northerly trending belts of volcanosedimentary rocks flanked by elongated bodies of granitic and intermediate composition plutonic rocks. These features clearly separate the gold belt from the Nabitah Fault Zone farther to the east. Gold mineralization in the prospects within the northern half of the belt are commonly associated with base metals (Cu, Zn, Pb and Ni), a fact that distinguishes them from the more southerly occurrences. A gold-silver association is common throughout the belt.

The results of the SGS sampling program at Umm Kharite North more or less paralleled the results of the previous Riofinex drilling. This shallow drilling appears to indicate the presence of shallow vein-type gold mineralization with values probably averaging in the 1-2 g/t range. No detailed geological information was available for WGM to review, nevertheless this prospect area appears to be a local centre for mineralization and probably warrants additional work in the form of IP surveying to define the zone of veining and sulphide mineralization below the oxidized zone (assuming a gold-pyrite relationship) followed by drilling.

The Shaib Al Maliyah Al Janubi and Shiab Al Maliyah Ash Shamali (As Siham) gold prospects consist of pyritized and limonite-stained quartz veins within sheared felsic volcanic rocks. Ancient mine workings consist of lines of shallow pits and stopes with mounds of waste material. Gold is confined to the veins. The ancient gold mines focused on quartz veins that returned significant gold intersections including 22.5 g Au/t over 6.0 m. The magnitude of the gold values in this general area was also shown by the hole at Al Khuwaymat which intersected 1.5 m assaying 45.3 g Au/t. The trenching program showed that gold and silver contents in C horizon soils increase toward the vein system and that arsenic may be a pathfinder for gold concentrations in the area. The ancient gold workings in the Al Himar area comprise a series of pyritized quartz lenses and veins within sheared mafic volcanic rocks. Many of the workings are spatially associated with NNE-trending topographic lineaments of uncertain origin that are visible in satellite images. Gold occurs with pyrite and minor galena, and sphalerite within the quartz lenses. Quartz veins in the main workings averaged 4.5 g Au/t and it is interesting that samples of wall rock were also mineralized, averaging 1.7 g Au/t (Gaukroger and Morfett). The fact that the host rock is gold-bearing indicates that the mineralization process involved the infiltration of gold-bearing fluids into permeable rocks creating the potential for broad, bulk-minable ore zones. No such mineralization was described in the area, however the overall historical approach to exploration in this area is seen as inadequate in every manner.

In the many gold prospects that surround the As Suq Mine (Figure 8), gold mineralization is spatially associated with quartz veins and breccia zones, some of which are silicified and pyritized shear zones, within tuffaceous and sedimentary rocks of the As Siham formation at the margins of and within the Bir Lamisah diorite pluton. Gold exhibits a sympathetic spatial relationship with pyrite within carbonatized sections of the shears. WGM completed a JORC-compliant resource estimate during 2009-10 as summarized in Table 10 which we understand may have been subsequently up-dated by Ma'aden based on mining experience. The mineral resources are hosted in three major gold-bearing shears which

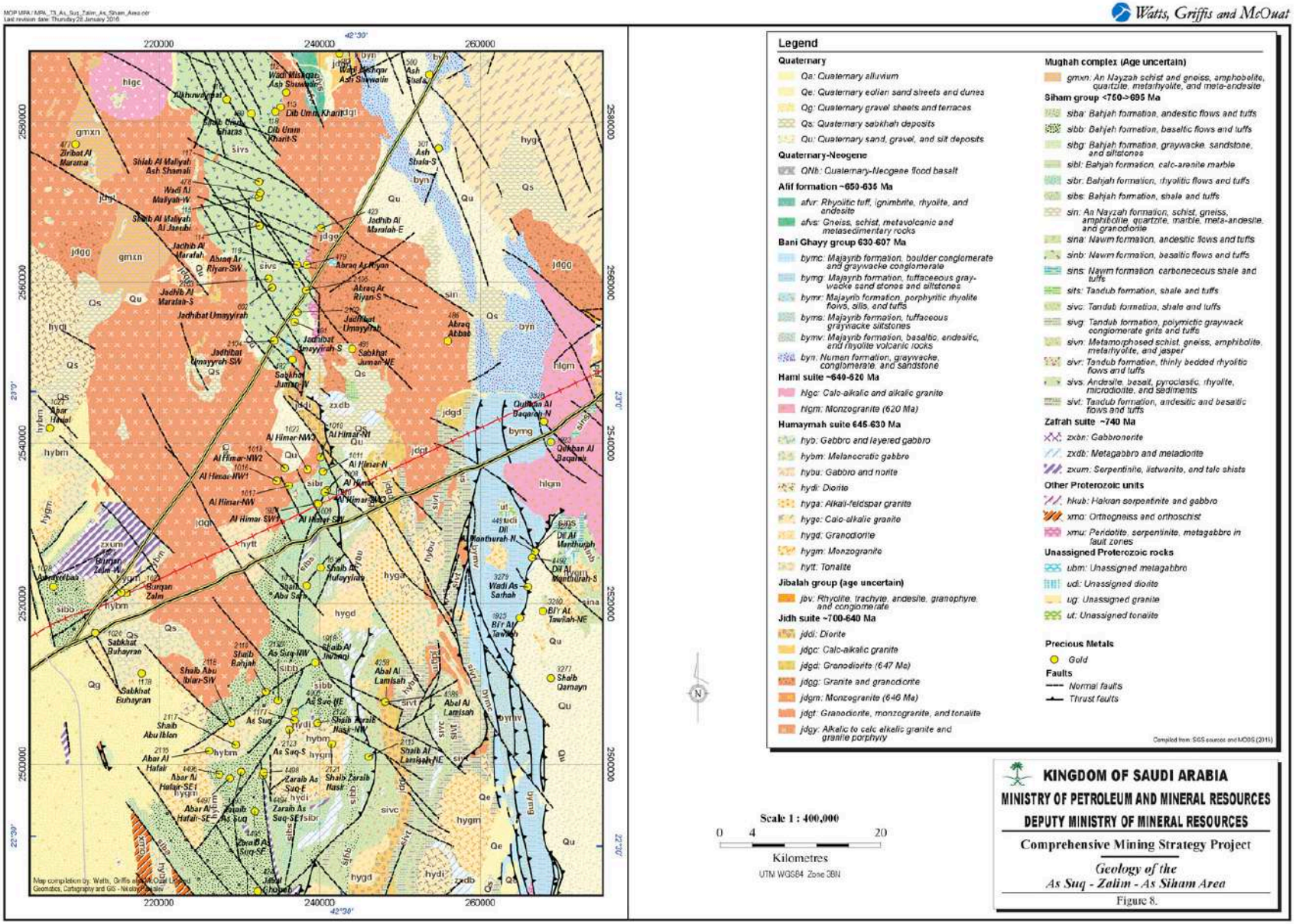
converge down-dip into a single steeply dipping structure. This part of the deposit has not been drill-tested, and additional drilling was recommended by WGM in both the down-dip and along strike directions.

Table 10
Mineral Resources for the As Suq Deposit
As Siham-Az Zeraib Gold Belt, Arabian Shield

Resource Type	Resource Category	Tonnes (Mt)	Gold Grade (g/t)	Silver Grade (g/t)
Oxide	Indicated	2.4	1.70	2.66
	Inferred	0.4	0.94	1.94
Transitional	Indicated	2.1	2.22	4.00
	Inferred	0.1	1.37	2.08
Sulphide	Indicated	3.7	1.68	4.36
	Inferred	0.1	1.62	3.22
Total	Indicated	8.1	1.82	3.77
	Inferred	0.5	1.11	2.16

Near the most southern end of the gold belt, the occurrences in the Abar al Hafair area are associated with gold-bearing quartz veins that carry pyrite and cut a post-tectonic diorite intrusion and surrounding felsic volcanic rocks. Altered roof pendants of mafic volcanic breccia and quartzite are mapable inclusions within the diorite mass. The veins are vertical and are approximately 30 m in length and are generally less than 0.5 m wide. Assays from grab samples, taken within the ancient workings by the BRGM returned a mean value of 4.6 g Au/t with a maximum value of 39.2 g Au/t (Corp and Elsass, 1981). Based on 41 grab samples, the veins averaged 15.5 g Au/t. In 1981 Riofinex cut 10 trenches totalling 375 m across the ancient workings. The trenches contained en echelon quartz veins approximately 30 m long and generally less than 50 cm wide within a weak alteration envelope. Three trenches showed values exceeding 1 g Au/t over a 2-3 m interval. Based on these results, Gaukroger and Morfett (1982) recommended that Riofinex discontinue its exploration. A BRGM review of the area (Viland, 1986) suggested that further work is warranted on the basis of the number of ancient workings clustered within and at the margins of the intrusion.

At Zaraib At Tal (formerly known as Azeraib), the pyritic quartz veins occur within sheared and intensely fractured granite (Figure 9). Low-grade gold values in the veins are associated with galena, pyrite and chalcopyrite. Gold is also present within the fractured wallrock. The ancient workings attest to the presence of coarse fee gold. Drilling showed that the vein systems dip 45^{o} NE near surface and flatten down-dip. True widths of the zone were as much as 10 m were found in the diamond drill holes. Gold occurs within and at the margins of pyritized quartz veins. Studies by BRGM also demonstrated that the veins are polymetallic with pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, bismuthinite and tellurides.


Watts, Griffis and McOuat
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Afif formation ~650-635 Ma
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
afvs: Gneiss, schist, metavolcanic and metasedimentary rocks
Bani Ghayy group 630-607 Ma
bymc: Majaynib formation, boulder conglomerate and graywacke conglomerate
bymg: Majaynib formation, tuffaceous graywacke sand stones and siltstones
bymr: Majaynib formation, porphyritic rhyolite flows, sills, and tuffs
byms: Majaynib formation, tuffaceous graywacke siltstones
bymv: Majaynib formation, basaltic, andesitic, and rhyolite volcanic rocks
byn: Numen formation, graywacke, conglomerate, and sandstone
Hami suite ~640-620 Ma
hlgc: Calc-alkalic and alkalic granite
hlgm: Monzogranite (620 Ma)
Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hybm: Melanocratic gabbro
hybu: Gabbro and norite
hydi: Diorite
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygm: Monzogranite
hytt: Tonalite
Jibalah group (age uncertain)
jbv: Rhyolite, trachyte, andesite, granophyre, and conglomerate
Jidh suite ~700-640 Ma
jddi: Diorite
jdgc: Calc-alkalic granite
jdgd: Granodiorite (647 Ma)
jdgg: Granite and granodiorite
jdgm: Monzogranite (646 Ma)
jdgt: Granodiorite, monzogranite, and tonalite
jdgy: Alkalic to calc alkalic granite and granite porphyry
Mughah complex (Age uncertain)
gmxn: An Nayzah schist and gneiss, amphobolite, quartzite, metarhyolite, and meta-andesite
Siham group <750->695 Ma
siba: Bahjah formation, andesitic flows and tuffs
sibb: Bahjah formation, baseltic flows and tuffs
sibg: Bahjah formation, graywacke, sandstone, and siltstones
sibl: Bahjah formation, calc-arenite marble
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, meta-andesite, and granodiorite
sina: Nawm formation, andesitic flows and tuffs
sinb: Nawm formation, basaltic flows and tuffs
sins: Nawm formation, carbonaceous shale and tuffs
sits: Tandub formation, shale and tuffs
sivc: Tandub formation, shale and tuffs
sivg: Tandub formation, polymictic graywack conglomerate grits and tuffs
sivn: Metamorphosed schist, gneiss, amphibolite, metarhyolite, and jasper
sivr: Tandub formation, thinly bedded rhyolitic flows and tuffs
sivs: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
sivt: Tandub formation, andesitic and basaltic flows and tuffs
Zafrah suite ~740 Ma
zxbn: Gabbronorite
zxdb: Metagabbro and metadiorite
zxum: Serpentinite, lisfwanite, and talc shists
Other Proterozoic units
hkub: Hakran serpentinite and gabbro
xmo: Orthogneiss and orthoschist
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ubm: Unassigned metagabbro
udi: Unassigned diorite
ug: Unassigned granite
ut: Unassigned tonalite
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Compiled from SGS sources and MODS (2011)
Scale 1 : 400,000
0 4 20
Kilometres
UTM WGS84 Zone 38N
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Comprehensive Mining Strategy Project
Geology of the
As Suq - Zalim - As Siham Area
Figure 8.

Recommendations

The presence of widespread ancient workings in the Kharit/Harriyah area, the clear evidence of gold in surface samples and in Riofinex's very shallow percussion holes at Dib Umm Kharit south and additional gold evidence in the SGS samples at Dib Umm Kharit North indicate a local centre of gold mineralization probably in the range of 1-2 g/t with higher grading sections, possibly at 5-7 g/t. WGM gives no credibility to the assay contents from the Riofinex percussion holes except that they show mineralization – percussion drilling is not appropriate for gold exploration. Based on the shallow exploration to date, WGM recommends a program of detailed 1:5,000 scale geological mapping to define the geological setting of the mineralization and IP surveying to define targets for drilling at vertical depths of 100-150 m. These targets could be resistive zones due to quartz veining and/or silicification, or chargeability anomalies due to disseminated pyrite below the level of surface oxidation. These targets should be diamond drilled with a minimum budget sufficient for 2,000 m of drilling.

The sampling at Harriah and in the As Siham area by Riofinex highlights a common problem with the early exploration of the Arabian Shield – the use of inappropriate sampling procedures. There is no justification for the use of 5-metre long trench samples when exploring for gold. In some instances, for example when exploring for porphyry gold mineralization, a 2-metre sample could be justified, but the use of longer intervals will generally result in lower gold contents being reported. Most mineralized zones are 1-2 m in width. The use of longer intervals averages mineralized rock with rock that is not mineralized (waste), and thus the analytical results are not representative of the mineralized zone. Longer intervals also hold a high risk of reducing average grades to a level that is uninteresting. The focus of initial sampling programs must always be to demonstrate the true distribution of mineralization and hopefully to enhance the attractiveness of the target. While the use of percussion drilling offers the ability to drill in arid terrain without the need for water, this drilling technique almost always under-samples the mineralization because heavy mineral particles (sulphides and gold) are not adequately extracted from the hole. Mineralized intervals also tend to be smeared resulting in down-hole contamination.

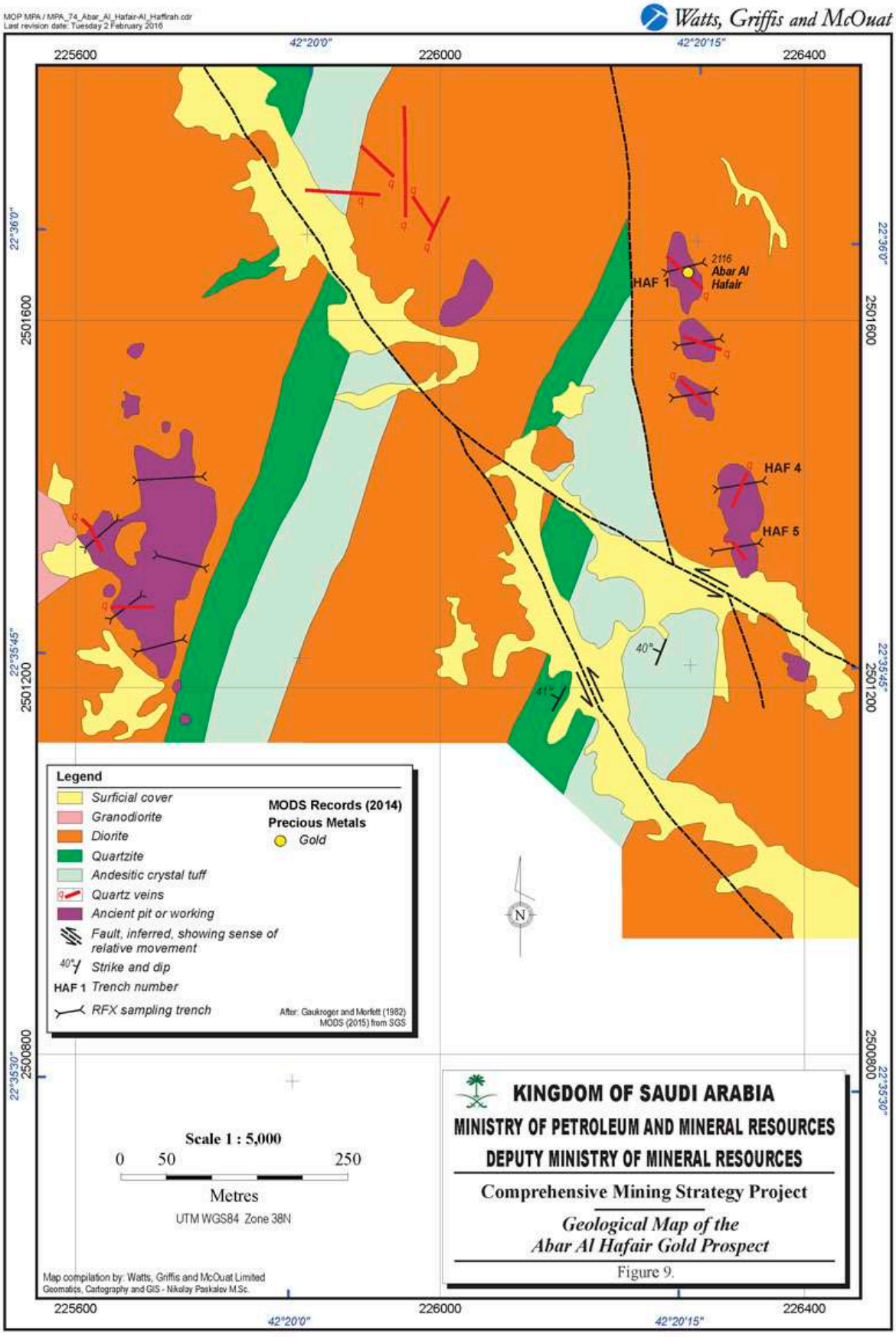
This can also cause dilution of mineralized intervals. Percussion drilling is useful only for showing the presence or absence of gold and no more. It cannot be used as a reliable guide to grade. As much of the initial work in the belt, including As Siham, involved percussion drilling, the rather negative conclusions of much of the early explorers can be discounted. The BRGM down-graded the As Suq prospect based on the initial exploration results, and largely on the basis of percussion drilling. In reviewing the same results, WGM commented on the general lack of IP surveying around As Suq even after it had been shown to be a useful exploration tool for exploration at As Suq. WGM recommended additional exploration at As Suq, which it regarded as a high-potential prospect, and a mine exists there today. WGM understands that the current operation has suffered from irregularities in the gold mineralization that were not recognized in the geological model although its consultants warned of irregularities and nuggety mineralization. As comparison of events leading up to production decisions at Al Hajar and As Suq might be revealing in that both deposits were rushed into production without a sound (complete and reliable) geological database. Care must be taken in such decisions. Only detailed diamond drilling and industry-standard analytical

procedures provide the quality of data needed to support feasibility studies which must always be carried out at an appropriate level of precision to allow a production decision.

The apparent lack of work on the Shaib Lamisah gold prospects is surprising given proximity to the As Suq Mine and the setting which includes a significant base metal deposit. Although the gold and base metals may be related to very different metallogenic processes, the proximity of these two mineralizing events suggests that the environment may have potential for gold mineralization over-printing a base metal system, such as occurs at Al Amar and several other base metal prospects. This possibility needs to be thoroughly explored with detailed geological mapping and sampling of the larger Shaib Al Lamisah area with supporting ground geophysical surveying to define the controls on gold mineralization and the full extent of the base metal system.

In the Aban al Hafair prospect cluster, the exploration completed to date has shown that gold occurs with pyrite in quartz veins that are hosted in the contact zone of a diorite pluton, a setting that is a highly prospective environment given that this geology is common to many of the Kingdom's operating gold mines. The ancient miners discovered and worked the surface of these veins and vein systems. Modern exploration has confirmed high grade gold values within the vein systems, but has failed to replicate these values in trenches. Further exploration is warranted to locate gold deposits which may be concealed at the margins and within the Al Haffirah pluton. Coarse gold mineralization can be difficult to assess and persistence is needed to develop appropriate sampling protocols which may include drilling larger (HQ) diameter drill holes. In some very important gold mines in the Canadian Shield, for example the Dome Mine, the gold was so irregular that within mined stopes only one hole out of 6 produced economically interesting grades. The geological setting and the cluster of workings at Aban al Hafair demand that additional systematic exploration be completed.

Exploration of the Zaraib at Tal prospect has shown that granite-hosted, gold-bearing quartz veins occur in shear zones over a strike length of 4,000 m. The width of the mineralized zone varies from 1 to 10 m within subparallel shears. Cross-sections of the zone show the inadequacy of the percussion drill system to assess this gold deposit. In most cases where diamond drill and percussion intersections are from the same zone, gold values within the percussion holes are much lower than the nearby diamond drill holes. Thus the calculated grade of the deposit is thought to be understated, perhaps substantially so. Diamond-drill intersections on 40 m centers over the No. 1 vein structure and to a depth of 500 m are required to assess the potential of the vein zone No. 1 and to confirm gold values found in surface samples (up to 13.60 g/t). Fracture systems of the magnitude found at the main prospect seldom end at the margin of the exposed veins and further exploration is warranted to trace the structure within and at the margins of the intrusive host, and regionally along strike. Given the many sulphide minerals present in the veins, IP surveying should be a very useful means of developing targets at depth for drill testing. No mention is made of exploration work on the Jabal Ghurrab gold occurrences to the NW which are located on the main structural lineament in this area. These also warrant detailed systematic geological mapping and sampling.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Last revision date: Tuesday 2 February 2016
Watts, Griffis and McOuat
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225600
226000
226400
22°36'0"
22°35'45"
22°35'30"
2501600
2501200
2500800
2116
Abar Al Hafair
HAF 1
HAF 4
HAF 5
40°
41°
Legend
Surficial cover
Granodiorite
Diorite
Quartzite
Andesitic crystal tuff
Quartz veins
Ancient pit or working
Fault, inferred, showing sense of relative movement
Strike and dip
HAF 1 Trench number
RFX sampling trench
MODS Records (2014)
Precious Metals
Gold
After: Gaukroger and Morfett (1982)
MODS (2015) from SGS
N
Scale 1 : 5,000
0 50 250
Metres
UTM WGS84 Zone 38N
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Map of the
Abar Al Hafair Gold Prospect
Figure 9.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

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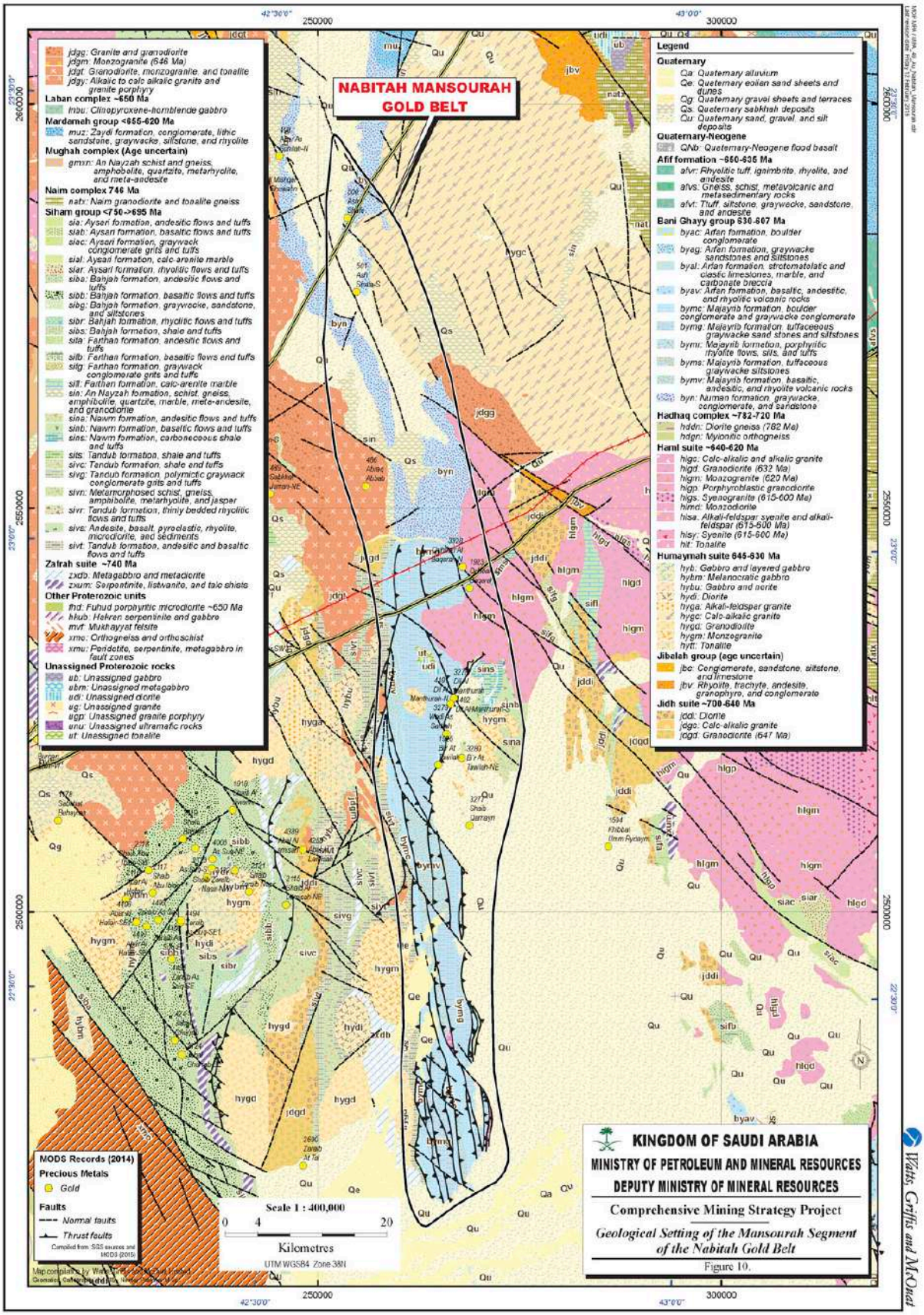
3.1.3.6 The Nabitah Gold Belt – The Mansourah Segment

Location, Distribution of Occurrences and History

The Mansourah Segment of the Nabitah Gold Belt is approximately 175 km in length striking approximately north-south between two NNW-trending Najd Faults, the Ruwah Fault Zone in the south and the Ar Rika Fault Zone in the north (Figure 10). The mineral belt occurs near the northern end of the structural zone that constitutes the Nabitah Fault Zone however in this area it appears to merge with the Hulayfah-Ad Dafinah-Ruwah Suture Zone. The complex structural geometry involving several closely spaced thrust faults is seen to resemble a graben or half-graben arrangement which has been named the Mujayhib Graben. Gold occurrences in the belt are hosted in Table 11.

At the northern end of the belt, the Ash Shafa, Ash Shafa South, Abraq Abbab, Quhban al Baqarah and Quhban al Baqarah North gold occurrences have been grab sampled but little else is known of the work on these occurrences. All were surveyed by airborne magnetometer during the early exploration by ARGAS. The area of ancient mine dumps, which extend over a strike of 900 m at Quhban al Baqarah, was trenched and sampled as this prospect is located on the northward extension of the Ghadarah-Bir Tawilah Au-W prospect. The most recent work on this gold belt has been exclusively carried out by Ma'aden, and the results of this work are unknown because Ma'aden is not obligated to publicly disclose the nature of the exploration programs its completes or the results of its work. What is contained in this section is taken from brief summaries provided by Ma'aden for the purposes of this study.


NABITAH MANSOURAH
GOLD BELT
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Afif formation ~650-635 Ma
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
afvs: Gneiss, schist, metavolcanic and metasedimentary rocks
afvt: Tfuff, siltstone, graywecke, sandstone, and andesite
Bani Ghayy group 830-867 Ma
byac: Arfan formation, boulder conglomerate
byag: Arfan formation, graywacke sandstones and siltstones
byal: Arfan formation, stromatolatic and clastic limestones, marble, and carbonate breccia
byav: Arfan formation, basaltic, andestitic, and rhyolitic volcanic rocks
bymc: Majaynia formation, boulder conglomerate and graywacke conglomerate
bymg: Majaynia formation, tuffaceous graywacke sand stones and siltstones
bymr: Majaynia formation, porphyritic rhyolite flows, sills, and tuffs
byms: Majaynia formation, tuffaceous graywacke siltstones
bymv: Majaynia formation, basaltic, andesitic, and rhyolite volcanic rocks
byn: Numan formation, graywacke, conglomerate, and sandstone
Hadhaq complex ~782-720 Ma
hddn: Diorite gneiss (782 Ma)
hdgn: Mylonitic orthogneiss
Hanil suite ~640-620 Ma
hlgc: Calc-alkalic and alkalic granite
hlgd: Granodiorite (632 Ma)
hlgm: Monzogrenite (620 Ma)
hlgp: Porphyroblastic granodiorite
hlgs: Syenogranite (615-600 Ma)
hlmd: Monzodiorite
hlsa: Alkali-feldspar syenite and alkali-feldspar (615-600 Ma)
hlsy: Syenite (615-600 Ma)
hlt: Tonalite
Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hybm: Melanocratic gabbro
hybu: Gabbro and norite
hydi: Diorite
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygm: Monzogranite
hytt: Tonalite
Jibalah group (age uncertain)
jbc: Conglomerate, sandstone, siltstone, and limestone
jbv: Rhyolite, trachyte, andesite, granophyre, and conglomerate
Jidh suite ~700-640 Ma
jdd: Diorite
jdgc: Calc-alkalic granite
jdgd: Granodiorite (647 Ma)
jdgg: Granite and granodiorite
jdgm: Monzogranite (646 Ma)
jdgt: Granodiorite, monzogranite, and tonalite
jdgy: Alkalic to calc alkalic granite and granite porphyry
Laban complex ~650 Ma
lmbu: Clinopyroxene-hornblende gabbro
Nardamah group <655-620 Ma
muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
Mughah complex (Age uncertain)
gmxn: An Nayzah schist and gneiss, amphobolite, quartzite, metarhyolite, and meta-andesite
Naim complex 746 Ma
natx: Naim granodiorite and tonalite gneiss
Siham group <750->695 Ma
sia: Aysari formation, andesitic flows and tuffs
siab: Aysari formation, basaltic flows and tuffs
siac: Aysari formation, graywack conglomerate grits and tuffs
sial: Aysari formation, calc-arenite marble
siar: Aysari formation, rhyolitic flows and tuffs
siba: Bahjah formation, andesitic flows and tuffs
sibb: Bahjah formation, basaltic flows and tuffs
sibg: Bahjah formation, graywacke, sandstone, and siltstones
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sita: Farthan formation, andesitic flows and tuffs
sitb: Farthan formation, basaltic flows and tuffs
sitg: Farthan formation, graywack conglomerate grits and tuffs
sitl: Farthan formation, calc-arenite marble
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, mete-andesite, and granodiorite
sina: Nawm formation, andesitic flows and tuffs
sinb: Nawm formation, basaltic flows and tuffs
sins: Nawm formation, carboneceous shale and tuffs
sits: Tandub formation, shale and tuffs
sivc: Tandub formation, shale and tuffs
sivg: Tandub formation, polymictic graywack conglomerate grits and tuffs
sivm: Metamorphosed schist, gneiss, amphibolite, metarhyolite, and jasper
sivr: Tandub formation, thinly bedded rhyolitic flows and tuffs
sivs: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
sivt: Tandub formation, andesitic and basaltic flows and tuffs
Zafrah suite ~740 Ma
zxdb: Metagabbro and metadiorite
zxum: Serpentinite, listvanite, and talc shists
Other Proterozoic units
fhd: Fuhud porphyritic microdiorite ~650 Ma
hlub: Hakran serpentinite and gabbro
mvt: Mukhayyat felsite
xmo: Orthogneiss and orthoschist
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
udi: Unassigned diorite
ug: Unassigned granite
ugp: Unassigned granite porphyry
unu: Unassigned ultramafic rocks
ut: Unassigned tonalite
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Scale 1 : 400,000
0 4 20
Kilometres
UTM WGS84 Zone 38N
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Geological Setting of the Mansourah Segment of the Nabitah Gold Belt
Figure 10.
Watts, Griffis and McOuat

Table 11
Name and Location of Gold Occurrences – Nabitah Gold Belt – Mansourah Segment, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
0500	Ash Shafa	Numan	Gold	42.5902780	23.3643060	Hufayrah, Dhalm	Low	dd
0501	Ash Shafa-S	Wadi Da"Kah	Gold	42.6026670	23.2816670	Hufayrah, Dhalm	Low	dd, v
0486	Abraq Abbab	Abraq Abab	Gold	42.6180000	23.0649720	Hufayrah, Dhalm	undefined	dd
3328	Quhban Al Baqarah-N	Baqarah-N	Gold	42.7361940	22.9763610	Hufayrah, Dhalm	VL	dd
1923	Quhban Al Baqarah	Baqarah	Gold	42.7449440	22.9529440	Hufayrah, Dhalm	VL	dd
3278	Dil Al Manthurah	Jabal Ghadarah Main	Gold	42.7278060	22.8300280	Hufayrah, Dhalm	Med	dd, v
4491	Dil Al Manthurah-N	Jabal Ghadarah Main	Gold	42.7276390	22.8300000	Hufayrah, Dhalm	Med	dd, v
4492	Dil Al Manthurah-S	Jabal Ghadarah-SE	Gold	42.7241940	22.8230560	Hufayrah, Dhalm	Med	dd, v
3279	Wadi As Sarhah	Wadi As Sarhah	Gold	42.7195000	22.7900830	Hufayrah, Dhalm	Med	dd, v
3280	Bi'r At Tawilah-NE	Bi'r At Tawilah-NE	Gold	42.7383610	22.7635000	Hufayrah, Dhalm	VL	dd, v
1925	Bi'r At Tawilah	Bi'r At Tawilah	Gold	42.7105280	22.7551940	Hufayrah, Dhalm	Med	dd, v
		Masarah	Gold			Hufayrah, Dhalm	High	dd, v
		Mansourah	Gold			Hufayrah, Dhalm	High	dd, v
3277	Shaib Qarnayn	Shaib Granayn	Gold	42.749417	22.6880280	Hufayrah, Dhalm	VL	v
		Umm Selam	Gold			Hufayrah, Dhalm	undefined	uncertain
		Amana	Gold			Hufayrah, Dhalm	undefined	uncertain

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins

The BRGM rediscovered and grab sampled the ancient workings at the Bir Tawilah main prospect (MODS 1925) during 1977. During 1980, 18 additional grab samples were taken which showed an average gold content of 6.2 g/t. Following that, Riofinex reviewed the area but carried out no work on the prospect. From 1981 to 1983, the BRGM mapped the main prospect at 1:2,500 scale and grab sampled veins and waste dumps. A soil geochemical survey was carried out on a 50 x 50 m grid and 475 samples were analyzed for gold and silver. Trenching (335 m) was carried out across and on strike from the main zone and 29 shallow percussion holes were completed (2,270 m). At the main prospect the "geological resources" were estimated at 97,500 t grading 20.5 g Au/t. During 1984, exploration resumed with 13 very short diamond drill holes (654 m) on the main prospect. The geological resources were re-estimated as 41,909 t at an average grade of 16.4 g Au/t to a depth of 100 m using a cut-off grade of 6.0 g Au/t and based on drill core intersections. The Bir Tawilah North prospect (MODS 3279) at Wadi as Sarhah, approximately 1,500 m north of the main Bir Tawilah prospect was also mapped and sampled by the BRGM during the same timeframe. Using a 0.25 g Au/t cut-off grade, the Indicated Mineral Resources in 2011 were estimated at 97.7 Mt averaging 0.54 g Au/t. Inferred Resources totalled 0.064 Mt averaging 0.47 g Au/t (SRK, 2011). The global open pitable gold resource was 1.7 Moz. Since that date, Ma'aden has carried out some drilling along the main structural zone but the results of this work are unknown to WGM. During 2014 the Mineral resources were optimized as an in-situ open pitable resource totalling 131 Mt averaging 0.44 g Au/t (1.873 Moz) (SRK, 2014).

The Dil Al Manthurah prospect, formerly known as the Jabal Ghadarah (MODS 3278) prospect, is located 8 km north of the main Bi'r Tawilah prospect and are found over a distance of 1,800 m on the aforementioned listwaenite zone which cuts mostly granodiorite in this area. Mapping, geochemical sampling, trenching and drilling by the BRGM showed that gold is concentrated within silicified rocks at the margin of a late granitic intrusion and within the pyritized and altered granite margin. Trenches have cut 30 m sections which assay 4.1 g Au/t. The BRGM drilled 18 short percussion holes (1,227) m to test mineralization in the altered granite-granodiorite and supergene alteration was intersected to a depth of approximately 40 m. Sedimentary rock in the roof of the granite was also mineralized locally. An initial estimate of the mineralized material indicated resources of 498,575 t with an average gold grade of 2.4 g/t. Another estimate by the BRGM using a higher cut-off grade totalled 330,000 t averaging 3.2 g Au/t.

Both Bi'r Tawilah and the (then) Jabal Ghadarah prospects were reviewed by WGM in 1989-91 and both were ranked very high and recommended for additional exploration. Following Ma'aden's acquisition of licences covering the area in the mid-1990s, additional systematic exploration was carried out in the form of a program of soil sampling, geological mapping, prospecting and completing reconnaissance drilling during the period 2003-2007. The drilling used a mixed approach to reduce overall costs and comprised 17 RC holes and 20 diamond core holes. The results were sufficiently encouraging that Ma'aden continued drilling during the period 2008-2011 culminating in an in-fill program based on a 50 m by 50 m hole spacing over most of the central Bi'r Tawilah deposit. During this period Ma'aden completed 343 drill holes (63,104 m) of which 258 were HQ-sized, vertical diamond (core) drill holes and 85 were RC drill holes at various angles, with average lengths of 203 m and 125 m, respectively.

Ma'aden's Al Manthurah and Masarah Deposits were discovered as a result of regional exploration carried out during the very early 2000s. This work was focused on testing the main structural; zone on which Bi'r Tawilah and Ghadarah are situated. Following promising surface grab sample results, and a program of surface mapping, 21 shallow RC holes (1,295 m) were initially drilled at 100 m spacing to test the zone. Based on the results of the RC holes an aggressive diamond drilling programme was commenced in 2003 and in-fill drilling of the uppermost 150 m of the deposit on 25 m centres was completed in 2005. A programme of deeper diamond drilling was undertaken in 2006 and 2007 and in-fill drilling on the deposit at depth on both 50 m and 25 m profile spacings with 25 m hole-to-hole separations on individual sections. The discovery led to a long period of diamond drilling augmented with RC drilling that culminated in 2013 with an in-fill drilling program (7,613.15 m) designed to allow the up-grading of the existing Inferred Mineral Resources into mostly Indicated Resources and ensure compliance with the JORC Code. During this exploration specific geotechnical data was acquired through a dedicated 970 m geotechnical drilling program for open pit design and optimisation. Samples were collected from additional drill holes (1,944.54 m) for comminution studies and metallurgical test-work. As of November, 2013, Mansourah was estimated to contain an Indicated Resource of 24.3 Mt grading 2.85 g Au/t (sulphide ore) plus 2.1 Mt grading 2.6 g Au/t (oxide ore). Inferred Resources for sulphide and oxide ore, respectively, were 8.9 Mt at 2.2 g Au/t and 0.4 Mt at 1.3 g Au/t. The total global gold resource was estimated to be 3.06 Moz (Ma'aden, 2014).

Because Masarah was discovered after Mansourah as a result of an expanded drilling program along strike from Mansourah, its exploration program lagged the other somewhat. The 2013 program entailed 20,226.34 m of drilling in 226 diamond drill (cored) holes which comprised 182 boreholes (15,854.8 m) for infill drilling, 9 boreholes (1,130 m) for RC hole twinning purposes, 18 boreholes (1,736.54 m) for metallurgical sampling purposes, 11 boreholes (435.0 m) for geo-statistical grid drilling. A further 6 boreholes (1,070 m) were drilled for geotechnical purposes.

As of November, 2012, the estimated JORC-compliant Mineral Resources for Bi'r Tawilah, Mansourah and Masarah were as shown in Table 12. Following a feasibility study carried out by AMEC during December, 2013, the resources were restated as Probably Reserves totalling 26.61 Mt grading 2.43 g Au/t at Mansourah and 5.76 Mt grading 2.20 g Au/t at Masarah based on a US $1,000 per ounce gold price.

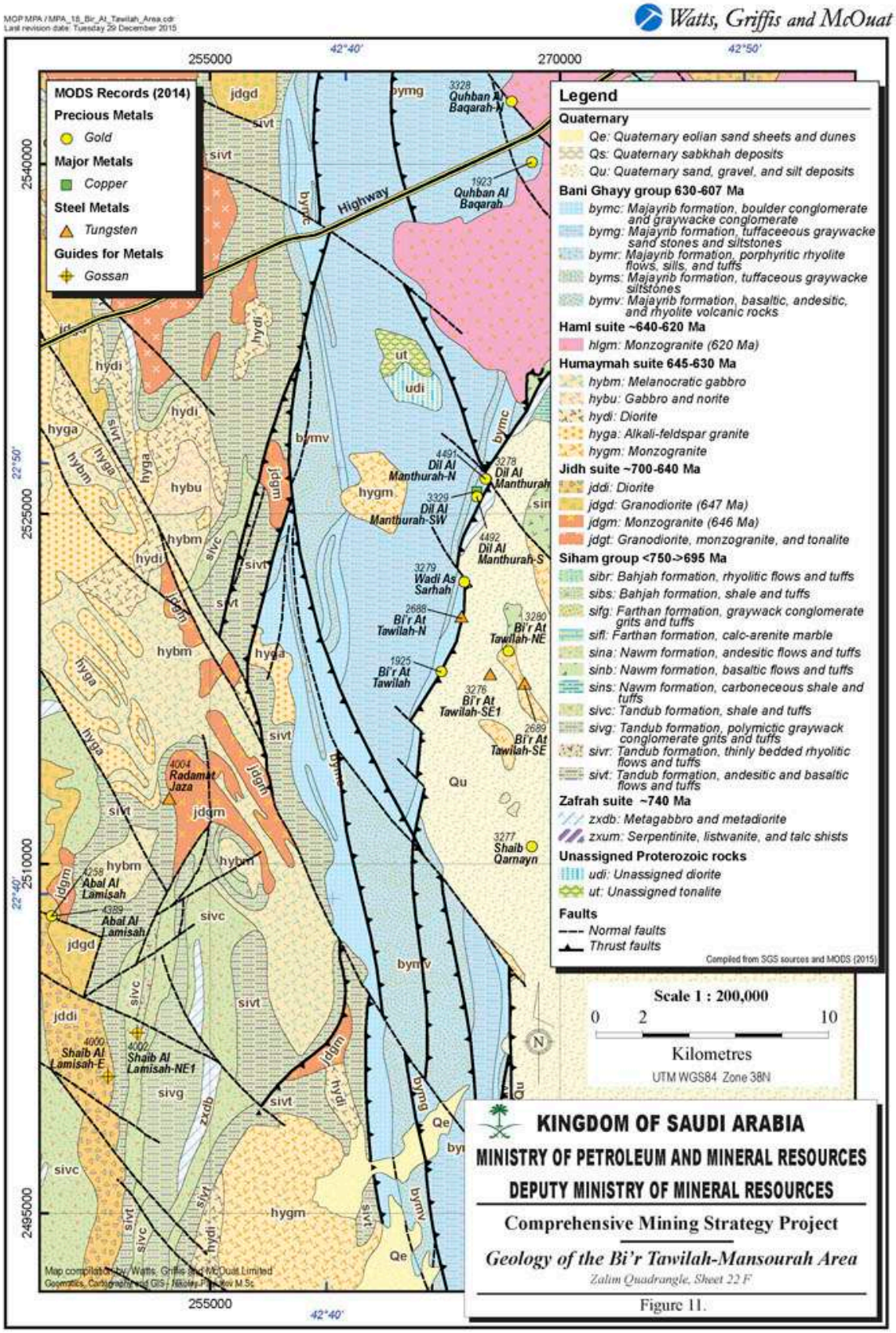
At the most southern end of the gold belt segment, the Shaib Qarnayn, Umm Selam and Amana prospects have been identified but it is uncertain whether any exploration has been done in these areas. The locations given for the prospects are consistent with a setting on or very close to the main structural trend of the belt.

Table 12
Mineral Resources for Mansourah and Masarah Deposits
Nabitah Gold Belt – Mansourah Segment, Arabian Shield

Deposit	Resource Type	Resource Category	Tonnes (Mt)	Gold Grade (g/t)
Bi'r Tawilah	Oxide	Indicated	20.1	0.49
		Inferred	0.0	------
	Sulphide	Indicated	77.6	0.55
		Inferred	0.06	0.47
Mansourah	Oxide	Indicated	2.1	2.60
		Inferred	0.4	1.30
	Sulphide	Indicated	24.3	2.85
		Inferred	8.9	2.20
Masarah	Oxide	Indicated	0.1	2.55
		Inferred	1.6	2.20
	Sulphide	Indicated	6.4	2.39
		Inferred	14.2	2.10

Geology

Gold mineralisation at Bi'r Tawilah is part of a mineralizing system that includes two additional deposits (Mansourah and Masarah) and several prospects (e.g. Ghadarah) within a relatively small 15 km radius (Figure 11). Ma'aden currently reports resources totalling 131 Mt of open pitable resources averaging 0.44 g Au/t, is hosted in a fractured, sheared and hydrothermally altered diorite and granite pluton that was emplaced into As Siham Formation mica schist. It has a thrust-faulted contact striking NNE with Bani Gavy clastic sediments in the structural footwall. Although mineralization is primarily hosted by the intrusion, it does extend into the hanging wall and footwall units. The structural zone into which the pluton


Watts, Griffis and McOuat
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
Steel Metals
Tungsten
Guides for Metals
Gossan
Legend
Quaternary
Qe: Quaternary eolian sand sheets and dunes
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Bani Ghayy group 630-607 Ma
bymc: Majayrib formation, boulder conglomerate and graywacke conglomerate
bymg: Majayrib formation, tuffaceous graywacke sand stones and siltstones
bymr: Majayrib formation, porphyritic rhyolite flows, sills, and tuffs
byms: Majayrib formation, tuffaceous graywacke siltstones
bymv: Majayrib formation, basaltic, andesitic, and rhyolite volcanic rocks
Haml suite ~640-620 Ma
hlgm: Monzogranite (620 Ma)
Humaymah suite 645-630 Ma
hybm: Melanocratic gabbro
hybu: Gabbro and norite
hydi: Diorite
hyga: Alkali-feldspar granite
hygm: Monzogranite
Jidh suite ~700-640 Ma
jddi: Diorite
jdgd: Granodiorite (647 Ma)
jdgm: Monzogranite (646 Ma)
jdgt: Granodiorite, monzogranite, and tonalite
Siham group <750->695 Ma
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sifg: Farthan formation, graywack conglomerate grits and tuffs
sifl: Farthan formation, calc-arenite marble
sina: Nawm formation, andesitic flows and tuffs
sinb: Nawm formation, basaltic flows and tuffs
sins: Nawm formation, carboneceous shale and tuffs
sivc: Tandub formation, shale and tuffs
sivg: Tandub formation, polymictic graywack conglomerate grits and tuffs
sivr: Tandub formation, thinly bedded rhyolitic flows and tuffs
sivt: Tandub formation, andesitic and basaltic flows and tuffs
Zafrah suite ~740 Ma
zxdb: Metagabbro and metadiorite
zxum: Serpentinite, listwanite, and talc shists
Unassigned Proterozoic rocks
udi: Unassigned diorite
ut: Unassigned tonalite
Faults
Normal faults
Thrust faults
Compiled from SGS sources and MODS (2015)
Scale 1 : 200,000
0 2 10
Kilometres
UTM WGS84 Zone 38N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Bi'r Tawilah-Mansourah Area
Zalim Quadrangle, Sheet 22 F
Figure 11.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nicolay P. Lavov M.Sc
255000
270000
42°40'
42°50'
2540000
2525000
2510000
2495000
22°50'
22°40'
Quhban Al Baqarah-N
Quhban Al Baqarah
Highway
Dil Al Manthurah-N
Dil Al Manthurah
Dil Al Manthurah-SW
Dil Al Manthurah-S
Wadi As Sarhah
Bi'r At Tawilah-N
Bi'r At Tawilah-NE
Bi'r At Tawilah
Bi'r At Tawilah-SE1
Bi'r At Tawilah-SE
Radamat Jaza
Shaib Qarnayn
Abal Al Lamisah
Abal Al Lamisah
Shaib Al Lamisah-E
Shaib Al Lamisah-NE1

was emplaced has a shallow easterly dip. It is a reverse fault with As Siham rocks thrust over Bani Gavy strata. An ophiolitic mélange representing primitive oceanic crust (serpentinites and listwaenite) metagabbros, metabasalts, marble lenses and amphibolites occupies the hanging wall of the thrust fault. The occurrence of listwaenite is especially important as this irregularly distributed rock occupies the same structural position along the same Bi'r Tawilah Thrust Fault to the north in the Jabal Ghadarah deposit and to the south in the Mansourah deposit, although the styles of alteration are somewhat dissimilar. Most of the section at Bi'r Tawilah is hydrothermally altered from an outer zone that is chloritized to more highly mineralized rocks that are sericitized, carbonatized and silicified. Conjugate shears and fracture sets and related breccia control the distribution of mineralization and accessory sulphides. Gold occurs in fractures that are often filled or coated with sulphides, or by quartz veinlets with sulphides and disseminated or impregnation of sulphides, generally pyrrhotite and pyrite in the serpentinite. Gold in deep portions of the deposit occurs as inclusions in injected silica. Gold also occurs in quartz veins within listwaenite at the margins of a granitic intrusion. Anomalous arsenic values (up to 1,225 ppm) are found within the ancient workings and the ultramafic host rock.

The Mansourah deposit has essentially the same structural setting as Bi'r Tawilah and is located on a major thrust fault that is either the same structure or a very closely associated parallel structure. The position of the Bany Gavy and Siham formations is the same as is the presence of brecciated and listwaenite-altered ultramafic rocks and serpentinite in the fault plane. All the rock units are intruded by lenticular intrusive bodies ranging from monzogranite to diorite in composition. Late quartz-feldspar porphyry, and granophyre dykes are also present. Gold mineralisation occurs in listwaenite and lenticular, sheared diorite bodies within the zone of shearing. Relatively higher-grade mineralisation is associated with chlorite–graphite–pyrite–arsenopyrite in fractures or brecciated quartz vein, as well as associated with disseminated and semi-massive pyrite-arsenopyrite veinlets in sheared diorite. In addition, there are zones of lower grade mineralisation occurring as a network of cm-scale quartz stockwork veining in listwaenite-breccia zones. As of November, 2013, Mansourah was estimated to contain an Indicated Resource of 24.3 Mt grading 2.85 g Au/t (sulphide ore) plus 2.1 Mt grading 2.6 g Au/t (oxide ore). Inferred Resources for sulphide and oxide ore, respectively, were 8.9 Mt at 2.2 g Au/t and 0.4 Mt at 1.3 g Au/t. The total global gold resource was estimated to be 3.06 Moz (Ma'aden, 2014).

The geology at Masarah, a 1.5 million ounce gold deposit, is virtually identical to that at Mansourah, the key connection being the main thrust fault that separates As Siham Group schists from Bany Gavy Group metasedimetary strata. The fault zone (deformation zone) is marked by intense hydrothermal activity and lozenges of ophiolitic rock that have been tectonically emplaced into the upper crust from much deeper levels. The mineralization style is the same as at Mansourah and is consistent with an orogenic gold model. Combined, the two deposits total 58 Mt containing more than 4.64 million ounces of gold (average grade 2.5 g/t).

Recommendations

At Bi'r Tawilah, a comparison of diamond drill and percussion drill results for the main zone showed a marked increase in grade thickness for the drill-core method. This proves the essential problem with percussion drilling – that significant sample loss can occur without visible evidence thus allowing the operator to believe that the samples are representative when they are not. In *this case* study carried out for Ma'aden, 2 m composite RC samples in both the oxide and sulphide mineralization systemically understated the grade when compared to the 2 m composite diamond drill core samples. From a global perspective, this is not unusual as the potential for under-reporting gold contents has been noted in many other prospects and deposits. RC holes are a cost-effective means of exploring large areas, however RC drilling produces unpredictable results when used for delineating ore deposits. In some cases, ore reserves in new operating mines have been substantially down-graded after RC drilling was shown to have over-sampled ore zones by smearing high-grade mineralization. New face-sampling RC technology is supposed to prevent this from happening, however results can still be unpredictable and must be corroborated by the twinning of a certain number of RC and diamond drill holes. Given the irregular distribution of gold in many deposits, producing a population of twinned holes with similar assay results can be difficult.

The exploration and discovery of the Mansourah and Masarah deposits is a good example of Ma'aden applying a basic geological model to its regional exploration. Initial indications of mineralization on surface were followed up using a well conceived geological model. Aggressive drilling programs followed resulting in many hundreds of holes being drilled, as had already been done at Bi'r Tawilah.

Given the many problems with percussion drilling, and even the variances often seen when comparing assays from RC drilling versus diamond drill core drilling, it can be concluded that excellent potential for additional gold discoveries exists considering the many prospects in the KSA that have been dismissed because the initial results did not meet expectations. While no additional exploration is needed on Bi'r Tawilah, Mansourah or Masarah, it is easy to see that considerable potential for additional mineralization exists along the main Nabitah structure associated with the Mansourah-Bi'r Tawilah gold belt. The potential for additional 'blind' discoveries is excellent even though there are few bedrock clues in this overburden-covered area to allow specific drill site targeting.

The exploration philosophy and process used by Ma'aden must be exported to the remainder of the gold belt and to other similar areas in the Arabian Shield. Essentially this means using the existing basic tools of prospecting to locate gold mineralization, and where bedrock is not exposed, geophysics, especially IP, to search for anomalies that may be associated with disseminated sulphides. All targets must be drilled sufficiently to eliminate their potential. This translates to a set of holes sufficient to test the target on 50-100 m sections along its length. For budgeting purposes, it would be wise to allow for 1,000 m to 1,500 m per target.

References

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SRK Consulting, 2011, **Mineral Resource Estimate for the Central Zone of the Bir Tawilah Gold Deposit, Saudi Arabia**, an independent consulting report prepared for Ma'aden Gold and Base Metals Company dated October, 2011, 135 pages, 3 Appendices.

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3.1.3.7 The Nabitah Gold Belt - Ad Duwayhi-Dahlat Shabab Segment

Location, Distribution of Occurrences and History

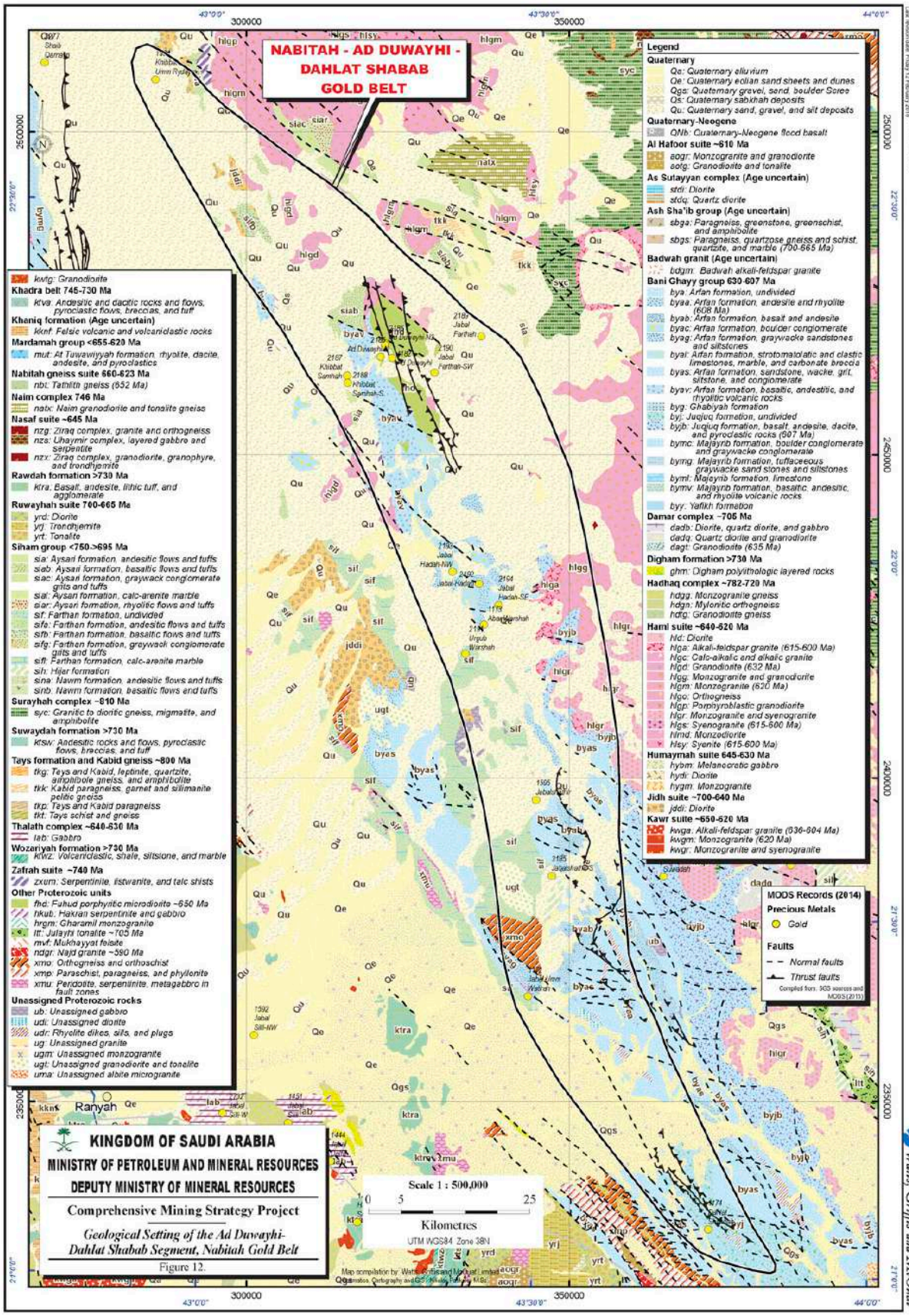
The Ad Duwayah-Dahlat Shabab segment of the Nabitah Gold Belt is approximately 165 km in length and strikes north-northwesterly between two Najd Faults, the Ruwah Fault Zone in the south and the Ar Rika Fault Zone in the north. In this sense, the geological setting is virtually the same as that of the Mansourah Segment of the Nabitah Gold Belt (Figure 12). The gold occurrences in the belt are summarized in Table 13.

Table 13

Name and Location of Gold Occurrences – Nabitah Gold Belt – Ad Duwayah-Dahlat Shabab Segment, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry *
				Longitude	Latitude			
1594	Khibbat Umm Rydaym	Jabal Ashaild	Gold	42.9166670	22.6666670	Ranyah	VL	dd, v
2189	Jabal Farthah	Jabal Farthah	Gold	43.4116670	22.3130560	Ranyah	Med	dd, v
2186	Ad Duwyhi-N2	Ad Duwyhi-N2	Gold	43.2677220	22.3015830	Ranyah	Med	dd, v
2297	Ad Duwyhi-N1	Ad Duwyhi-N1	Gold	43.2665560	22.2999440	Ranyah	Med	dd, v
2185	Ad Duwyhi-N	Ad Duwyhi-N	Gold	43.2606390	22.2828890	Ranyah	High	dd, v
1182	Ad Duwyhi	Ad Duwyhi	Gold	43.2778330	22.2815000	Ranyah	High	stockwork v, dd, v
2190	Jabal Farthah-SW	Jabal Farthah-SW	Gold	43.3420830	22.2618060	Ranyah	VL	dd, v
2187	Khibbat Samhah	Samhah	Gold	43.2105560	22.2558330	Ranyah	Med	dd, v
2188	Khibbat Samhah-S	Samhah	Gold	43.2116670	22.2461670	Ranyah	Med	dd, v
2193	Jabal Hadah-NW	Jabal Hathah-W	Gold	43.3722220	21.9833330	Ranyah	Undefined	v, uncertain
2192	Jabal Hadah	Jabal Hathah-E	Gold	43.4120560	21.9666390	Ranyah	VL	dd, v
2194	Jabal Hadah-SE	Quz Wurshah	Gold	43.4416670	21.9375000	Ranyah	VL	dd, v
1173	Abar Warshah	B'ir Warshah	Gold	43.4203330	21.9100000	Ranyah	Med	v
2191	Urgub Warshah	Urghub Wurshah	Gold	43.3926390	21.8695000	Ranyah	Med	dd, v
1595	Jabal Shathir	Jabal Ishata	Gold	43.5000000	21.6666670	Ranyah	Undefined	dd, v
3185	Jabal Shathir-S	Jabal As Simar	Gold	43.5250000	21.5605560	Ranyah	VL	undetermined
1172	Jabal Umm Watirah	Jabal Umm Matirah	Gold	43.4916670	21.3918890	Ranyah	Med	v
1174	Dahlat Shabab	Dahlat Shahab	Gold	43.7630280	21.0680000	Wadi Aldwasir	Med	dd, v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins; fracture fillings = ff


NABITAH - AD DUWAYHI -
DAHLAT SHABAB
GOLD BELT
Legend
Quaternary
Qe: Quaternary eluvium
Qe': Quaternary eolian sand sheets and dunes
Qgs: Quaternary gravel, sand, boulder Scree
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary–Neogene flood basalt
Al Hafoor suite ~610 Ma
aogr: Monzogranite and granodiorite
aotg: Granodiorite and tonalite
As Sutayyan complex (Age uncertain)
stdi: Diorite
stdq: Quartz diorite
Ash Sha'ib group (Age uncertain)
sbga: Paragneiss, greenstone, greenschist, and amphibolite
sbgs: Paragneiss, quartzose gneiss and schist, quartzite, and marble (700-665 Ma)
Badwah granit (Age uncertain)
bdgm: Badwah alkali-feldspar granite
Bani Ghayy group 630-607 Ma
bya: Arfan formation, undivided
byaa: Arfan formation, andesite and rhyolite (608 Ma)
byab: Arfan formation, basalt and andesite
byac: Arfan formation, boulder conglomerate
byag: Arfan formation, graywacke sandstones and siltstones
byal: Arfan formation, stromatolatic and clastic limestones, marble, and carbonate breccia
byas: Arfan formation, sandstone, wacke, grit, siltstone, and conglomerate
byav: Arfan formation, basaltic, andestitic, and rhyolitic volcanic rocks
byg: Ghabiyah formation
byj: Jugjuq formation, undivided
byjb: Jugjuq formation, basalt, andesite, dacite, and pyroclastic rocks (607 Ma)
bymc: Majayrib formation, boulder conglomerate and graywacke conglomerate
byms: Majayrib formation, tuffaceous graywacke sand stones and siltstones
bym: Majayrib formation, limestone
bymv: Majayrib formation, basaltic andesitic, and rhyolite volcanic rocks
byy: Yafikh formation
Damar complex ~705 Ma
dadb: Diorite, quartz diorite, and gabbro
dadq: Quartz diorite and granodiorite
dagt: Granodiorite (635 Ma)
Digham formation >730 Ma
ghm: Digham polylithologic layered rocks
Hadhaq complex ~782-720 Ma
hdgg: Monzogranite gneiss
hdgn: Mylonitic orthogneiss
hdfg: Granodiorite gneiss
Hami suite ~640-620 Ma
Hd: Diorite
Hga: Alkali-feldspar granite (615-600 Ma)
Hgc: Calc-alkalic and alkalic granite
Hgd: Granodiorite (632 Ma)
Hgg: Monzogranite and granodiorite
Hgm: Monzogranite (620 Ma)
Hgo: Orthogneiss
Hgp: Porphyroblastic granodiorite
Hgr: Monzogranite and syenogranite
Hgs: Syenogranite (615-600 Ma)
Hmd: Monzodiorite
Hsy: Syenite (615-600 Ma)
Humaymah suite 645-630 Ma
hybm: Melanocratic gabbro
hydi: Diorite
hygm: Monzogranite
Jidh suite ~700-640 Ma
jddi: Diorite
Kawr suite ~650-620 Ma
kwga: Alkali-feldspar granite (636-604 Ma)
kwgm: Monzogranite (620 Ma)
kwgr: Monzogranite and syenogranite
kwtg: Granodiorite
Khadra belt 745-730 Ma
kva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
Khaniq formation (Age uncertain)
kknf: Felsic volcanic and volcaniclastic rocks
Mardamah group <655-620 Ma
mut: At Tuwawiyyah formation, rhyolite, dacite, andesite, and pyroclastics
Nabitah gneiss suite 660-623 Ma
nbt: Tathlith gneiss (652 Ma)
Naim complex 746 Ma
natx: Naim granodiorite and tonalite gneiss
Nasaf suite ~645 Ma
nzg: Ziraq complex, granite and orthogneiss
nzs: Uhaymir complex, layered gabbro and serpentite
nzx: Ziraq complex, granodiorite, granophyre, and trondhjemite
Rawdah formation >730 Ma
ktra: Basalt, andesite, lithic tuff, and agglomerate
Ruwayhah suite 700-665 Ma
yrd: Diorite
yrj: Trondhjemite
yrt: Tonalite
Siham group <750->695 Ma
sia: Aysari formation, andesitic flows and tuffs
siab: Aysari formation, basaltic flows and tuffs
siac: Aysari formation, graywack conglomerate grits and tuffs
sial: Aysari formation, calc-arenite marble
siar: Aysari formation, rhyolitic flows and tuffs
sif: Farthan formation, undivided
sifa: Farthan formation, andesitic flows and tuffs
sifb: Farthan formation, basaltic flows and tuffs
sifg: Farthan formation, greywack conglomerate grits and tuffs
sifl: Farthan formation, calc-arenite marble
sih: Hilar formation
sna: Nawm formation, andesitic flows and tuffs
snb: Nawm formation, basaltic flows and tuffs
Surayhah complex ~810 Ma
syc: Granitic to dioritic gneiss, migmatite, and amphibolite
Suwaydah formation >730 Ma
ktsw: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
Tays formation and Kabid gneiss ~800 Ma
tkg: Tays and Kabid, leptinite, quartzite, amphibole gneiss, and amphibolite
tkk: Kabid paragneiss, garnet and sillimanite pelitic gneiss
tkp: Tays and Kabid paragneiss
tkt: Tays schist and gneiss
Thalath complex ~640-630 Ma
tab: Gabbro
Wozariyah formation >730 Ma
ktwz: Volcaniclastic, shale, siltstone, and marble
Zafrah suite ~740 Ma
zxum: Serpentinite, listwanite, and talc shists
Other Proterozoic units
fhd: Fuhud porphyritic microdiorite ~650 Ma
hkub: Hakiah serpentinite and gabbro
hrgm: Gharamil monzogranite
ltt: Julayhi tonalite ~705 Ma
mvf: Mukhayyat felsite
ndgr: Najd granite ~590 Ma
xmo: Orthogneiss and orthoschist
xmp: Paraschist, paragneiss, and phyllonite
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
udi: Unassigned diorite
udr: Rhyolite dikes, sills, and plugs
ug: Unassigned granite
ugm: Unassigned monzogranite
ugt: Unassigned granodiorite and tonalite
uma: Unassigned albite microgranite
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Compiled from: MGS sources and MODS (2015)
Ranyah
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Ad Duwayhi-Dahlat Shabab Segment, Nabitah Gold Belt
Figure 12.
Scale 1 : 500,000
0 5 25
Kilometres
UTM WGS84 Zone 38N
Watts, Griffis and McOuat

The Ad Duwayhi (Duwyhi) gold prospect (1182) is located near the northern end of the gold belt. North of this point, the belt extends below sand cover and is difficult to trace. Three less explored prospects are found in the immediate vicinity: the Ad Duwayh North (N, N1 and N2) prospects (2185, 2297 and 2186). On behalf of SAMS, Schaffner visited 12 ancient workings within an area measuring 915 x 260 m during the 1950s. The ancient workings of Ad Duwayah are generally 33-91 m in length, but one trenched area was continuous for more than 450 m. Eighteen samples of dump rock averaged collected at that time averaged 6.5 g Au/t. Mine tailings were also sampled in 40 test pits with the 10 highest-grade pits producing an average gold content of 9.4 g/t and eight others averaging 5.1 g/t. During the BRGM's work in 1980-81, an exploration program at Ad Duwayhi consisted of 1:2,500-scale geological mapping and the completion of 25 percussion drill holes totaling 2,320 m. Continuing exploration at Ad Duwayhi consisted of the sampling of 570 m of trenches, proton magnetometer surveying and some petrographic reviews of the mineralization. The BRGM reported banded arsenopyrite-bearing quartz which contained 12.5 to 22.7 g Au/t, and brown altered rock which carried 6 to 7g Au/t. On the Southwest Hill Zone, the BRGM's surface sampling program along seven profiles across the zone (394 rock samples) and 175 surficial samples on a 25 x 25 m grid revealed that only one profile cut across significant gold mineralization with seven contiguous samples averaging 4.8 g/t along a horizontal fracture. Twelve wadi-sediment samples collected from the north side of the North Hill carried a maximum gold content of 60 ppb. Another area with few veins but marked by abundant red hydrothermal alteration averaged 3 g Au/t based on 15 samples.

Ancient placer workings at Ad Duwayhi, distributed over an area of 1-2 km^2, were found to comprise a series of vertical, reinforced shafts which extended to bedrock, and horizontal drifts extending for average distances of approximately 5 m. A potential volume of 200,000 m^3 of 'bedrock alluvium' was calculated to average 0.7 g Au/t. Although this grade is considered by BRGM to be economic, the currently defined volume is thought to be insufficient to warrant exploitation. However, the true extent of these deposits in the Ad Duwayah area is unknown, and the BRGM recommended further exploration. After trenching, the auriferous veins were sampled and assays were obtained ranging from approximately 1 to 111 g Au/t. Diorite and rhyolitic wallrock generally contained low gold values, but 'siliceous diorite' in one trench produced a gold assay of 14.21 g/t. Additional percussion drilling was carried out on four zones: the arsenopyrite zone, the trench T1 quartz vein, the south vein zone and the southwest hill area. The drilling produced evidence of high-grade quartz veins associated with gold-bearing wallrock. A gold intersections of 0.61 g/t over 69 m in hole ADU-NO, and 0.83 g Au/t over 54 m in hole ADU-P4 indicate a potential for large tonnages of relatively low-grade mineralization. Follow-up diamond drilling supported the concept of a large low-grade bulk-tonnage resource as summarized in the following table. The southwest zone, characterized by weakly veined but strongly altered intrusive and rhyolitic rocks, was estimated to contain an open pitable resource of 13.9 Mt grading 0.45 g Au/t (Table 14).

Table 14
Summary of Diamond Drilling in the Ad Duwayhi Prospect (modified after Martel & Jantin, 1983)

1983)	Target	Number of Holes	Section Spacing	Best Results			Average Gold	Estimated Resource		
				g Au/t	g Ag/t	Width		Width	Length	Tonnes
Arsenopyrite	Quartz vein	4	50 m	49.54	13.15	6.0 m	12.0	9 m	60 m	83,400
Trench T-1	Quartz vein	2	50 m	1.35	-	3.0 m	-	-	-	-
South Vein	Quartz vein	4	100-275 m	3.00	1.70	3.0 m	1.8	3 m	500 m	300,000
Southwest Hill	Altered zone	12	50-100 m	6.90	Low	21.0 m	0.45	Undefined Pitable Zone		13,900,000
				9.97	-	3.0 m	-	-	-	-
				2.00	-	18.0 m	-	-	-	-
Trench T-34	Quartz vein	1	-	0.22	-	3.0 m	-	-	-	-
Trench T-33	Quartz vein	1	-	0.85	-	3.0 m	-	-	-	-
	Mag anomaly	2	100 m	-	18.03	18.0 m	-	-	-	-

In addition, the arsenopyrite zone was estimated to contain a resource of 83,000 t at an average grade of 12 g Au/t across an average width of 9 m (Martel-Jantin, 1983). Resource drilling continued during the 1990s and the early 2000s. In total, the exploration drilling amounted to 574 holes totaling 74,087 m of which 1,992 m were percussion drilling, 12,064 m were diamond core drilling and 60,031 m were reverse circulation (RC) drilling. During 2004, as part of a feasibility study, Snowden consultants carried out a resource estimate using a 0.5 g Au/t cut-off grade which indicated total JORC-compliant Indicated and Measured Resources of 19.0 Mt averaging 3.2 g Au/t for a total contained gold resource of 1.94 Moz.

Mineral development in the Ad Duwayah area, for which this specific project is a cornerstone, is conditional on the completion of a water pipeline from Taif, a 500 km long conduit to bring treated wastewater to the area for mining operations. WGM understands that this pipeline is being constructed and that the Ad Duwayhi area will become a mining hub to support the development of additional projects in the region such as Ma'aden's projects at Mansourah, Masarah and Bi'r Tawilah. These projects fall under Ma'aden's CAG project which are all subject to limited local water availability. The water pipeline is viewed as a long-term investment which will benefit other projects, potentially including agriculture. WGM believes that the potential for additional gold deposits in the area is sufficient to provide an incentive for completion of the pipeline.

The Jabal Farthah gold prospect (MODS 2189), is located about slightly east of the northern end of the belt and approximately 13 km east of Ad Duwayah. It is a relatively minor occurrence compared to Jabal Farthah Northwest (2190) found 8 km to the southwest. Exploration in the region of the Northwest prospect was initiated by SAMS in 1954. During the 1980-81 field season, the BRGM reported that 23 bedrock grab samples contained an average gold content of 4.6 g/t (Elsass and others, 1982). A later report describes the collection of 23 quartz samples averaging 2.74 g Au/t and six host rock samples averaging 1.44 g Au/t in the Ad Duwayah area during November, 1980 (Vazquez-Lopez and others, 1984). Following this work, five percussion drill holes totaling 380 m were completed in January 1982 to explore 400 m of strike along the most southwesterly vein. One of these holes (FRTP3) was drilled down-dip. For analytical purposes, sample lengths of 3 m were used in the collection of cuttings from the holes. The maximum gold content in any single sample was 2.46 g/t. The BRGM concluded that the vein was regularly dipping but

discontinuous, and narrowed sharply at depth. Based upon this work, no further exploration was carried out and no follow-up study was recommended. There is no record of work carried out on the smaller Jabal Farthah prospect to the northeast.

The Samhah gold prospects (MODS 2187 and 2188) are located approximately 1 km apart and about 8 km west of the Ad Duwayhi deposit. The prospects are a series of ancient pits, generally less than 30 m long, that are irregularly developed on quartz veins over strike lengths of as much as 100 m. The two Samhah prospects were explored as part of the program that covered the Ad Duwayhi prospect. In modern times, Schaffner visited the area on behalf of SAMS during 1954. In 1966, the USGS completed 1:100,000 scale regional reconnaissance geologic mapping of the area but it was not until the 1980-81 field season that more detailed mapping and grab sampling of the workings was completed by the BRGM, showing that the gold content of the veins averaged 4.2 g/t in samples (Elsass, Cartier, and others, 1983). This was followed by an 8-hole 560 m program of percussion drilling on the northern prospect (2187). The best intersection was 3 g Au/t in an arsenopyrite-bearing section of uncertain thickness. The southern prospect (2188) was also tested with three holes totaling 210 m. The best intersection averaged 1,048 g Au/t (30.6 oz/ton!) across a 3-metre section in a SE-striking vein. A second interval contained 0.23 g Au/t across 6 m. Most holes contained low but anomalous gold contents in the vein structures that dip northerly at 70°-90°. The BRGM concluded that the zone had limited size potential, with no potential for economic grades based on the rarity of good intersections.

The Jabal Hadah (formerly Hathah) and Abar Warshah (formerly Bir Wurshah) prospects are found in an area 35 km south of Ad Duwayhi. These are recorded as MODS 2192 (Jabal Hadah), 2193 (Jabal Hadah NW), 2194 (Jabal Hadah SE), 1173 (Abar Warshah), 2191 (Urgub Warshah). A total of 10 separate mineralized sites are recognized. The earliest detailed exploration work on the Jabal Hadah-Bir Warshah area was in 1954 by SAMS, consisting of reconnaissance examinations of bedrock exposures and the excavation of trenches and test pits on six of the many ancient workings in a 36 km^2 area (Schaffner, 1954a). At and average gold content of 6.2 g/t, with a maximum value of 12 g/t, grab samples contained higher gold contents than bedrock chip samples. Bedrock samples assayed less than 1.4 g/t except for two samples which contained 10.3 g/t and 10.6 g/t. Alluvium in the area carried as much as 12.7 g Au/t in the size fraction between 3.2 mm and 5.1 cm, and although anomalous, the finest fraction (< 3.2 mm) was consistently lowest in gold. Although 18 samples of ferruginous rock were analyzed for base metals and associated elements (e.g. V and Mn), none of these samples were analyzed for gold. Follow-up exploration during 1980 produced 161 samples from 10 separate sites, 115 of which came from the more northerly Jabal Hadah SE and Abar Warshah prospects. The Urgub Warshah occurrence contributed 46 samples (Vazquez-Lopez and others, 1984). The average gold content of 35 quartz samples taken from three sites was 5.1 g/t, whereas 11 samples of wallrock averaged 1.6 g/t. Significant gold contents to a maximum of 37.2 g/t were found in both quartz veins and wall rock at seven sites near Jabal Hadah. Using a larger sample population of 62 samples of quartz, gold concentrations averaged 2.38 g/t; 11 wallrock samples averaged 0.56 g Au/t. Subsequent geologic mapping of the Jabal Hathah quadrangle (21/43A), was carried out at a scale of 1:100,000 by DGMR during the 1981-82 field season (Rowaihy, 1984). There is no record of follow-up work until the USGS carried out exploration during 1997-97 consisting of trenching: 721 m at

Abar Warshah and 394 m at Urgub Warshah, as well as soil and panned concentrate geochemical sampling (Elliott and others, 1998). Bedrock samples produced gold contents comparable to previous sampling programs, and visible gold was noted at Urgub Warshah. Ground-based magnetic and IP surveys were also completed indicating several zones of high chargeability and low resistivity. A 1,000 m program of diamond core drilling was recommended at Abar Warshah and Urgub Warshah. Exploration was also made of the Jabal Hadah NW prospect (one trench, 1:2,000 scale mapping, selected grab sampling), but the gold assays were low (<0.2 g/t) and the small size of the workings did not warrant a recommendation from the USGS for further work. It is uncertain if the recommendation for additional drilling at Abar Warshah and Urgub Warshah was implemented.

The Jabal Umm Watirah gold prospect (MODS 1172), formerly known as Jabal umm Matierah, is located 53 km SSE of the Urgub Warshah area. According to the USGS, the ancient workings are developed along four parallel limonite-stained quartz veins. According to Hackett, early exploration at Jabal umm Watirah was carried out by the DGMR as part of an exploration program initiated to follow up on base-metal anomalies reported by Bogue (1954). The follow-up work was dedicated to exploring for gold, and it showed that the quartz veins were relatively low in gold as compared to friable, limonitic and fractured sulfide-bearing wallrocks. During 1979, the USGS evaluated the Jabal Ishmas-Wadi Tathlith gold area, and a 1:1,000 scale geological base map was prepared of the sand-filled ancient pits and workings at the site (Worl, 1979). Average gold contents for various sample types were: dump samples = 3.54 g/t (12 samples); channel samples = 11.0 g/t (3 samples); and, grab samples = 6.64 g/t (8 samples). Continuing work by the DGMR during the 1979-80 field season comprised the surveying of a 50-m grid over the workings, additional 1:1,000 scale geological mapping, the analysis of dump and rock-chip samples from the ancient workings, the analysis of 26 wadi-sediment samples from the vicinity of the workings, and the drilling of 10 diamond drill holes totaling 1,391.15 m. Dump samples averaged 2.33 g Au/t, somewhat less than previous suites of such samples. In evaluating the results of surface sampling, the USGS concluded that a factor of 2.3 to 3.1 should be utilized as a 'grade estimator' to convert the gold content in dump samples to the in-situ gold content in bedrock (Hackett, 1982). Some wadi-sediment samples contained anomalous gold concentrations, but the results were inconclusive due to the limited drainage development in the prospect area, and limited secondary dispersal of auriferous material. Diamond drilling intersected nine parallel zones of hydrothermal alteration. Drill core was split and sampled utilizing 20 cm intervals. In intervals where the core was highly broken and poorly recovered, some samples were as great as 1.35 m in length. Of the mineralized zones, the most continuous and best mineralized was the 'A-Zone', which was intersected over a strike length of 400 m and to a maximum vertical depth of 85 m, extending below the maximum depth drilled. All zones carried anomalous gold and all exhibit some variation in dip, thickness, and composition (Hackett). During 1980 and 1981, proton magnetometer, dipole-dipole IP (25 and 50-m electrode separation) and SP surveys were performed along profiles with a 50-metre spacing (Oskoui and others, 1984). The magnetic profile indicated broad lithologic signatures, and the IP detected resistivity anomalies attributed to zones of altered and quartz-veined bedrock. The SP survey detected a previously unknown zone south of the formerly drill-tested area. Follow-up Geonics EM-16 VLF surveying (10-m stations) detected some strong cross-overs attributed to the north-northeast-striking quartz veins and altered rocks (Last and Oskoui, 1983). Three anomalous zones were recommended for diamond drilling

based on the interpretation of the EM-16 survey, and three holes varying in length from 67.3 to 89.9 m (total 230.4 m) were drilled during 1983. Two holes, JUM-11 and JUM-13, remained within the structural hanging wall of the A-Zone where narrow mineralized zones carried a maximum of 1.15 g Au/t across 20 cm. Borehole JUM-12, targeted on a VLF-indicated conductor interpreted to represent the southern extension of the A-Zone, intersected 3.48 g Au/t across 1 m within a quartz-veined, pyrite and arsenopyrite-bearing zone. During the 1983-84 exploration program, the prospect grid was extended 600 m to the south, and follow-up EM-16 and horizontal loop EM surveys utilized a 10-m station interval (Last and others, 1988). These surveys delineated the southerly extension of the conductor in the vicinity of the mineralized A-Zone together with three NNE-trending subparallel conductors having a 700 m strike length. Follow-up work by the USGS included diamond drilling however only the most obvious mineralized zones were tested. The USGS estimated that the prospect contained a resource of 300,000 tonnes averaging 7.3 g Au/t across a true thickness of 3.1 m. This resource was based on a limited number of diamond drill holes (13 holes totalling 1,621.55 m) and the use of an MIBK analytical technique that may have resulted in the under-reporting of gold contents[4]. Based on present standards and guidelines, this resource would not meet internationally accepted resource classification criteria. During 1996-1998, follow-up exploration resulted in magnetometer surveying of the prospect area and IP surveying over selected sections, as well as two drilling programs totaling 19 holes (2,897 m), mostly composed of NQ-sized diamond drilling, and the remainder being RC drilling. A high percentage (39%) of the drill holes intersected at least 5 g Au/t over a 2 m interval, and many had multiple intersections as shown in Table 15 (Elliot and others, 2001). WGM is aware of no follow-up exploration since this work was completed.

[4] MIBK is an acronym for the methyl isobutyl ketone extraction process for gold. The sample charge is not fired, but rather it is placed in the solvent which dissolves readily leachable (free) gold. The gold content is usually determined by AA or another instrumental technique. However, due to a lack of high-temperature firing, the ketone cannot dissolve gold that is encapsulated in silica or sulphide phases. It is therefore a potentially partial extraction process. The possibility of under-reporting gold due to refractory gold remaining in the sample tail must be considered.

Table 15
Summary of Drill Hole Results for 1995-1995 Program at Jabal Umm Watirah

DDH	Interval (metres)			Gold	DDH	Interval (metres)			Gold
	From	To	Width	(g/t)		From	To	Width	(g/t)
95-1	12.4	12.8	0.4	6.7	96-2	137	143.3	6.3	5.9
	54.8	55.7	0.9	3.1		162.7	168.9	6.2	2.9
	63.7	65.2	1.5	2.6		188.9	196.2	7.3	6.3
	97.4	104	6.6	4.3	96-3	117.9	123.4	5.5	1.6
	126	127.8	1.8	3.0	96-4	23.7	32.8	9.1	4.3
	146.1	148.1	2.0	3.1	96-5	19	21.9	2.9	3.8
	153.6	159.6	6.0	9.7		121.2	122.1	0.9	22.7
	168.1	170.6	2.5	2.6	97-1	159	160.5	1.5	3.0
95-2	62.2	68.4	6.2	1.8	97-2 *	55	60	5.0	2.1
	102.4	109	6.6	1.2	97-3	75	75.5	0.5	15.7
	116.3	118.7	2.4	2.7	97-4 *	30	32	2.0	5.8
	130.8	132.3	1.5	2.7	97-5	88	90	2.0	7.2
95-3	133.3	140.8	7.5	6.1	97-6	120.5	121	0.5	1.7
96-1	69.2	69.7	0.5	9.4	97-7	35	37	2.0	0.1
	81.6	82.1	0.5	9.2	97-8	46	47.5	1.5	5.8
					97-9	81	82.5	1.5	2.1
					97-10	28.5	29	0.5	1.5

* *Note: intersections in 97-2 and 97-4 are located in sections above 60 m that were drilled by RC.*

The gold prospect at Dahlat Shabab (MODS 1174) is located about 44 km southeast of the Jabal Umm Watirah prospect in a similar geologic setting. The trend of the southern end of the gold belt is rotated to the southeast due to drag on the sinistral Ruwah Fault Zone immediately south of Dahlat Shabab. Ancient workings cover an area measuring approximately 2 km in length and 500 m in width. SAMS examined the prospect as part of its shield-wide reconnaissance during 1954. A total of 82 samples were analyzed from 12 ancient mine sites and gold contents of up to 265 g/t or 7.73 oz/ton were reported (Schaffner, 1954c). The samples were largely quartz vein material from outcrops, mine dumps and quartz float. Waste samples taken from alongside the ancient workings averaged 15.77 g Au/t, possibly representing evidence that the ancient miners focused on the higher grading ore. Wallrock samples carried only low gold values of 0.33 to 2.40 g/t. The USGS mapped the Dahlat Shabab area at 1:100,000 scale during 1972-73 as part its reconnaissance geological mapping of the Bi'r Juqjuq Quadrangle (Hadley, 1976). Sampling at that time consistently up-held the high-grade nature of the mineralization. On the basis of the surveys carried out to that time, the USGS estimated a resource of 210,000 t in the immediate prospect area (Worl, 1979). During 1979-80, Riofinex resampled quartz veins and wallrock bordering the vein stockworks – these vein samples carried up to 5.8 g Au/t whereas wallrock averaged 0.7 g Au/t. The following year Riofinex assessed the placer gold potential of the prospect area (Boyle and Atkinson, 1982). Riofinex concluded that the potential of the hard-rock Dahlat Shabab prospect as well as the alluvial gold was too low to warrant additional exploration. WGM has no record of any further work being carried out at this site.

The Rayyaniyah-Zain West area contains a cluster of gold prospects located 40-50 km east of the end of the gold belt in the Dahlat Shabab area. These include Rayyaniyah (0654), Zain (0653), Zain West (3118 – also known as Tha'an), Bi'r Zain (1591), Fahthan (4576) and others. Most of the gold occurrences are small, however the Zain West prospect appears to have the greatest potential size. Previous work in the area as early as the 1950s identified gold-bearing quartz veins that contained nuggety gold, returning gold

assays as high as 105.6 g/t (3.08 oz/ton!). Ancient dumps were estimated to contain 300 to 500 short tons of material estimated to average 16.5 g Au/t and 77.5 g Ag/t. Following mapping by the USGS during the period 1964-65, the Zain West site was sampled in detail in 1979-80 according to Howes (1982) low but anomalous average gold concentrations to a maximum of 4 g/t and one sample from a shear zone intersection contained 17 g/t. Follow-up reconnaissance sampling by the SGS in 2002 produced 38 samples ranging from 0.14 g Au/t to 16.55 g Au/t. WGM reviewed the area but could find no evidence for a structural connection to the Ad Duwayah-Dahlat Shabab Gold Belt. These occurrences appear to be isolated and possibly associated with the emplacement of granitic plutons.

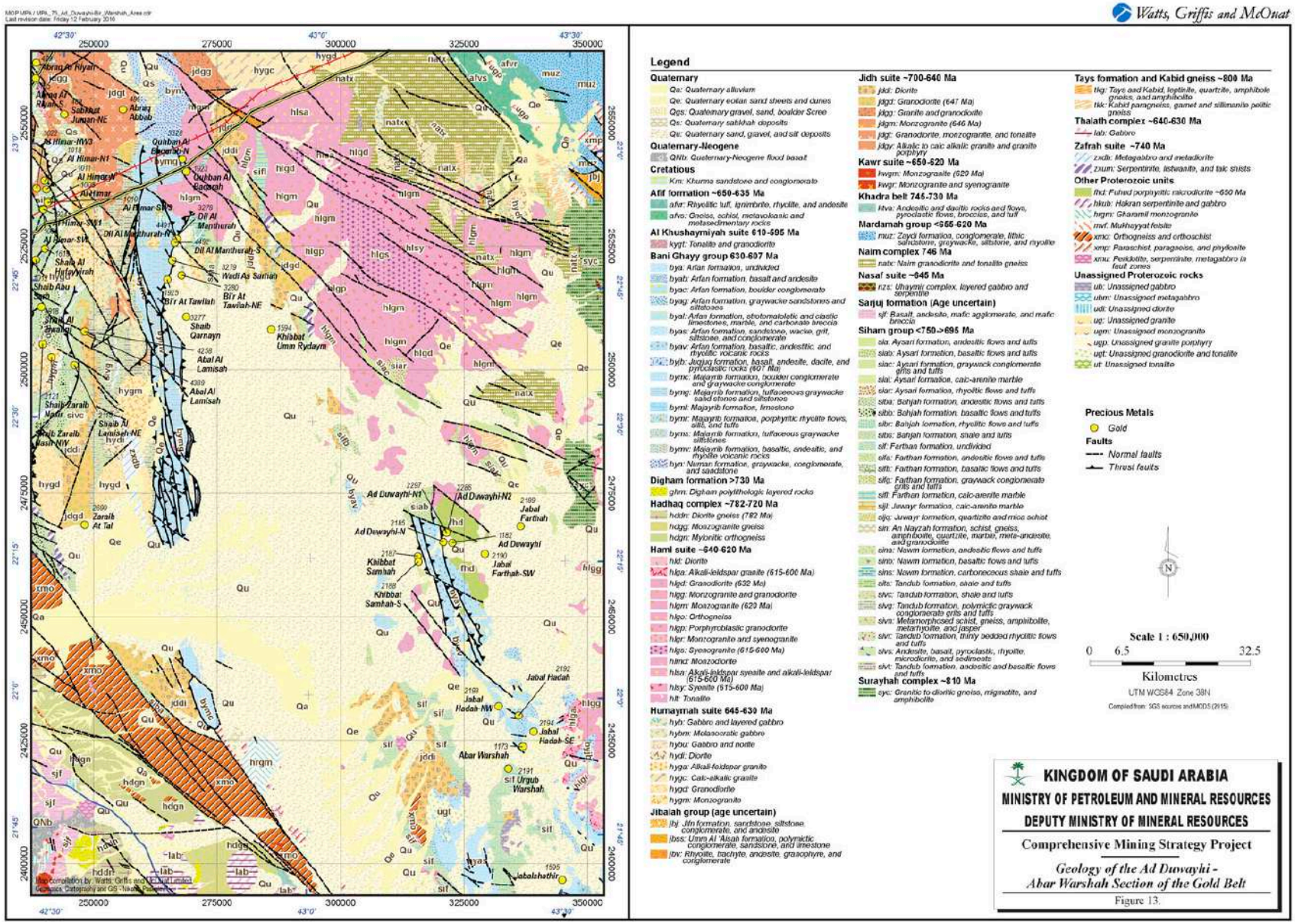
Geology

The Ad Duwayah area is underlain by tightly-folded andesitic to dacitic metavolcanic rocks intruded by a variety of felsic to intermediate plutons and dikes (Agar, 1988) (Figure 13). Quartz veins are common throughout the region, becoming most abundant at Ad Duwayah where they are controlled by intersecting fracture sets. The immediate area of the deposit consists of a circular, alluvium filled basin partially surrounded by rising to as much as 50 m above the central basin. Below the surficial materials, the principal rock types expected to be encountered in the planned open pit are mesozonal intrusive rocks: granodiorite, diorite, rhyolite and microdiorite. The granodiorite is believed to have been intruded by the diorite, which was in turn intruded by a swarm of NNE-trending, subvertical, rhyolite and microdiorite dikes. Cutting across the older rock units is a porphyritic granite dike system that trends in a NW direction, nearly normal to the trend of the rhyolite and microdiorite dike swarm (Figure 14). A closely related sill-like body, that has been called Square Quartz Porphyry, occurs below the south-western circular hill. Four major lithological units are present: (1) granite/granodiorite/porphyry; (2) diorite/microdiorite; (3) rhyolite/rhyolite porphyry; and, (4) quartz/quartz stock work. Although the quartz porphyry is the principal host for gold mineralisation, the rhyolite is also believed to be associated with gold mineralisation. All lithologies are affected by cataclasis accompanied by a high degree of silicification and some chloritization. Plagioclase is hydrothermally altered to carbonate, sericite and clay, and mafic minerals are replaced by chlorite. Most of the gold resource at occurs in a NE-striking, SW-dipping mineralized zone referred to as the Main Vein Zone (Doebrich et al 2004) which dips at -45° to -60° at surface and flattens to -30° at depth. It is associated with a SE- dipping square quartz porphyry dike. Individual veins within this zone are randomly oriented. Mineralisation styles include (1) quartz–molybdenum veins and quartz vein breccias primarily in and peripheral to the granite, (2) gold-bearing stockwork and sheeted veins; and, (3) gold-bearing tabular veins. Figure 15 presents a schematic on the Ad Duwayhi deposit showing the spatial relationship of these styles of mineralisation.

The Khibbat Samhah area is underlain by tightly folded, vertically-dipping metavolcanic and volcaniclastic rocks which are intruded by dioritic and granodioritic plutons of probable Hulayfah age (Elsass and others, 1982). To the east, these rocks are overthrust by younger metaclastic rocks along a north-striking thrust fault. According to Agar (1984), these structures probably developed as normal faults with reverse dislocation occurring during late orogenic compression of the basin. Quartz veins occur within the older

layered rocks which are described as being metasiltite (Martel-Jantin, 1983). The veins are thought to have evolved from hydrothermal fluids originating within the dioritic intrusions (Clegg, 1984). In this sense, the Samhah mineralization may be similar metallogenically similar to the deposits found farther to the north in the Afif Terrane and associated with Idah Suite intermediate intrusions. The fact that bonanza grade mineralization is found locally, with an intersection of 1,048 g Au/t (30.6 oz/ton!) across a 3-metre section in a SE-striking vein, suggests that gold is very irregularly distributed in these veins systems.

The Jabal Hadah – Abar Warshah area is underlain by metasedimentary and metavolcaniclastic rocks of the Siham Group which are folded with N-S trending vertical axes, and intruded by granitic rocks of the Haml Batholith (Figures 16 and 17). The layered sequence is composed of meta-andesitic agglomerate, conglomerate, siltstone, sandstone, greywacke and limestone. In the area of the Abar Warshah and Jabal Hadah SE occurrences, carbonate and meta-andesite is the dominant country rock whereas at Urgub Warshah, a greenschist-conglomerate assemblage is dominant. Although designated as quartz vein-type mineralization, the mineralized sites commonly contain finely-disseminated gold in wallrock adjacent to the veins. Visible gold was seen in silicified siltstone at Abar Warshah. The host rocks are generally sheared in the presence of quartz veins. The veins are predominantly NW-trending, however some are east-west while others strike north-easterly. Dips vary from -45^{o} to -80^{o}. Galena and chalcopyrite are seen in some limonitic veins. Geophysical surveying indicated that the quartz-veins and sheared rocks may coincide with a magnetic low that was thought to reflect alteration of the ultramafic rocks. Several chargeability anomalies were correlated with favourable zones for additional exploration, presumably in relation with disseminated sulphides. The USGS concluded that the Urgub Warshah occurrence, within an area 4 km x 3.2 km, was considered to be the most economically interesting. Only low gold values were detected at Jabak Hadah (Elliott and others, 1998).


Watts, Griffis and McOuat
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Qgs: Quaternary gravel, sand, boulder Scree
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Cretatious
Km: Khuma sandstone and conglomerate
Afif formation ~650-635 Ma
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
afvs: Gneiss, schist, metavolcanic and metasedimentary rocks
Al Khushaymiyah suite 610-595 Ma
kygt: Tonalite and granodiorite
Bani Ghayy group 630-607 Ma
bya: Arfan formation, undivided
byab: Arfan formation, basalt and andesite
byac: Arfan formation, boulder conglomerate
byag: Arfan formation, graywacke sandstones and siltstones
byal: Arfan formation, stromatolitic and clastic limestones, marble, and carbonate breccia
byas: Arfan formation, sandstone, wacke, grit, siltstone, and conglomerate
byav: Arfan formation, basaltic, andesitic, and rhyolitic volcanic rocks
byjb: Jeguig formation, basalt, andesite, dacite, and pyroclastic rocks (607 Ma)
byrc: Majaryib formation, boulder conglomerate and graywacke conglomerate
byrg: Majaryib formation, tuffaceous graywacke sandstones and siltstones
byrl: Majaryib formation, limestone
byrr: Majaryib formation, porphyritic rhyolite flows, sills, and tuffs
byrs: Majaryib formation, tuffaceous graywacke siltstones
byrv: Majaryib formation, basaltic, andesitic, and rhyolite volcanic rocks
byn: Nuwan formation, graywacke, conglomerate, and sandstone
Digham formation >730 Ma
gfm: Digham polylithologic layered rocks
Hadhaq complex ~782-720 Ma
hddr: Diorite gneiss (782 Ma)
hdgg: Monzogranite gneiss
hdgn: Mylonitic orthogneiss
Haml suite ~640-620 Ma
hld: Diorite
hlga: Alkali-feldspar granite (615-606 Ma)
hlgd: Granodiorite (632 Ma)
hlgg: Monzogranite and granodiorite
hlgm: Monzogranite (620 Ma)
hlgo: Orthogneiss
hlgp: Porphyroblastic granodiorite
hlgr: Monzogranite and syenogranite
hlgs: Syenogranite (615-600 Ma)
hlmd: Monzodiorite
hlsa: Alkali-feldspar syesite and alkali-feldspar (615-600 Ma)
hlsy: Syenite (615-600 Ma)
hlt: Tonalite
Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hybm: Melasoeratic gabbro
hyou: Gabbro and norite
hydi: Diorite
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygm: Monzogranite
Jibalah group (age uncertain)
jby: Jibi formation, sandstone, siltstone, conglomerate, and andesite
jbss: Umm Al 'Alsa formation, polymictic conglomerate, sandstone, and limestone
jbv: Rhyolite, trachyte, andesite, granophyre, and conglomerate
Jidh suite ~700-640 Ma
jdd: Diorite
jdgd: Granodiorite (647 Ma)
jdgg: Granite and granodiorite
jdgm: Monzogranite (646 Ma)
jdgr: Granodiorite, monzogranite, and tonalite
jdgv: Alkalic to calc alkalic granite and granite porphyry
Kawr suite ~650-620 Ma
kwgm: Monzogranite (629 Ma)
kwgr: Monzogranite and syenogranite
Khadra belt 745-730 Ma
khva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
Mardamah group <955-620 Ma
muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
Naim complex 746 Ma
natx: Naim granodiorite and tonalite gneiss
Nasaf suite ~645 Ma
nzs: Uhaymir complex, layered gabbro and serpentite
Sarjuj formation (Age uncertain)
sjf: Basalt, andesite, mafic agglomerate, and mafic breccia
Siham group <750->695 Ma
sia: Aysari formation, andesitic flows and tuffs
siab: Aysari formation, basaltic flows and tuffs
siac: Aysari formation, graywack conglomerate grits and tuffs
sial: Aysari formation, calc-arenite marble
siar: Aysari formation, rhyolitic flows and tuffs
siba: Bahjah formation, andesitic flows and tuffs
sibb: Bahjah formation, basaltic flows and tuffs
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sif: Fartbaa formation, undivided
sifa: Farthan formation, andesitic flows and tuffs
sifb: Farthan formation, basaltic flows and tuffs
sifg: Farthan formation, graywack conglomerate grits and tuffs
sifl: Farthan formation, calc-arenite marble
sijl: Jinwayr formation, calc-arenite marble
sijq: Jinwayr formation, quartzite and mica schist
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, meta-andesite, and granodiorite
sina: Nawm formation, andesitic flows and tuffs
sinb: Nawm formation, basaltic flows and tuffs
sins: Nawm formation, carboneceous shale and tuffs
silt: Tandub formation, shale and tuffs
sltc: Tandub formation, shale and tuffs
sltg: Tandub formation, polymictic graywack conglomerate grits and tuffs
slva: Metamorphosed schist, gneiss, amphibolite, metarhyolite, and jasper
slvr: Tandub formation, thinly bedded rhyolitic flows and tuffs
slvs: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sedimeats
slvt: Tandub formation, andesitic and basaltic flows and tuffs
Suraybah complex ~810 Ma
syc: Granitic to dioritic gneiss, migmatite, and amphibolite
Tays formation and Kabid gneiss ~800 Ma
tkg: Tays and Kabid, leptinite, quartzite, amphibole gneiss, and amphibolite
tkk: Kabid paragneiss, garnet and sillimanite pelitic gneiss
Thaiath complex ~640-630 Ma
tab: Gabbro
Zafrah suite ~740 Ma
zxdb: Metagabbro and metadiorite
zsum: Serpentinite, listwanite, and talc shists
Other Proterozoic units
fhd: Fuhud porphyritic calcrodiorite ~650 Ma
hkub: Hakran serpentinite and gabbro
hgm: Gharamil monzogranite
mvf: Muhayyat felsite
xmo: Orthogneiss and orthoschist
xmp: Paraschist, paragneiss, and phyllonite
xmu: Peridotite, serpentinite, metagabbro to feuf zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
udi: Unassigned diorite
ug: Unassigned granite
ugm: Unassigned monzogranite
ugp: Unassigned granite porphyry
ugt: Unassigned granodiorite and tonalite
ut: Unassigned tonalite
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Scale 1 : 650,000
0 6.5 32.5
Kilometres
UTM WGS84 Zone 38N
Compiled from: SGS sources and MODIS (2015)
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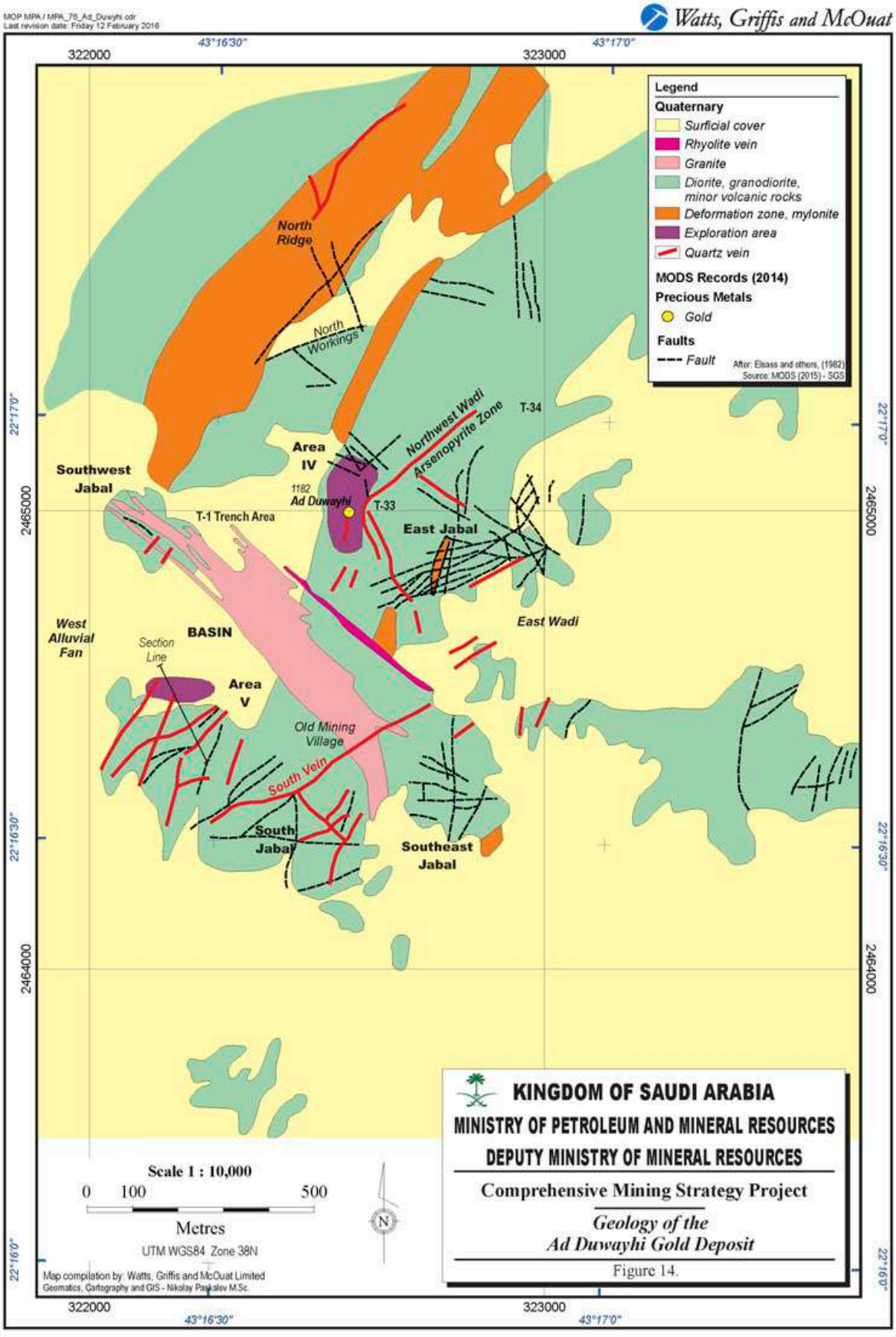
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Ad Duwayhi - Abar Warshah Section of the Gold Belt
Figure 13.


MOP MPA / MPA_76_Ad_Duwayhi.cdr
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
43°16'30"
43°17'0"
322000
323000
22°17'0"
22°16'30"
22°16'0"
2465000
2464000
Legend
Quaternary
Surficial cover
Rhyolite vein
Granite
Diorite, granodiorite, minor volcanic rocks
Deformation zone, mylonite
Exploration area
Quartz vein
MODS Records (2014)
Precious Metals
Gold
Faults
Fault
After: Elsass and others, (1982)
Source: MODS (2015) - SGS
North Ridge
North Workings
Northwest Wadi Arsenopyrite Zone
T-34
Area IV
1182
Ad Duwayhi
T-33
Southwest Jabal
T-1 Trench Area
East Jabal
East Wadi
West Alluvial Fan
BASIN
Section Line
Area V
Old Mining Village
South Vein
South Jabal
Southeast Jabal
Scale 1 : 10,000
0 100 500
Metres
UTM WGS84 Zone 38N
N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pavkalev M.Sc.
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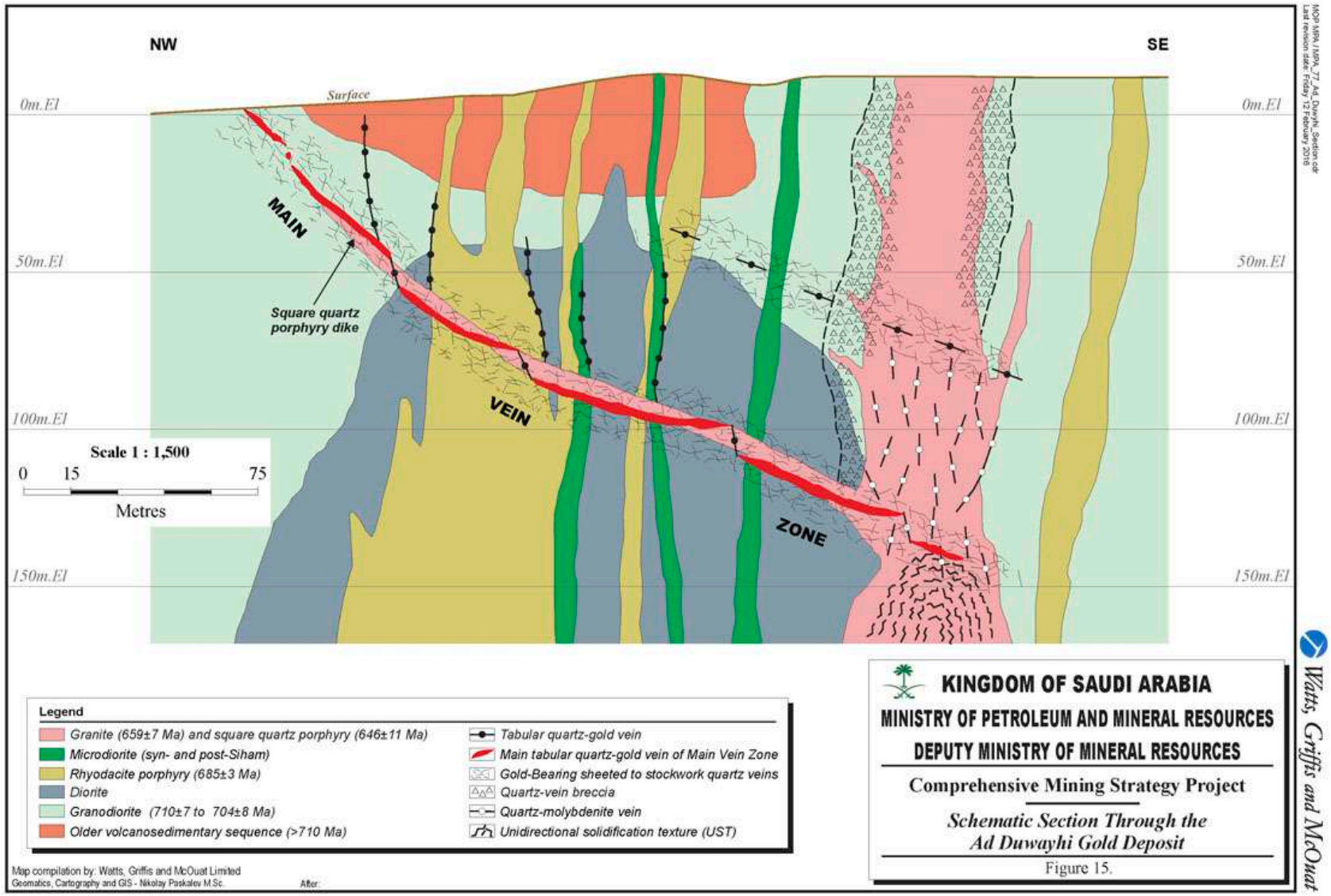
Comprehensive Mining Strategy Project
Geology of the
Ad Duwayhi Gold Deposit
Figure 14.


NW
SE
Surface
0m.El
50m.El
100m.El
150m.El
MAIN
Square quartz porphyry dike
VEIN
ZONE
Scale 1 : 1,500
0 15 75
Metres
Legend
Granite (659±7 Ma) and square quartz porphyry (646±11 Ma)
Microdiorite (syn- and post-Siham)
Rhyodacite porphyry (685±3 Ma)
Diorite
Granodiorite (710±7 to 704±8 Ma)
Older volcanosedimentary sequence (>710 Ma)
Tabular quartz-gold vein
Main tabular quartz-gold vein of Main Vein Zone
Gold-Bearing sheeted to stockwork quartz veins
Quartz-vein breccia
Quartz-molybdenite vein
Unidirectional solidification texture (UST)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
After:
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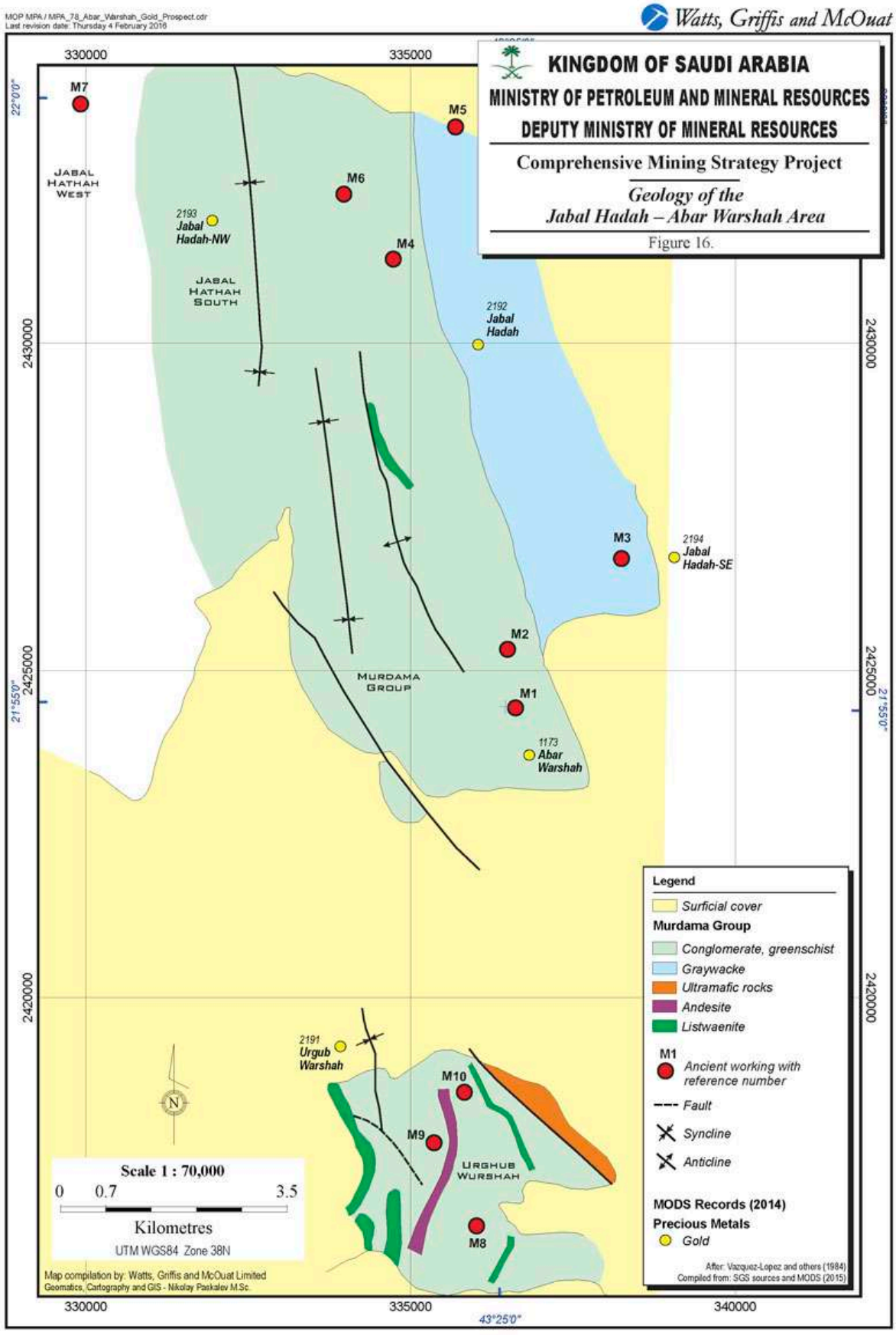
Comprehensive Mining Strategy Project
Schematic Section Through the Ad Duwayhi Gold Deposit
Figure 15.
Watts, Griffis and McOuat

At Jabal umm Watirah (Matirah), mineralization in the northern part of the prospect is hosted within a uniformly dipping weakly metamorphosed (greenschist) sequence of metabasalt and meta-andesite and associated pyroclastics (Figure 18). The host rocks in the southern part consist of metarhyolite and metadacite (Hackett, 1982). These rocks are overlain by andesitic to dacitic lithic arenites of volcanic origin, and the entire assemblage is folded on axial planes striking ESE to SE and dipping north-easterly at -40^{o} to -55^{o}. According to the USGS, the ancient workings are developed along four parallel limonite-stained quartz veins that strike approximately 015^{o} (NNE) or approximately normal to the axial planes of the folds (Hackett and others, 1989). Three of these occur within a 200-m-wide section, and the fourth lies 450 m to the east. Diamond drilling intersected nine parallel zones of hydrothermal alteration, and verified that the gold-bearing veins dip westerly at -45^{o}, and intersect the host strata at approximately 80^{o} in the south and 55^{o} in the north. Of the mineralized zones, the most continuous and best mineralized was the 'A-Zone', which was intersected over a strike length of 400 m and extended down-dip below 85 m, the maximum vertical depth drilled. Two similar but thinner zones are located above the A Zone, and six are found below in the structural footwall. All zones carry anomalous gold and all exhibit some variation in dip, thickness, and composition (Hackett). The visible alteration consists of silicification with associated pyrite and arsenopyrite. Geophysical surveying has indicated that the mineralized zone has no magnetic expression, probably due to the alteration of magnetic phases such as magnetite and Fe-Mg minerals to hematite and chlorite, respectively. The fact that higher gold concentrations are found in altered wallrocks than in the veins is thought to indicate that the quartz veins may have been emplaced during a late–stage event along previously mineralized structures. Silver is not generally found in economically significant amounts. Adjacent to the veins, pyrite and arsenopyrite commonly make up 10% of the rock volume, and in altered wallrocks a direct correlation is noted between sulfide and gold contents. WGM believes that this may be due to strong sulphidation reactions which accompanied gold mineralization. However, this relationship is not found in the typically low-sulfide gold-bearing quartz veins, and WGM attributes this to a lack of Fe-minerals which might have scavenged sulphur. Coarse gold is reported from the veins, but Hackett also reports assays greater than 100 ppm from vein samples which carried no visible gold, indicating a very fine grained phase of the gold mineralization. The USGS concluded that gold is associated with quartz veins, with the gold and sulfide content being directly related to the width of the altered zone, a simplistic interpretation which WGM would contest. Hackett further concluded that there is no genetic relationship between gold and sulfide because they were introduced as separate gold-quartz and pyrite-arsenopyrite-minor gold hydrothermal phases, a conclusion that WGM cannot support. Based on a gold cut-off grade of 4 g/t across 1 m, a drill-indicated resource of 300,000 tonnes was estimated to average 7.3 g Au/t across an average true thickness of 3.1 m at Jabal umm Watirah (Hackett). At the time, this estimate probably followed industry-standard practices but WGM is of the view that even if valid, the estimate would not meet current regulatory standards under either Canada’s National Instrument 43-101 or Australia’s JORC Code.


MOP MPA / MPA_78_Abar_Warshah_Gold_Prospect.cdr
Last revision date: Thursday 4 February 2016
Watts, Griffis and McOuat
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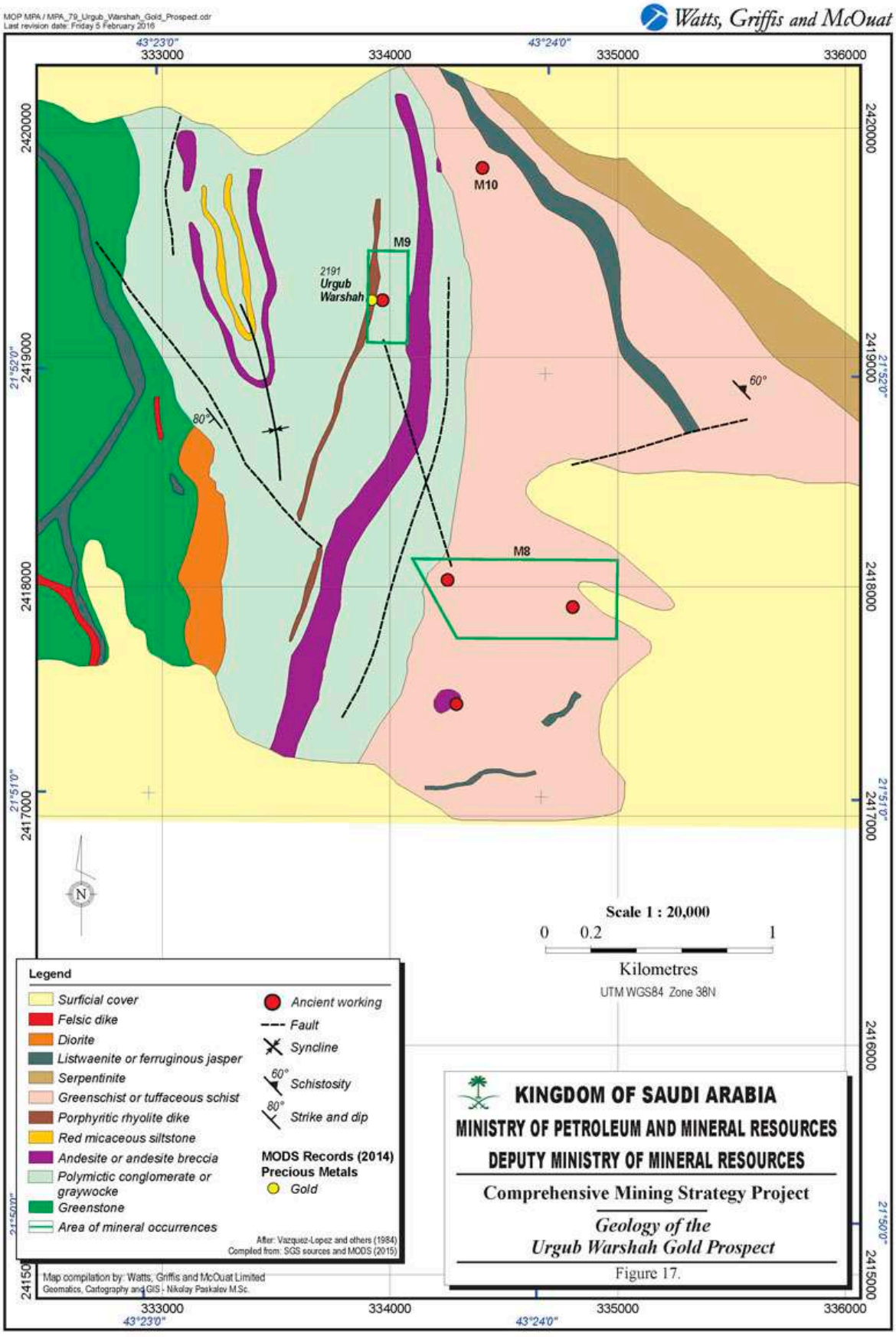
Comprehensive Mining Strategy Project
Geology of the
Jabal Hadah – Abar Warshah Area
Figure 16.
330000
335000
340000
2430000
2425000
2420000
22°0'0"
21°55'0"
43°25'0"
M7
M5
M6
M4
M3
M2
M1
M10
M9
M8
JABAL HATHAH WEST
JABAL HATHAH SOUTH
MURDAMA GROUP
URGHUB WURSHAH
2193 Jabal Hadah-NW
2192 Jabal Hadah
2194 Jabal Hadah-SE
1173 Abar Warshah
2191 Urgub Warshah
N
Scale 1 : 70,000
0 0.7 3.5
Kilometres
UTM WGS84 Zone 38N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
Legend
Surficial cover
Murdama Group
Conglomerate, greenschist
Graywacke
Ultramafic rocks
Andesite
Listwaenite
M1 Ancient working with reference number
Fault
Syncline
Anticline
MODS Records (2014)
Precious Metals
Gold
After: Vazquez-Lopez and others (1984)
Compiled from: SGS sources and MODS (2015)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Last revision date: Friday 5 February 2016
Watts, Griffis and McOuat
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43°24'0"
333000
334000
335000
336000
2420000
2419000
2418000
2417000
2416000
2415000
21°52'0"
21°51'0"
21°50'0"
M10
M9
2191
Urgub
Warshah
M8
60°
80°
N
Scale 1 : 20,000
0 0.2 1
Kilometres
UTM WGS84 Zone 38N
Legend
Surficial cover
Felsic dike
Diorite
Listwaenite or ferruginous jasper
Serpentinite
Greenschist or tuffaceous schist
Porphyritic rhyolite dike
Red micaceous siltstone
Andesite or andesite breccia
Polymictic conglomerate or graywocke
Greenstone
Area of mineral occurrences
Ancient working
Fault
Syncline
60° Schistosity
80° Strike and dip
MODS Records (2014)
Precious Metals
Gold
After: Vazquez-Lopez and others (1984)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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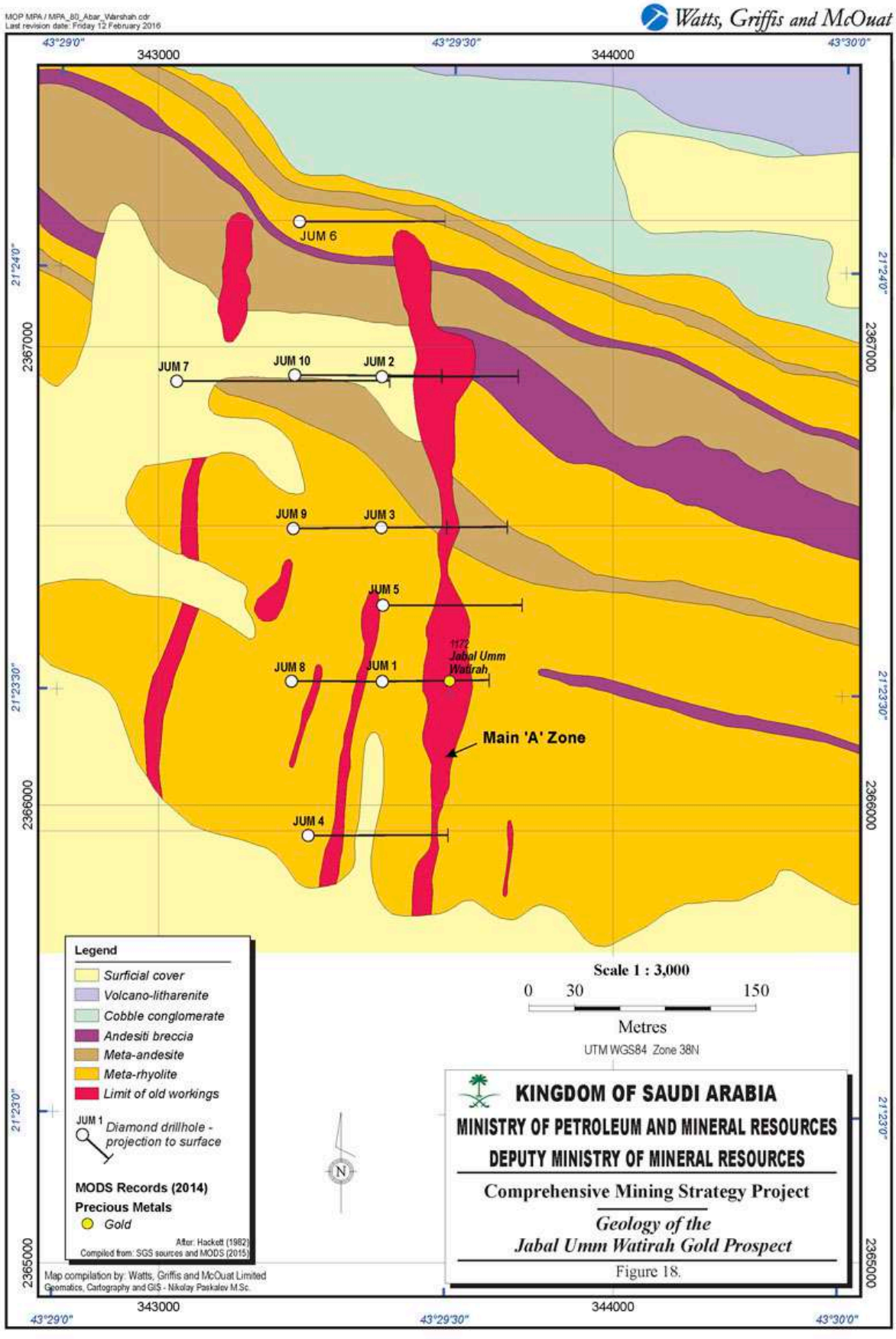
Geology of the
Urgub Warshah Gold Prospect
Figure 17.

The gold prospect at Dahlat Shabab is hosted in weakly metamorphosed Murdama group volcanic wacke, porphyritic andesite, andesitic tuff breccia and agglomerate. Gold-bearing quartz veins strike NNE to ENE and dip 60° to 70° to the NW, approximately normal to the orientation of the layered strata. The veins are white, massive to sheeted and generally range in thickness from 20 to 65 cm. Occurrences of quartz-veined breccia are also noted. The ancient workings have followed these veins for a maximum of 150 m, however the presence of irregularly distributed trenches along the trend of the veins suggests that they may continue for 500 m or more (Bishop, 1982). Five groups of veins are present, surrounded by strong but patchy propylitic alteration and lesser silicification and feldspathization in the adjacent country rocks (Howes, 1982). Gold assays from a variety of sampling programs suggest a substantial amount of vein-type mineralization grading between 10 g/t and 30 g/t. The Dahlat Shabab prospect was estimated to contain a resource of 210,000 t with an average gold content between 12 and 18 g/t (Worl, 1979). As this estimate is based solely on surface sampling without any drill hole evidence of continuity at depth, this estimate is not compliant with any current international regulatory standard.

The cluster of gold prospects in the Rayyaniyah-Zain West is located 40-50 km east of the end of the gold belt in the Dahlat Shabab area. WGM reviewed the area but could find no evidence for a structural connection to the Ad Duwayah-Dahlat Shabab Gold Belt. These occurrences appear to be isolated and possibly associated with the emplacement of granitic and tonalitic plutons. Zain West (3118) has been the most promising with gold contents as high as 105.6 g/t (3.08 oz/ton!), probably due to the presence of coarse nuggety gold. Several sampling programs have been completed with general agreement that the gold contents of quartz veins are in the range of 0.14 g/t to 16.55 g Au/t, however some large quartz bodies are barren. The mineralization has been attributed to extensional fracturing caused by Najd faulting. At the nearby Fahthan (Faathan) occurrence, veins contain an average of 6.7 g Au/t and 6.9 g Ag/t. There area is thought to be moderately interesting, but it has not yet been sufficiently explored to generate targets for drilling.

Recommendations

Trenching at Ad Duwayhi has shown that the bedrock is overlain by up to 6 m of surficial deposits, of which the lower two thirds is consolidated eluvium and the upper third is unconsolidated eolian sand and alluvium. Samples taken from the lowermost 30 m of alluvium contained a maximum of 4 g Au/t, and averaged 0.73 g Au/t (Elsass and others, 1982). The initial work on the main Ad Duwayhi prospect was methodical and documented the distribution of gold, and the petrography of the mineralization. With time, the problematic character of percussion drilling was revealed as continuing diamond drilling showed the earlier results to be unreliable. Then earlier assays were also compromised by inappropriate analytical procedures. Despite the short-comings of the work, WGM viewed Ad Duwayhi as a very promising exploration target. WGM's earlier assessment of the work also pointed to the fact that there had been inadequate attention paid to the abnormal abundance of gold occurrences and prospects


MOP MPA / MPA_80_Abar_Warshah.cdr
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
43°29'0"
343000
43°29'30"
344000
43°30'0"
21°24'0"
2367000
21°23'30"
2366000
21°23'0"
2365000
JUM 6
JUM 7
JUM 10
JUM 2
JUM 9
JUM 3
JUM 5
JUM 8
JUM 1
1122
Jabal Umm
Watirah
Main 'A' Zone
JUM 4
Legend
Surficial cover
Volcano-litharenite
Cobble conglomerate
Andesiti breccia
Meta-andesite
Meta-rhyolite
Limit of old workings
JUM 1
Diamond drillhole - projection to surface
MODS Records (2014)
Precious Metals
Gold
After: Hackett (1982)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
N
Scale 1 : 3,000
0 30 150
Metres
UTM WGS84 Zone 38N
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the
Jabal Umm Watirah Gold Prospect
Figure 18.

concentrated at Ad Duwayhi, a tectonically complex area distinguished by the presence of major faults and abundant intermediate intrusive rocks – an ideal setting for gold mineralization. WGM recommended additional regional exploration as part of a program of further work at the Ad Duwayhi prospect. WGM also recommended that the placer gold potential of the alluvium be evaluated through additional exploration. More recently, Snowden demonstrated that the RC holes almost invariably show a markedly smaller gold assay peak when compared against the corresponding diamond hole. It is suggested that that the RC holes are under-sampling the in-situ gold mineralisation, possibly as a result of losing the fine gold fraction contained along the small quartz veins and which are exposed and liberated by the action of the RC hammer (Snowden, 2011). Snowden expressed the view that significant potential exists to increase the resources at Ad Duwayhi through the down dip extension of the main vein and drilling on a nominal 100 m grid spacing.WGM continues to hold the opinion that the region surrounding Ad Duwayhi is very promising for additional discoveries and warrants continuing systematic exploration through detailed geological mapping, geochemical surveying, IP geophysical surveying where the presence of disseminated sulphides suggests it may be useful and reconnaissance diamond drilling.

The Khibbat Samhah and Khibbat Samhah South exploration has been inadequate to justify the BRGM's conclusion regarding low potential. Grab sampling has demonstrated that the two prospects contain anomalous concentrations of gold. The failure of the percussion drilling to yield assays comparable to the surface grab samples should not be interpreted to represent the degree to which the veins are mineralized. Canadian case histories have shown that the analysis of drill core rarely produces assay results which adequately represent the actual gold content of veins in the presence of coarse irregularly distributed gold. At the Giant Yellowknife Mine, Northwest Territories, Canada, the deposit was explored underground during 1945 when then grades were thought to be 14.1 g Au/t, however based on later production data, the grade was found to average 25.7 g/t (Dadson and Emery, 1968). There are many examples of these outcomes. Diamond drilling can only therefore indicate the relative degree to which a vein system is mineralized, and provide some indication of gold distribution. In respect to percussion drilling, as was used at the two Samhah prospects, the inherent ambiguities are significantly greater and therefore the analytical data even less of a reliable indicator. This drilling cannot be used as an absolute measure of economic potential. Given the favorable geologic setting of the Ad Duwayah-Samhah area and the bonanza gold grades found locally (>1,000 g/t), a potential for larger veins and disseminated wallrock mineralization must be considered, and further systematic exploration is warranted initially consisting of detailed mapping and channel sampling. If the veins or alteration zones surrounding the veins are found to contain several percent sulphide (pyrite), than IP surveying may be a useful tool for identifying drill targets at depth. All drilling should be diamond core drilling and all assaying for gold must be by the fire assay method.

The initial work in the Jabal Hadah-Abar Warshah was adequately carried out as it located and assessed the various ancient workings, and detected anomalous gold contents in the known quartz veins. Because assaying of grab samples from quartz veins generally results in the detection of irregular gold contents, the exploration to date is inadequate. Further systematic geologic and geochemical exploration, as described in the foregoing recommendations for the Ad Duwayah-Samhah area, is required to better delineate the mineralization in this highly prospective area.

At Jabal umm Watirah the initial work on the prospect adequately identified the ancient workings as gold-bearing auriferous and worthy of follow-up exploration. Over the years and successive exploration programs, a considerable amount of data was assembled on the geology, geochemistry and geophysical characteristics of the gold-bearing zones. Despite this, the relationship between the gold-bearing structures and regional geology should have been better defined. There is a distinct possibility that silica-encapsulated (refractory) gold may not have been dissolved during sample preparation utilizing the MIBK technique as described by Hackett, leading to under-reporting of gold contents. This problem is avoidable by using standard fire assaying procedures. The sampling of drill core across the alteration zone over short intervals is commendable, and aids greatly in the understanding of the geology of the mineralizing system. The report on drilling would be greatly enhanced if drill logs were included as the existing drill sections do not contain sufficient data to replace detailed lithology logs. WGM agrees that the wide, relatively higher grading gold mineralization adjacent to the quartz veins may indicate that the veins were emplaced into a previously mineralized structure. The gold in the veins may have been scavenged from the surrounding rocks. If true, then the veins should not be a major consideration in the exploration of this prospect. At the time of the initial resource estimate, there was insufficient drilling to warrant a resource estimate that is compliant with international standards. The geological resource reported by Hacket is interesting but probably meaningless and could potentially lead to the prospect being dismissed through inexperience as being too small to be of interest. The geophysical surveys produced useful data as attested to by the drill testing of various IP and EM anomalies, even considering the fact that the EM-16 survey was hampered by the use of transmitter station in an inappropriate geographic location. An examination of the raw data profiles indicates that some interpretative errors may have been made as a result of the manner in which the processed data were contoured. Thus, while the ‘A conductor' partly coincides with the main zone of veining, strong cross-overs between this and the ‘A1' conductor are formational responses along the east-southeast-striking andesite-rhyolite-conglomerate contact. The final three diamond drill holes targeted on VLF anomalies at Jabal umm Watirah were adequate to evaluate the ability of EM-16 surveying to detect quartz-veined zones. However, it is evident from the relatively low grades intersected in these holes, that the strength of an anomaly may have no bearing on gold mineralization. Because of their locations, these holes added very little to the overall understanding of the prospect, and did nothing to further test the higher grade section of the A-Zone. The most recent IP survey by the SGS was detailed in its approach using a 25 m "a" and collecting data from n=1 to n=6 across a 500 m section length, however the anomalies detected do not have pant-leg geometries typical of a dipole-dipole array and some anomalies are golf-ball shaped which are partially artefacts of the modelling software (Geosoft). The SGS concluded that one of the largest mineralized zones was detected, but other smaller zones were not, concluding that the electrode spacing may have been too wide. WGM reviewed the IP survey results as presented in the SGS report, and concluded that the data included a significant amount of noise generated at the time the readings were taken. This noise could have been reduced or eliminated through more diligent action by the equipment operators. As a structurally controlled deposit, the mineralization at Jabal umm Watirah may be irregular as can be seen in the drilling and therefore a substantial amount of drilling is needed to adequately define mineralized zones. In WGM’s view, RC drilling is unsuitable for drilling structurally complex deposits such as this due to the lack of structural information provided, and the potential for gold being smeared from

narrow high-grade zones. WGM believes that the large size of the structural system within which gold occurs warrants that the Jabal umm Watirah area be a focus for additional exploration. We also believe that the nature of the mineralization may change along strike as different lithologies are intersected. Exploration to date provides no explanation for the higher grade mineralization between sections 1400 N. and 1600 N. WGM's previous compilation of data on a longitudinal section demonstrated that higher-grade mineralization plunged along a zone representing the intersection between the A-Zone structure and the basalt-andesite unit. Given WGM's metallogenic model relating gold and sulphide to iron scavenging sulphur from hydrothermal fluids, it would be expected that host-rock lithology would have an impact on mineralization in terms of grade and thickness. This longitudinal section should be used to aid in the selection of follow-up drill sites. The A-Zone mineralization is considered to be open along strike and down plunge. Furthermore, any of the other eight mineralized structures may show significant improvement if explored in all dimensions. On the basis of the favorable geologic setting and strong mineralization of the area, the prospect warrants further exploration using a combination of detailed IP surveying and systematic, grid-based diamond core drilling. Future exploration should be budgeted on the basis of several years of dedicated drilling and several hundred drill holes.

The current exploration at Dahlat Shabab adequately demonstrates that the prospect is mineralized at a level (12 to 18 g Au/t) that is economically significant. Without drill hole evidence showing continuity, the USGS resource estimate must be considered indicative only, however it is surprising to WGM that follow-up work has not been carried out. The prospect is at a preliminary exploration stage. Although the sampling has been extensive, the nature of the sampling is not systematic and the reported grades may not be representative of the average grade of the prospect. The presence of ancient workings, the high grades found in waste rock and the assays to date strongly indicate the presence of gold mineralization that is coarse, nuggety and irregularly distributed. WGM recommends that additional exploration be carried out to systematically map the veins and the alteration patterns surrounding them. Sulphide contents need to be assessed to the extent that the usefulness can be determined of IP surveying to trace the veins at depth for the purpose of targeting drill holes. Finally, the prospect is sufficiently interesting to warrant diamond core drilling with a minimum budget sufficient for 10 holes – say 2,500 m of drilling.

The best gold prospect in the Rayyaniyah-Zain area appears to be the Zain West prospect. No work beyond reconnaissance mapping and sampling has been completed. Before any additional work is carried out, the prospect must be mapped in detail at 1:5,000 scale. Trenches should be excavated on the major veins to allow for detailed mapping and systematic channel sampling. Given the presence of coarse, irregularly distributed gold, relatively large 2-3 kg samples should be collected for analysis and 500 gram samples should be pulverized in preparation for screened fire assaying, the method of choice for nuggety gold. If it can be demonstrated that gold mineralization is continuous, more or less, then additional exploration should be carried out in support of a drilling program. IP surveying might be useful in delineating quartz veins, silicified zones or sulphide-bearing zones at depths of 100-200 m. The best targets should be drill tested with a minimum budget sufficient for 2,000 m of diamond core drilling.

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3.1.3.8 The Nabitah Gold Belt – Bishah Segment

Location, Distribution of Occurrences and History

The Bishah Segment of the Nabitah Gold Belt is approximately 175 km in length and strikes approximately north-south (Figure 19). The northern end of the gold belt, as defined herein, is marked by the northwest-trending Rawah Fault, a Najd Fault that dislocates the northern continuation of the gold belt in a left-handed manner towards the northwest. The Jabal Dalfa Au-Ag prospect (MODS 1444) is situated about 35 km ESE of Ranyah marking the northern end of the Bishah Segment of the Nabitah Gold Belt. The gold belt extends approximately north-south to its southern limit marked by the Wadi Ath Thifan occurrences (2708 and 2711) and the Jabal Hubayyah SE Occurrence (1445). An additional 20 gold occurrences are found along this segment of the Nabitah Fault Zone between these two end points (Table 16).

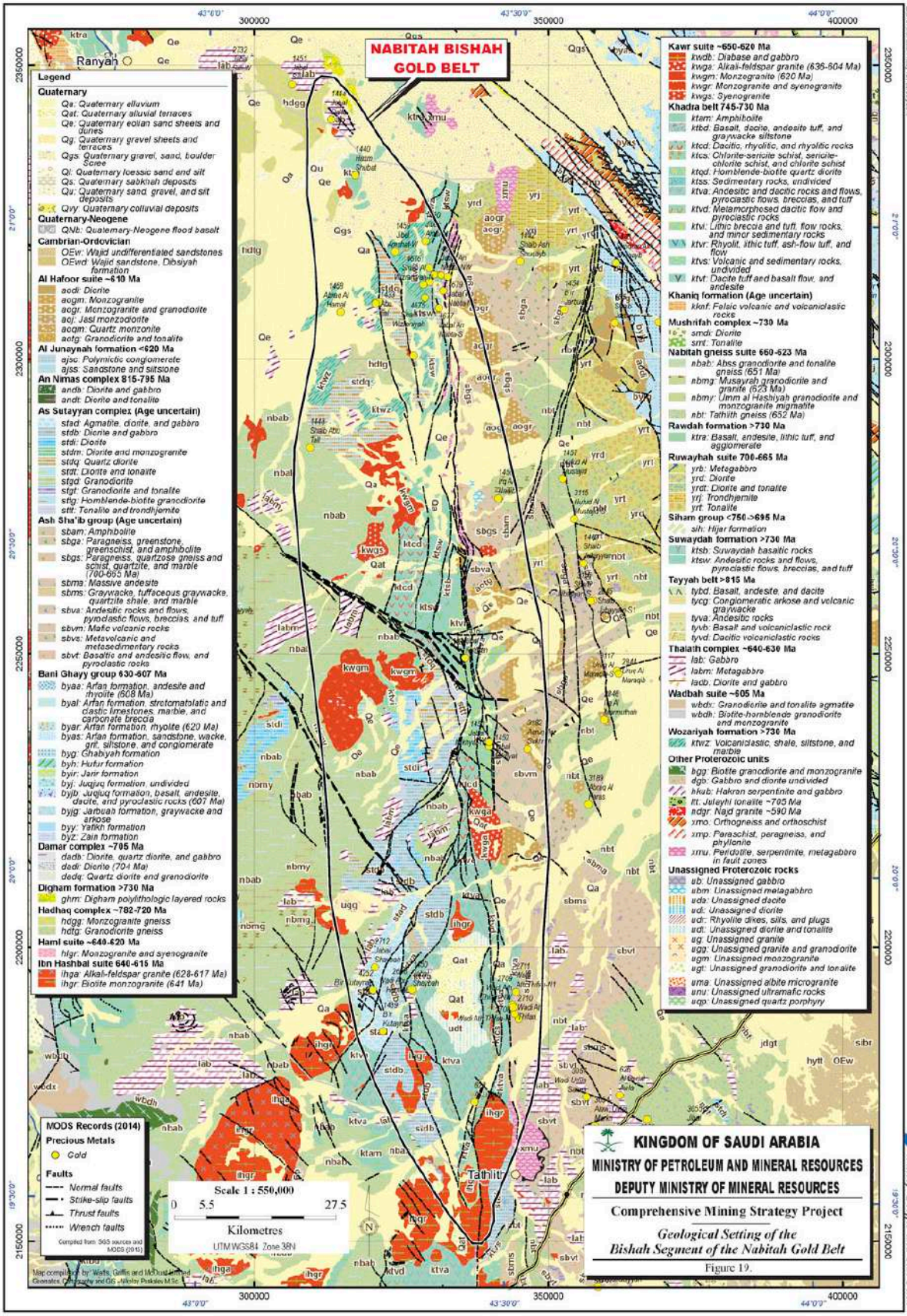
At the northern end of the belt, the Hazm Shubat ancient workings on milky quartz veins are associated with a quartz breccia zone 1,000 m long and approximately 5 m wide. The initial five samples collected by the USGS produced gold values between 0.7 and 23 g/t (Worl, 1977). During 1984, the SGS carried out ground magnetic, VLF-EM and Genie EM (horizontal loop electromagnetic) surveys using a 50 x 50 m grid within an area of 1 km by 0.5 km outlining two conductive zones possibly related to a mafic intrusion. Five diamond drill holes were recommended, however it is uncertain if these holes were completed.

Table 16
Name and Location of Gold Occurrences – Nabitah Gold Belt – Bishah Segment, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
1444	Jabal Dalfa	Jabal Dalfa	Gold	43.1997220	21.1583610	Ranyah	VL	v
1440	Hazm Shubat	Chaim	Gold-Silver	43.2402500	21.0733890	Ranyah	VL	v
1460	Jibal Amshat	Umm Shat Sharq	Gold-Silver	43.3559440	20.9732500	Ranyah	Med	v
1459	Jibal Amshat-W	Umm Shat Gharb	Gold	43.3064440	20.9563890	Ranyah	Med	v
4673	Jabal As Suwayda-SE	Jabal As Suwayda-SE	Gold	43.3703610	20.9218890	Ranyah	Low	v, shears

4678	Jabal An Nabta-NW	Jabal Nabitah	Gold	43.3819720	20.9214170	Ranyah	Low	v
4679	Jabal An Nabta-NE	Jabal Nabitah	Gold	43.3935830	20.9188610	Ranyah	Low	v
1449	Jabal An Nabta	Jabal Nabitah	Gold	43.3856390	20.8971670	Ranyah	Low	v
4675	Shaib Al Wizraniyah	Shaib Al Wizraniyah	Gold	43.3561390	20.8862780	Ranyah	Low	v
0651	Jabal Ishshimas	Jabal Ishshimas	Gold	43.2804170	20.8784720	Ranyah	Low	v
1433	Abu Tal	Abu Tal	Gold	43.2752500	20.8763610	Ranyah	VL	v
4677	Jabal An Nabta-S	Jabal Nabitah	Gold	43.3791670	20.8707220	Ranyah	Low	v
1458	Abraq Al Hamal	Ishmas Kabir	Gold	43.2186940	20.8629170	Ranyah	Med	v, dd
1447	Jabal Ishmas-SE	Jabal Ishmas-SE	Gold	43.3387500	20.7970830	Ranyah	Low	v
1448	Shaib Abu Tall	Jabal Kattab	Gold	43.1711940	20.6542500	Ranyah	VL	v
1456	Irq An Naqib	Najeeb	Gold	43.4790280	20.5790280	Ranyah	Med	v
1436	Jibal Kutman	Bani Qutman	Gold	43.4273890	20.3346670	Bishah	Med	v, dd
1453	Jabal Mikhyat-N	Jabal Mokhyat-N	Gold	43.4681940	20.2055000	Bishah	Med	v
1452	Jabal Mikhyat	Jabal Mokhyat	Gold	43.4683610	20.1985560	Bishah	Med	v
3182	Aqrun As Sukhrah	Jabal Sohra	Gold	43.5303610	20.1955000	Bishah	Med	v
3189	Abraq Al Faras	Hafiyah Janoob	Gold	43.6303610	20.1112780	Bishah	VL	v
2711	Wadi Ath Thifan-N1	Wadi Ath Thifan-N1	Gold	43.5151390	19.8214170	Bishah	Med	v
2708	Wadi Ath Thifan-N	Wadi Ath Thifan-N	Gold	43.5136110	19.7882780	Bishah	Med	v
1445	Jabal Hubayyah-SE-E	Jabal Hubayyah-SE-E	Gold	43.5196670	19.7800000	Bishah	VL	v
0628	Al Lutaga	Al Lutagah	Gold	43.4494440	19.6522500	Bishah	VL	v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins


NABITAH BISHAH
GOLD BELT
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qgs: Quaternary gravel, sand, boulder Seree
Ql: Quaternary loessic sand and silt
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Qvy: Quaternary colluvial deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Cambrian-Ordovician
OEw: Wajid undifferentiated sandstones
OEwd: Wajid sandstone, Dibsiyah formation
Al Hafoor suite ~610 Ma
aodi: Diorite
aogm: Monzogranite
aogr: Monzogranite and granodiorite
aoj: Jasl monzodiorite
aoqm: Quartz monzonite
aotg: Granodiorite and tonalite
Al Junaynah formation <620 Ma
ajsc: Polymictic conglomerate
ajss: Sandstone and siltstone
An Nimas complex 815-795 Ma
andb: Diorite and gabbro
andt: Diorite and tonalite
As Sutayyan complex (Age uncertain)
stad: Agmatite, diorite, and gabbro
stdb: Diorite and gabbro
stdi: Diorite
stdm: Diorite and monzogranite
stdq: Quartz diorite
stdt: Diorite and tonalite
stgd: Granodiorite
stgt: Granodiorite and tonalite
stg: Hornblende-biotite granodiorite
sttt: Tonalite and trondhjemite
Ash Sha'ib group (Age uncertain)
sbam: Amphibolite
sbga: Paragneiss, greenstone, greenschist, and amphibolite
sbgs: Paragneiss, quartzose gneiss and schist, quartzite, and marble (700-695 Ma)
sbma: Massive andesite
sbms: Graywacke, tuffaceous graywacke, quartzite shale, and marble
sbva: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
sbvm: Mafic volcanic rocks
sbvs: Metavolcanic and metasedimentary rocks
sbvt: Basaltic and andesitic flow, and pyroclastic rocks
Bani Ghayy group 630-607 Ma
byae: Arfan formation, andesite and rhyolite (608 Ma)
byal: Arfan formation, stromatolatic and clastic limestones, marble, and carbonate breccia
byar: Arfan formation, rhyolite (620 Ma)
byas: Arfan formation, sandstone, wacke, grit, siltstone, and conglomerate
byg: Ghabiyah formation
byh: Hufur formation
byir: Jarir formation
byj: Juqjuq formation, undivided
byjb: Juqjuq formation, basalt, andesite, dacite, and pyroclastic rocks (607 Ma)
byjg: Jarboah formation, graywacke and arkose
byy: Yafikh formation
byz: Zain formation
Damar complex ~705 Ma
dadb: Diorite, quartz diorite, and gabbro
dadi: Diorite (704 Ma)
dadq: Quartz diorite and granodiorite
Digham formation >730 Ma
ghm: Digham polylithologic layered rocks
Hadhaq complex ~782-720 Ma
hdgg: Monzogranite gneiss
hdtg: Granodiorite gneiss
Haml suite ~640-620 Ma
hlgr: Monzogranite and syenogranite
Ibn Hashbal suite 640-615 Ma
lhga: Alkali-feldspar granite (628-617 Ma)
lhgr: Biotite monzogranite (641 Ma)
Kawr suite ~650-620 Ma
kwdb: Diabase and gabbro
kwga: Alkali-feldspar granite (636-604 Ma)
kwgm: Monzogranite (620 Ma)
kwgr: Monzogranite and syenogranite
kwgs: Syenogranite
Khadra belt 745-730 Ma
ktam: Amphibolite
ktbd: Basalt, docite, andesite tuff, and graywacke siltstone
ktcd: Dacitic, rhyolitic, and rhyolitic rocks
ktcs: Chlorite-sericite schist, sericite-chlorite schist, and chlorite schist
ktqd: Hornblende-biotite quartz diorite
ktss: Sedimentary rocks, undivided
ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
ktvd: Metamorphosed dacitic flow and pyroclastic rocks
ktvl: Lithic breccia and tuff, flow rocks, and minor sedimentary rocks
ktvr: Rhyolit, lithic tuff, ash-flow tuff, and flow
ktvs: Volcanic and sedimentary rocks, undivided
ktvt: Dacite tuff and basalt flow, and andesite
Khaniq formation (Age uncertain)
kknf: Felsic volcanic and volcaniclastic rocks
Mushrifah complex ~730 Ma
smdi: Diorite
smt: Tonalite
Nabitah gneiss suite 660-623 Ma
nbab: Abss granodiorite and tonalite gneiss (651 Ma)
nbmg: Musayrah granodiorite and granite (623 Ma)
nbmy: Umm al Hashiyah granodiorite and monzogranite migmatite
nbt: Tathlith gneiss (652 Ma)
Rawdah formation >730 Ma
ktra: Basalt, andesite, lithic tuff, and agglomerate
Ruwayhah suite 700-665 Ma
yrb: Metagabbro
yrd: Diorite
yrdt: Diorite and tonalite
yrj: Trondhjemite
yrt: Tonalite
Siham group <750->695 Ma
slh: Hijar formation
Suwaydah formation >730 Ma
ktsb: Suwaydah basaltic rocks
ktsw: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
Tayyah belt >815 Ma
tybd: Basalt, andeste, and dacite
tycg: Conglomeratic arkose and volcanic graywacke
tyva: Andesitic rocks
tyvb: Basalt and volcaniclastic rock
tyvd: Dacitic volcaniclastic rocks
Thalath complex ~640-630 Ma
lab: Gabbro
labm: Metagabbro
lacb: Diorite and gabbro
Wadbah suite ~605 Ma
wbdx: Granodiorite and tonalite agmatite
wbdh: Biotite-hornblende granodiorite and monzogranite
Wozariyah formation >730 Ma
ktwz: Volcaniclastic, shale, siltstone, and marble
Other Proterozoic units
bgg: Biotite granodiorite and monzogranite
dgb: Gabbro and diorite undivided
hkub: Hakran serpentinite and gabbro
ltt: Juleyhi tonalite ~705 Ma
ndgr: Najd granite ~590 Ma
xmo: Orthogneiss and orthoschist
xmp: Paraschist, paragneiss, and phyllonite
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
uda: Unassigned dacite
udi: Unassigned diorite
udr: Rhyolite dikes, sills, and plugs
udt: Unassigned diorite and tonalite
ug: Unassigned granite
ugg: Unassigned granite and granodiorite
ugm: Unassigned moazogranite
ugt: Unassigned granodiorite and tonalite
uma: Unassigned albite microgranite
uru: Unassigned ultramafic rocks
uqp: Unassigned quartz porphyry
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Strike-slip faults
Thrust faults
Wrench faults
Compiled from: SGS sources and MODS (2015)
Scale 1 : 550,000
0 5.5 27.5
Kilometres
UTM WGS84 Zone 38N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Bishah Segment of the Nabitah Gold Belt
Figure 19.
Watts, Griffis and McOuat

Also in the northern part of the belt, the Jibal Amshat and Jibal Amshat West prospects (formerly Umm Shat Sharq and Umm Shat Gharb) comprise 12 diversely oriented ancient workings scattered across a 2 km^2 area. Of 20 one-metre long channel samples taken across the veins at Jibal Amshat West, only one gave an interesting gold value: 6.8 g/t. Dump samples assayed 2.6 g Au/t. The USGS remapped the prospects in 1976 at a scale of 1:1,000 and three new trenches were excavated. Of 22 channel samples taken across and along the main vein zone, one returned 5.8 g Au/t but most contained less than 0.6 g/t. The potential gold resource was estimated by Worl to be 75,560 t at 10 to 14 g/t. Subsequent mapping and sampling produced very different results with values as high as 10.0 g Au/t within the vein and elevated Au, As, and Mo values within the wall rock. The importance of NE-trending structures appears to have been enhanced, possibly as a result of the newly recognized metallogenic role of the Nabitah Fault Zone. Diamond drilling was recommended. The SGS completed ground magnetic, VLF-EM, and HLEM (Genie) surveys in 1983-84 on a 50 m by 50 m grid. The VLF-EM and HLEM surveys both showed that the vein zone beneath the ancient working was conductive, and extended northwards for 200 m. During 1988 the USGS drilled five very shallow diamond core and percussion holes (390.3 m) on three 100 m profiles to test the main vein. Gold values were lower than expected; the best was 1,000 ppb over 1.5 m (Walker et al, 1989). Exploration at Jibal Amshat produced similar results.

At the Jabal As Suwayda-SE prospect, gold-bearing quartz veins occur within sheared felsic volcanic rocks within a N-trending shear zone that dips 70°W that can be traced over a strike length of 12 km. The prospect was discovered by the USGS in 1986 during 1:250,000 scale regional mapping, and it was mapped in detail at that time. Five chip sample traverses across sericitized wall rock at the margins of the vein showed very low gold values with a strong arsenic association with minor copper and molybdenum values. For unknown reasons, no vein quartz was assayed but further work was recommended on the pyrite-sericite shear zone which is up to 35 m wide.

At the Abraq Al Hamal prospect, formerly known as Ishmas Kabir, an ESE-striking NNW-dipping zone of brecciated quartz-carbonate vein is hosted in sheared diorite striking. Ancient workings are found over a strike length of 530 m. The SGS carried out the first recorded sampling in 1963 with gold assays as high as 29 g/t with 12 g Ag/t over a length of 33.5 m. The sampling method is unknown, and the samplers may have been selective in what they collected over a 518 m length of the zone. The USGS re-evaluated the prospect in 1976 with detailed geological mapping and the excavation of three trenches (110 m). One selected chip sample from the vein returned 18.5 g Au/t, and mine dump samples also showed interesting values. No specific trench sample assays were reported. The potential mineral resource was estimated at 207,000 t grading 14-30 g/t Au to a depth of 265 m (Worl, 1979). Subsequent ground magnetic, VLF-EM, and HLEM (Genie) surveys in 1986 used a 50 m by 50 m grid for control. The EM surveys detected the vein zone below the ancient workings, and indicated possible extensions. Four diamond drill holes (420 m) were recommended to test the conductive zones (Last and others, 1988). In 1988 the USGS tested the zone with four diamond drill holes (1,023 m) on sections 100 and 200 m apart. The drilling showed no continuity of structure or of the vein below the workings, and gold values were much lower than expected (a maximum of 1.6 g/t over 0.33 m). Although results were disappointing the work showed that gold occurs

with limonite within oxidized veins and within quartz-sericite alteration zones at the margins of the vein. No further work was recommended (Walker et al, 1989).

The Jibal Kutman prospect (1436), formerly known as Bani Qutman, lies within the north-trending Nabitah fault zone. Mineralization is associated with a discontinuous series of north-trending quartz veins up to 2 m wide within a zone marked by ancient workings approximately 400 m long. Initial grab samples collected from ancient mine dumps during 1979 by the USGS contained as much as 3.54 g Au/t (Worl, 1979). Worl estimated that the resource potential of the prospect was 60,750 t averaging between 6 and 9 g Au/t. Composite dump samples collected during follow-up geological mapping (1:2,000 scale) and sampling by the USGS in the early 1980s assayed as high as 27 g Au/t. Three very short diamond drill holes totaling 349 m were completed in 1980. The results of this drilling are not reported, however the fact that very little exploration was done in this area afterwards suggests that the results were not interesting. The area is not mentioned in the report by Ian Clegg entitled "A Compilation of Prospects Drilled by the DMMR and the Private Sector, 1366-1404 (1936-1984)" published in 1985. No mention is made of additional work by WGM in its 1992 review report entitled "Extent, Status & Adequacy of Mineral Exploration in the Southern Arabian Shield" (1992), although WGM stated: "Drill testing of selected veins and any geophysically or geochemically anomalous areas is recommended at a maximum of 50 m intervals. Experience in the Canadian shield has shown that this will require about 2,500 m of core drilling". An exploration licence covering the Jibal Kutman area was taken out by Kefi Minerals ("**Kefi**") in 2012 under a joint venture with Abdul Rahman Saad Al-Rashid & Sons Company Limited. According to Kefi, the previous drilling the best results of the previous drilling included 5 m at 5.2 g Au/t and 90 g Ag/t (with highlights of 0.5 m at 13.0 g Au/t and 180 g Ag/t, 0.4 m at 12.5 g Au/t and 173 g Ag/t); and 1.6 m at 6.8 g Au/t and 66 g Ag/t. However, as this was not wire-line drilling, core recoveries of only 15% were the norm. After Kefi's initial geological mapping, the first phase of 50 diamond drill holes (4,569 m) was completed with holes on 50 m sections spaced between 25 m and 40 m on each section, very much as previously recommended by WGM. This drilling identified two new zones of mineralisation called the South and West Zones in addition to the original Main Zone. Drilling has continued since that time with a combination of core drilling and RC drilling. In May, 2013 KEFI released a maiden JORC resource for Jibal Kutman of 312,532 oz of gold at 0.94 g/t. Of this 207,988 oz at 0.89 g Au/t was in the West Zone, 51,328 oz at 0.81g Au/t was in the South Zone and 53,328 oz at 1.55 g Au/t in the Main Zone. An updated ore resource was published in a news release on 14 September, 2015 indicating a JORC-compliant global resource of 28.4Mt grading 0.8 g Au/t of which 6.6 Mt grading 0.95 g Au/t will be mined as an open pitable oxide resource and heap-leached to produce 28,000 oz of gold per year from 2018 onwards.

Fifteen (15) kilometres SSE of Jabal Qutman, the Jabal Mikhyat and Jabal Mikhyat North prospects (MODS 1552 and 1453), formerly known as Jabal Mokhyat, are associated with ancient mine workings both in bedrock and in alluvium. The initial sampling resulted in gold assays as high as 92 g/t in quartz material (Schull, 1993). It was estimated that ancient miners may have worked an area of 40-60 ha for alluvial gold where it was reported that samples of wadi gravel carry 1 g of gold per cubic metre, however comprehensive follow-up sampling during 1973 failed to reproduce the earlier claims. Bedrock sampling showed that 17 samples out of 97 carried in excess of 1 g Au/t. Riofinex sampled ancient mine dumps in 1982 and the

USGS resampled in 1989. One sample with visible gold assayed 180 g/t however most samples carried less than 1 g/t. During 1993, the USGS carried out additional reconnaissance-type prospecting resulting in 140 samples, only 13 of which assayed higher than 0.05 g Au/t (highest was 10.3 g/t). The USGS estimated a local bedrock resource of 25,000 ounces of gold and recommended 500 m of shallow RC-percussion drilling. The resource estimate is based on many assumptions for which there is little supporting evidence. At the same time, the USGS assessed the alluvial gold potential by collecting two large (66 and 64 kg) samples which were sieved and then processed to create a concentrate that was then cyanide leached using 500 g splits – no gold was detected. During 2005, the SGS carried out a reconnaissance of the site and confirmed that the gold mineralization was associated with chalcopyrite, galena, sphalerite and pyrite, and that it was metallogenically related to the Nabitah Fault Zone. The SGS also assessed the potential for alluvial gold in the area due to the presence of many ancient gold placer mines. These workings were first report by Schmidt et al (1981) on the basis of 728 samples taken by the USGS from pits and trenches 2.5 m in depth. The average gold content was reported to be 4.4 mg/m^3 and the highest grading areas contained 40 mg/m^3. The USGS reported that the ancient placer diggings, worked approximately 2,600 years ago, are located in small headwater wadis distributed over a 30 km^2 area with an aggregate area of approximately 1.2 km^2. It was estimated that the workings produced 50 kg of gold in total. The USGS concluded that the potential for a present-day placer gold operation is very poor. USGS geologists returned to the Jabal Mokhyat prospects, Bookstrom in 1992 and Schull in 1993. In the report the two authored, Schull mostly deals with the bedrock geology of gold-bearing “buck” quartz veins – only 8 samples out of 139 assayed greater than 0.5 g Au/t. Many of these were north-south trending, and apparently associated with Nabitah shearing. The highest gold assay was 10.3 g/t in white milky crystalline quartz. Schull estimated that a near surface resource of 25,000 ounces of gold might be present at a grade of 3 g/t and gave a low-priority recommendation for 500 m of shallow RC-percussion drilling to test the main gold-bearing vein. Bookstrom re-examined the ancient alluvial gold workings and collected two 65 kg samples each of which was visually searched for gold nuggets, and then processed through a Knelson concentrator and then heavy liquids to concentrate the heavy minerals. The concentrates were visually examined for gold nuggets and only one small nugget was recovered from one of the samples. Based on the weight of the nugget, the grade of the original sample was 0.02 g Au/t (20 ppb). The USGS also collected 32 10 kg samples from which a 500 g split was cyanide leached to test for the presence of gold of any grain size. No gold was detected in any of the samples indicating that the ancient placer miners recovered nearly all of the gold of the Jabal Mokhyat placers, or there was very little to recover in the first place. Bookstrom concluded the ancient tailings had no potential for redeveloped as a source of gold.

Near the southern end of the gold belt, the Wadi Ath Thifan-N and Wadi Ath Thifan-N1 (Thafan) ancient mine sites (MODS 2711 and 2708) were the subject of reconnaissance sampling by the SGS during 2005. Most of the workings are quite small (less than 5 m x 10 m). The samples taken by the SGS included 10 quartz and “chert”, samples that carried gold contents ranging from trace levels to 11.4 g/t (2.4 g/t average). A strong association was noted between gold, silver and copper, with the same sample set carrying an average of 34 ppm Ag (max. 153 ppm Ag) and 546 ppm Cu (max. 1733 ppm Cu).

Approximately 80 km along strike to the south of Jibal Kutman, the mineralization at the Al Lugata (Lugatah) prospect (0628) represents the southern end of the Bishah Segment of the Nabitah Gold Belt. At this point,

the Nabitah Fault Zone merges with the suture between the Nabitah and Asir terranes. The site was first visited in 1957 however the first modern results were reported by Overstreet (1978) who sampled the prospect in 1965 during the course of regional geological mapping. The USGS mapped the prospect in detail (1:1,000 scale) during 1976 and collected 64 samples (dump, grab, and channel) from the ancient workings as reported by Worl (1979), who estimated that the prospect contained 19 Mt of potentially mineralized material averaging 2.5 g Au/t. The USGS expressed the view that the Al Lugata prospect was one of the two best gold prospects within the entire area bordering the Asir and Tathlith terranes. Additional exploration was recommended by both the USGS and subsequently by WGM (1992) to identify additional resources. During the period 2001 to 2004, the SGS carried out exploration comprising detailed geological mapping, topographic surveying, trenching and drilling. In 2003, electrical resistivity surveying was tested on two profile lines to determine the location and possible extent of the shear zone and associated quartz veins. A magnetic survey was also completed over the whole area for the same purpose. High conductivity anomalies were found on both profiles, confirming the existing vein systems, however the there was no apparent response to many of the other sub-parallel vein systems that were known from previous drilling. The SGS drilling program undertaken during the period 2003-2004 resulted in a total of 24 diamond drill holes totalling 2,287.8 m. A total of 450 samples were analyzed for gold, copper, lead, zinc and silver. The method of gold analysis was not reported. Based on its work, the SGS estimated that the Lugata deposit contained an Indicated Resource of 414,126 tonnes grading 5.10 g Au/t at a cut-off grade of 0.3 g/t, together with Inferred Resources estimated to be 6,667,941 tonnes grading 4.5 g Au/t. The total gold resource is thought to be slightly in excess of 1 million ounces. WGM has no record of additional work at Al Lugata since that time. Given present international standards for classifying mineral resources, it is doubtful that the SGS estimates would qualify as more than Inferred because 24 shallow holes are insufficient to demonstrate continuity in the geology and mineralization even allowing for the fact that the zone is not steeply dipping.

Geology

The Hazm Shubat mineralization consists of milky quartz with minor pyrite, galena, hematite and malachite. The miners exploited a quartz breccia zone 1,000 m long and approximately 5 m wide within calcareous amphibolite.

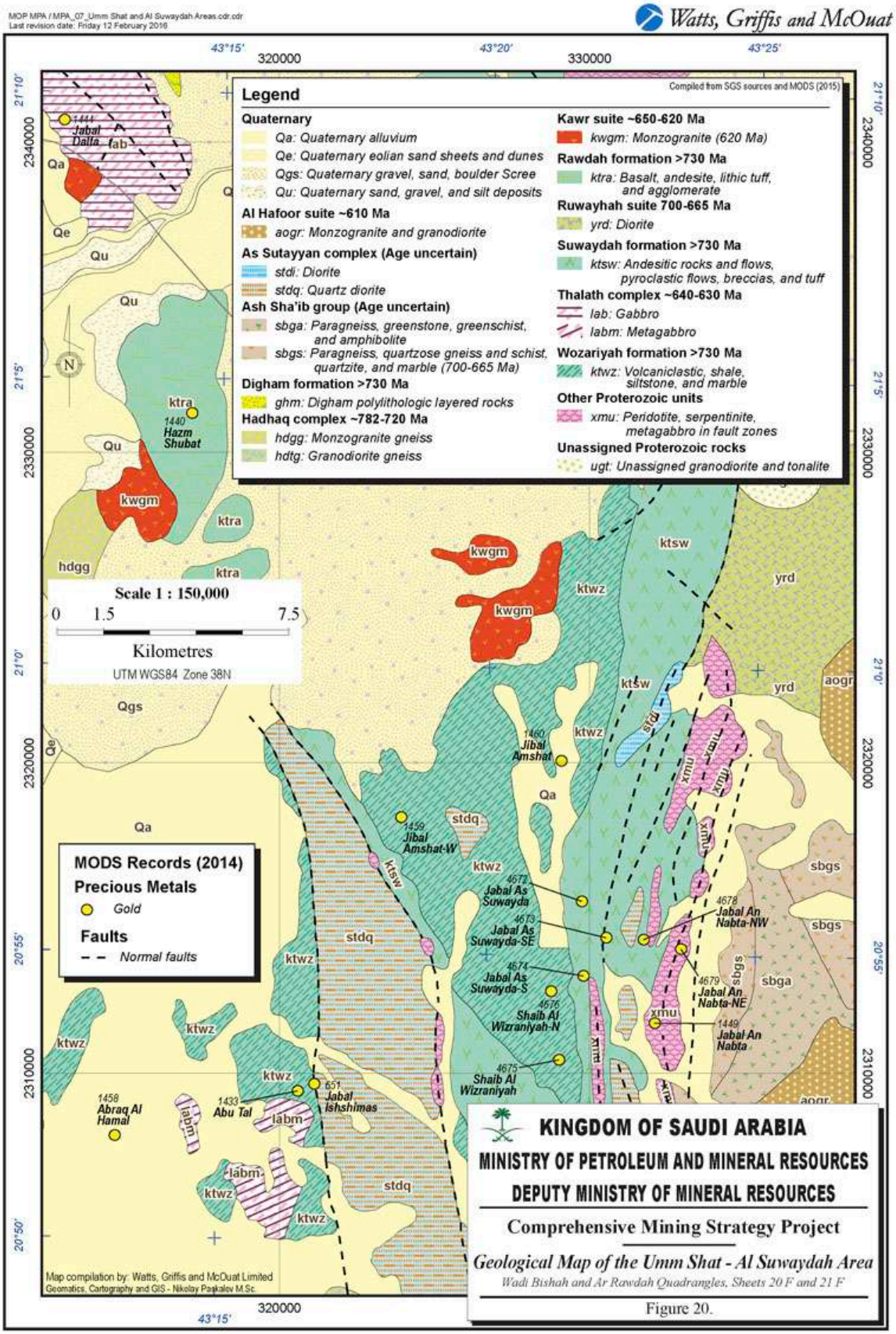
Gold at the Jibal Amshat occurs with pyrite, galena, and chalcopyrite in quartz veins and vein zones within a fractured and sheared monzodiorite. Two types of gold-bearing structures were identified: gently N-dipping, NNE to E striking ferruginous fault zones with milky quartz, and steeply dipping breccia zones with quartz and calcite. The ferruginous quartz veins occur within secondary faults. The main breccia zones have been traced for 2.2 km within the intrusion on a WNW trend that may be Najd related. In general, gold contents were low, however no attention appears to have been given to the pyrite-chlorite-calcite alteration of the monzodiorite which is associated with the veins.

The Jabal As Suwayda-SE gold-bearing quartz veins occur within a north-trending pyrite-sericite shear zone that is up to 35 m wide. As part of the Nabitah Fault Zone, the structure is regional in scale (Figure

20). The alteration associated with gold mineralization shows an arsenic association, however the amount of quartz in the shear zone is not well reported. The exploration to date has been spotty and so little is known about the distribution of gold in the zone. The structure is clearly part of the Nabitah deformation zone. Similar geology occurs at Abraq Al Hamal where an ESE-striking NNW-dipping sericite-carbonate-pyrite alteration zone encloses brecciated quartz-carbonate veins. The host rock is sheared diorite, and gold occurs in association with pyrite, chalcopyrite and minor galena in the quartz veins and to a lesser extent in the altered rocks. Ancient workings are found over a strike length of 530 m.

The Bani Qutman prospect (1436) lies within the N-trending Nabitah fault zone where the zone cuts a sequence of intermediate to felsic tuffs with minor sedimentary interbeds. Mineralization occurs in several areas along the Nabitah structure and is associated with a discontinuous series of north-trending quartz veins up to 2 m wide within a zone marked by ancient workings approximately 400 m long (Figure 21). The veins contain minor pyrite and are enveloped by siliceous and propylitic alteration zones. Samples from mine dumps contained as much as 27 g Au/t. The USGS estimated that the resource potential of the prospect was 60,750 t averaging between 6 and 9 g Au/t (Worl, 1979). Three very short diamond drill holes totaling 349 m were completed in 1980, the results of which are uncertain. Drill core recoveries were poor. Kefi Minerals has substantially added to the value of the project with the discovery of additional zones now totaling 28.4 Mt at an average grade of 0.8 g Au/t. The geological setting of the deposit on the Nabitah Fault Zone has not changed significantly since its discovery.

The Jabal Mikhyat and Jabal Mikhyat North (Jabal Mokhyat) prospects are located on the main structural trend of the Nabitah belt, and are composed of a complex arrangement of microfractured quartz veins and alteration in a zone 200 m or more long and up to 30 m wide. The host rocks comprise greenstone (felsic to mafic metavolcanic rocks), volcaniclastic rocks, carbonate and silica-rich metasedimentary rocks. The quartz is milky white and locally Fe-stained as a result of the oxidation of 1 mm pyrite veinlets. Visible gold is rare. The veins are gently dipping to sub-horizontal, N-trending and up to 2 m wide. Although veins are widespread and many sampling programs have been completed by the USGS, only a small percentage of samples assayed above trace levels for gold (>0.05 g/t) with the highest value being 10.3 g/t. A few samples with visible gold gave higher grade assays typically in the range of 9-10 g/t, however these were relatively rare (1% of the population). The alluvial gold potential of the Jabal Mikhyat area has been tested several times by the USGS, and each time the grades in alluvium or in ancient mine tailings have been too low to be commercially interesting. Although the original samples suggested an average gold content of 4.4 mg/m^3 and as much as 40 mg/m^3 locally, the most recent USGS tests by Bookstrom, the first on two 65-kilogram samples and the second on a group of 32 10-kilogram samples, generally showed no detectable gold above trace amounts. Bookstrom concluded that the ancient mine tailings have no potential to be redeveloped as a source of gold (Schull, 1993).


MOP MPA / MPA_07_Umm Shat and Al Suwaydah Areas.cdr.cdr
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
Compiled from SGS sources and MODS (2015)
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Qgs: Quaternary gravel, sand, boulder Scree
Qu: Quaternary sand, gravel, and silt deposits
Al Hafoor suite ~610 Ma
aogr: Monzogranite and granodiorite
As Sutayyan complex (Age uncertain)
stdi: Diorite
stdq: Quartz diorite
Ash Sha'ib group (Age uncertain)
sbga: Paragneiss, greenstone, greenschist, and amphibolite
sbgs: Paragneiss, quartzose gneiss and schist, quartzite, and marble (700-665 Ma)
Digham formation >730 Ma
ghm: Digham polylithologic layered rocks
Hadhaq complex ~782-720 Ma
hdgg: Monzogranite gneiss
hdtg: Granodiorite gneiss
Kawr suite ~650-620 Ma
kwgm: Monzogranite (620 Ma)
Rawdah formation >730 Ma
ktra: Basalt, andesite, lithic tuff, and agglomerate
Ruwayhah suite 700-665 Ma
yrd: Diorite
Suwaydah formation >730 Ma
ktsw: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
Thalath complex ~640-630 Ma
lab: Gabbro
labm: Metagabbro
Wozariyah formation >730 Ma
ktwz: Volcaniclastic, shale, siltstone, and marble
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ugt: Unassigned granodiorite and tonalite
Scale 1 : 150,000
0 1.5 7.5
Kilometres
UTM WGS84 Zone 38N
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
1444 Jabal Dalla
1440 Hazm Shubat
1460 Jibal Amshat
1459 Jibal Amshat-W
4672 Jabal As Suwayda
4673 Jabal As Suwayda-SE
4674 Jabal As Suwayda-S
4676 Shaib Al Wizraniyah-N
4675 Shaib Al Wizraniyah
4678 Jabal An Nabta-NW
4679 Jabal An Nabta-NE
1449 Jabal An Nabta
651 Jabal Ishshimas
1433 Abu Tal
1458 Abraq Al Hamal
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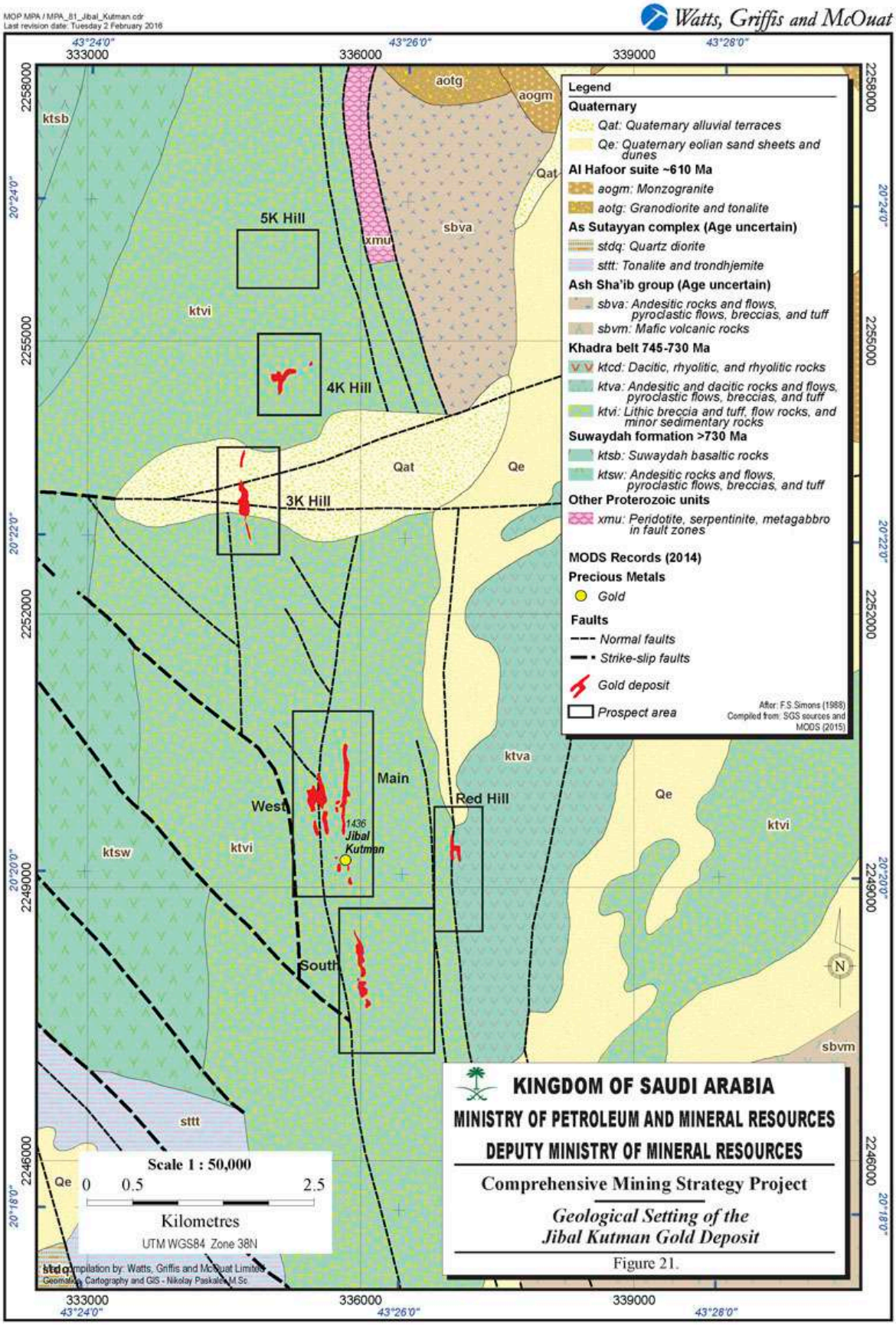
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Map of the Umm Shat - Al Suwaydah Area
Wadi Bishah and Ar Rawdah Quadrangles, Sheets 20 F and 21 F
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
43°15'
320000
43°20'
330000
43°25'
21°10'
21°5'
21°0'
20°55'
20°50'
2340000
2330000
2320000
2310000

Figure 20.

Near the southern end of the gold belt, mineralization at the Thifan (Thafan) prospects is predominantly carried by quartz veins that are hosted in andesite, dacitic tuff, altered granite/granodiorite and a series of sedimentary rocks including sandstone, black shale, limestone and marble. In 10 samples of quartz and "chert", gold values ranged from trace levels to 11.4 g/t and averaged 2.4 g/t. A strong association was noted between gold, silver and copper, with the same sample set carrying an average of 34 ppm Ag (max. 153 ppm Ag) and 546 ppm Cu (max. 1733 ppm Cu). The indicator elements Sb, As and Pb were also anomalous in this set with maximum values of 352 ppm Sb, 9,014 ppm As and 1,379 ppm Pb. Sulphide mineralization occurs as chalcopyrite, galena and pyrite within a hydrothermal alteration zone characterized by silicification, chloritization and carbonatization. The alteration assemblage suggests an epithermal affinity to WGM, and a genetic role for the local intrusions cannot be excluded.

At the southern end of the gold belt, quartz-vein stockworks and folded quartz vein remnants containing fine free gold occur at the Lugatah prospect in sheared and altered rocks within the Nabitah Fault Zone which at this point merges with the suture that joins the Asir terrane to the east and the Tathlith terrane to the west. A pod-like, sheared and sericite-silica altered body, first thought to be porphyry, is approximately 600 m long and 40-80 m wide (Figure 22). Quartz veins are up to 2 m wide. The chlorite schist unit which hosts altered lenses may be a tectonic slice caught up in the large deformation zone represented by the Nabitah structure (Overstreet, 1978). The zone is also described as being in chlorite schists that are affected by strong mylonitization of metasedimentary and metavolcanic rocks. Heavy north-south shearing, such as shears associated with the Nabitah regional fault, separate schist units from the granitic rocks in this area. The USGS obtained values up to 15.4 g Au/t in grab samples essentially duplicating the results of earlier samplers such as Worl, and reported that no sulfide mineralization was observed. It was assumed that gold was very finely disseminated free gold. However the SGS reports the presence of chalcopyrite, arsenopyrite, sphalerite, tetrahedrite, galena, and pyrite. Gold mineralization occurs as aggregates of fine grains and as streaks in both quartz vein fractures and adjacent alteration zones. High gold values occur at the selvage zones and/or in alteration bands composed of chlorite, sericite, quartz and minor carbonates. Gold values as high as 152.2 g/t were discovered in some strongly mineralized SGS drill holes (e.g. DDH-C007 at 38.5 m and DDH-C007 at 23.50 m). The "orebody" at Al Lugatah is an elongated package of semi-parallel quartz veins striking north-south, 650 m in length and about 100 m of real thickness dipping 45° to the WSW. In the northern part of the system, which is higher in average gold content, the abundance of quartz veins is greater and the zone is wider (+/- 100 m) versus 50 to 60 m wide in the south. Mylonite is present in structures cutting both volcanic and granitic rocks. The SGS estimates that Lugatah contains a total gold resource in excess of 1 million ounces at a grade of approximately 4.54 g Au/t.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Last revision date: Tuesday 2 February 2016
Watts, Griffis and McOuat
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336000
339000
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20°20'0"
20°18'0"
aotg
aogm
Qat
ktsb
5K Hill
xmu
sbva
ktvi
4K Hill
Qat
Qe
3K Hill
ktva
Main
West
Red Hill
1436
Jibal
Kutman
ktsw
ktvi
Qe
ktvi
South
sbvm
sttt
Qe
N
Legend
Quaternary
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Al Hafoor suite ~610 Ma
aogm: Monzogranite
aotg: Granodiorite and tonalite
As Sutayyan complex (Age uncertain)
stdq: Quartz diorite
sttt: Tonalite and trondhjemite
Ash Sha'ib group (Age uncertain)
sbva: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
sbvm: Mafic volcanic rocks
Khadra belt 745-730 Ma
ktcd: Dacitic, rhyolitic, and rhyolitic rocks
ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
ktvi: Lithic breccia and tuff, flow rocks, and minor sedimentary rocks
Suwaydah formation >730 Ma
ktsb: Suwaydah basaltic rocks
ktsw: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Strike-slip faults
Gold deposit
Prospect area
After: F.S.Simons (1988)
Compiled from: SGS sources and MODS (2015)
Scale 1 : 50,000
0 0.5 2.5
Kilometres
UTM WGS84 Zone 38N
stdq
Compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskaleva, M.Sc
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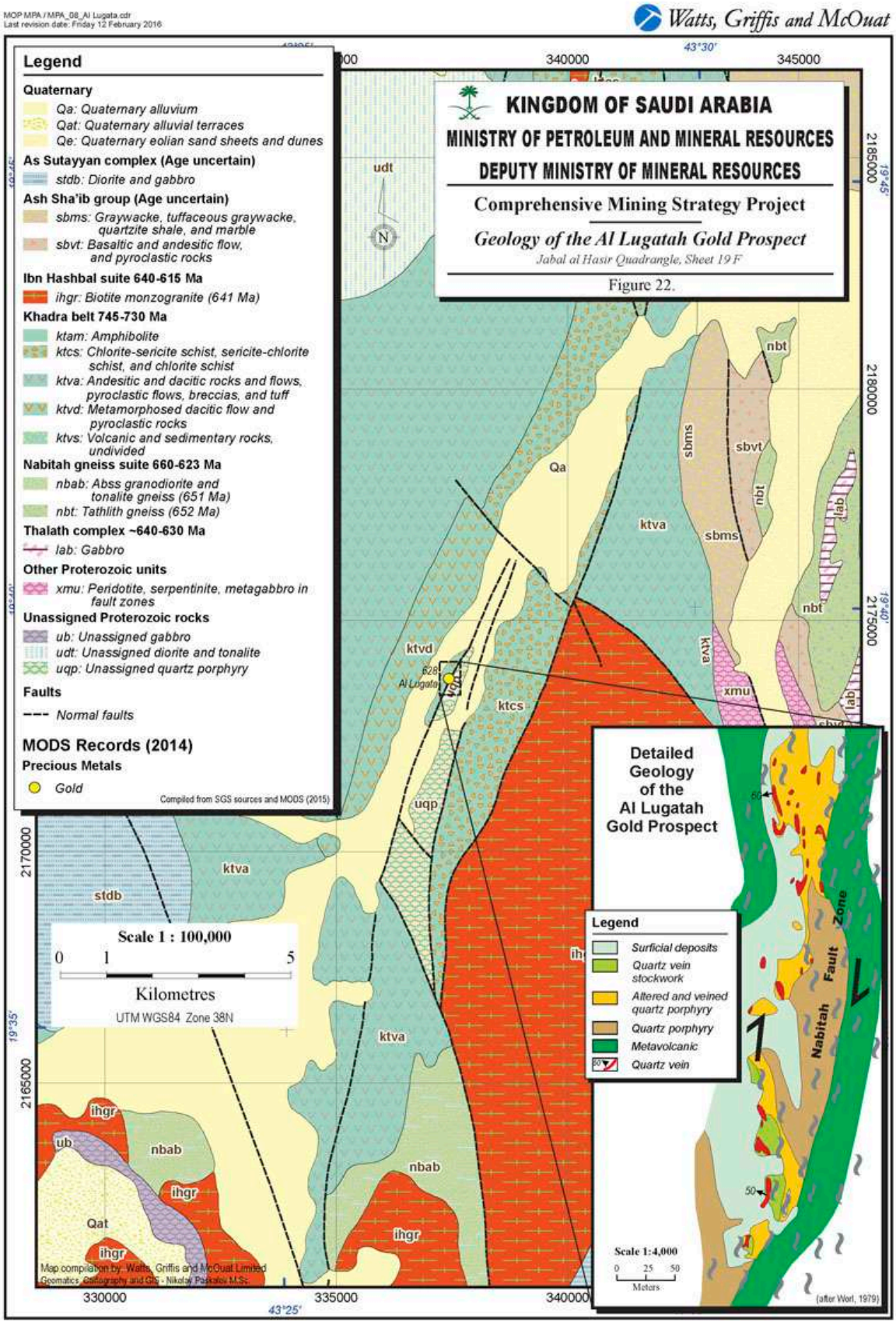
Geological Setting of the
Jibal Kutman Gold Deposit
Figure 21.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Last revision date: Friday 12 February 2016
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Geology of the Al Lugatah Gold Prospect
Jabal al Hasir Quadrangle, Sheet 19 F
Figure 22.
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
As Sutayyan complex (Age uncertain)
stdb: Diorite and gabbro
Ash Sha'ib group (Age uncertain)
sbms: Graywacke, tuffaceous graywacke, quartzite shale, and marble
sbvt: Basaltic and andesitic flow, and pyroclastic rocks
Ibn Hashbal suite 640-615 Ma
ihgr: Biotite monzogranite (641 Ma)
Khadra belt 745-730 Ma
ktam: Amphibolite
ktcs: Chlorite-sericite schist, sericite-chlorite schist, and chlorite schist
ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
ktvd: Metamorphosed dacitic flow and pyroclastic rocks
ktvs: Volcanic and sedimentary rocks, undivided
Nabitah gneiss suite 660-623 Ma
nbab: Abss granodiorite and tonalite gneiss (651 Ma)
nbt: Tathlith gneiss (652 Ma)
Thalath complex ~640-630 Ma
lab: Gabbro
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
udt: Unassigned diorite and tonalite
uqp: Unassigned quartz porphyry
Faults
Normal faults
MODS Records (2014)
Precious Metals
Gold
Compiled from SGS sources and MODS (2015)
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 38N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
Detailed Geology of the Al Lugatah Gold Prospect
Legend
Surficial deposits
Quartz vein stockwork
Altered and veined quartz porphyry
Quartz porphyry
Metavolcanic
Quartz vein
Nabitah Fault Zone
Scale 1:4,000
0 25 50
Meters
(after Worl, 1979)
43°30'
43°25'
19°45'
19°40'
19°35'
340000
345000
330000
335000
2185000
2180000
2175000
2170000
2165000
udt
Qa
ktva
sbms
sbvt
nbt
lab
ktvd
ktcs
xmu
uqp
stdb
ihgr
ub
nbab
Qat

Recommendations

As with many prospects in the Kingdom, the Hazm Shubat ancient workings benefited initially from well-planned exploration work, but appear to have suffered from a lack of follow-up work. The drilling of five diamond drill holes was recommended, but never completed. Even minor prospects with gold values as high as 22 g/t warrant some consideration as valuable targets. Prospects such as this require the drilling of approximately 1,000 m of core (5-10 holes) as the ultimate arbitrator of exploration potential. Without drilling, Hazm Shubat's potential is a complete unknown. In a similar sense, the low initial gold values at Jibal Amshat may be indicative of a prospect with low potential, although alteration in the monzogranite may indicate some un-tested potential for porphyry-type gold mineralization that should be assessed by additional geological mapping and surface sampling. Nevertheless, a mineralized structure probably associated with Nabitah faulting is traceable for more than 2 km. At Jabal As Suwayda-SE, the Nabitah structure shows indications of a gold-sulphide association which would be an ideal target for IP surveying. IP should be used to determine if sections of the host structure are significantly enriched in disseminated sulphides – these would represent high-priority targets for diamond core drilling.

The drilling results at Abraq Al Hamal seem out of proportion to the strength of the structure and alteration in this area. The prospect should be re-evaluated in a modern metallogenic context to assess if the four holes completed adequately tested the zone. Modern IP surveying might augment what is known, especially insofar as the depth potential below 200 m because it is doubtful that the original survey achieved this depth of penetration.

The use of IP surveying as a means of identifying targets with potential for gold mineralization is supported by the presence of disseminated pyrite at Jabal Qutman and various other areas that Kefi Minerals explores (e.g. Selib). Kefi has used IP data as a means of modelling subsurface targets in 3D, thus offering much improved targeting of drill holes. Kefi's exploration philosophy, including its reliance on IP surveying to trace zones and identify targets for drilling as well as its aggressive use of diamond drilling, should be replicated by others who explore in the KSA, and especially along the Nabitah Fault Zone. IP surveying is recommended over all target areas using no more than a 100 metre profile separation and a 50-metre electrode ('a') spacing for readings from n=1 to n=6 or more. A dipole-dipole array is favoured although it is a more time-consuming method of surveying.

The Jabal Mikhyat (Jabal Mokhyat) prospects are located on the main structural trend of the Nabitah belt. The exploration to date has been unable to move beyond surface sampling due to a general lack of assays that prove consistent gold assays above low-grade levels. While it is difficult to dismiss a prospect only on the basis of surface results, the Jabal Mikhyat prospects seem to lack sufficient merit to justify continuing exploration. However, the work carried out to date must be assessed to determine if it has sufficient scope that the results adequately represent the mineralization. Much of the work has been repetitive - a better outcome cannot be expected if the approach doesn't change. The suitability of the gold analysis is a big question because the nuggety mineralization present may not be well represented in the assay population - screened fire assaying is needed for representative results and this was not done. Reviewers should

assess the degree to which new exploration, in particular geophysical surveying, might generate targets for drilling both locally and in the surrounding area. The recent discovery of the Jabal Qutman deposit may also have implications for the Jabal Mikhyat area. The USGS estimated a local bedrock resource of 25,000 ounces of gold and recommended 500 m of RC-percussion drilling. The resource estimate was based on nothing more than speculation. In any case, WGM cannot support the use of percussion drilling for gold exploration, but WGM does agree that 500-1,000 m of diamond core drilling might be warranted if some degree of continuity of the gold mineralization can be demonstrated on surface such that the drilling can target an identifiable zone rather than a single quartz vein. Based on the USGS work, WGM concludes there is no economic viability to be developed from the alluvial deposits or mine tailings in the area and recommends no further work on the aspect of the prospect.

The mineralization at the Thifan (Thafan) prospects is of moderate grade, averaging only 2.4 g Au/t in quartz vein samples, however its epithermal geochemical signature of Au-Ag-Cu-Pb-Sb-As is interesting as is the strong hydrothermal alteration reported by the SGS. The alteration is a classic mesothermal assemblage of silicification and carbonatization within a propylitically altered outer envelope. The prospect should be mapped in detail at 1:5,000 or 1:2,500 scale to determine the geological affinity of the mineralization. Given the clear association with copper, it should be possible to trace the zone visually for the purpose of locating trenches for channel sampling. In the absence of good bedrock exposure, IP surveying should also be a useful means of tracing the gold-bearing zone in alluvium-covered areas. The strong base metals associations also indicate that IP could be very useful in delineating targets for diamond drilling at depths between 100 and 200 m. Following a general program of systematic exploration, a 1,200 to 2,000 m test drilling program is recommended.

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3.1.3.9 The Tathlith Gold Belt

Location, Distribution of Occurrences and History

The Tathlith terrane is a relatively small (40 km x 120 km) block of older and more highly metamorphosed crust that has been thrust westwards on top of rocks belonging to the Asir Terrane. The suture joining the Asir and Tathlith terranes is very close to the north-south Nabitah suture (fault) along which the Asir and the Malahah-Najran Terranes are joined a short distance more to the west. The Tathlith Gold belt has previously been referred to as the Jabal Ithmas-Wadi Tathlith Gold Belt (Worl, 1979). In this report, WGM has differentiated between the structure and gold occurrences that are related to the Nabitah (Table 17 and Figure 23), and the occurrences that are related to the structure which sutures the two terranes (Table 18). The Asir-Tathlith suture is accompanied by a large number of subparallel faults along which gold occurrences are distributed within the Tathlith Terrane, the most notable of which is Jibal al Hajar (MODS 0619), formerly known as the ancient “Hajr Mine” or “Hamdah Mine” and not to be confused with Al Hajar (0649) in the Wadi Shwas Gold Belt. Other ancient mines in the immediate area include B’ir Al Qiyya (1434 - was “Bi’r al Hamadan” or “Jabal al Geat”), Wadi Al Buwaytnah (1441 - formerly “Haj’r Gharb”) and Jibal Al Hajar-NW4 (1463 - formerly “Jabal Hajr”). Collectively, the occurrences described herein are referred to as the Tathlith Gold Belt. It is distinct from the gold belt that follows the Nabitah structure. This favourable zone extends from the Bi’r Jarbuah (1454) and Al Gariat Avala (0626) prospects in the north to the prospects known as Wadi al Mafgar, MODS 3067 (formerly Jabal Al Ar) and Wadi As Sayil, 1461 (formerly Gata al Masana) in the south, a distance of 200 km. In fact, the structural zone may extend beneath alluvium in the north and take in additional isolated prospects that seem to be isolated occurrences such as Hafiyah (3189) and Umm Rujud (3183).

Within the Tathlith Terrane, a cluster of gold occurrences is located approximately 17 to 44 km east of the Asir-Tathlith suture (Figure 23A). These appear to be associated with, or even hosted on strong NNW- to NNE-trending lineaments which are probably related to the terrane collision and suturing event. In this case, these gold occurrences are directly related to causative forces which created the Tathlith Gold Belt even though they are not specifically on the main structural trend. This cluster stands out within the Arabian Shield as a particularly dense group of gold occurrences, one of which is given a high priority ranking in the MODS (Table 18). Only 4 out of more than 800 MODS records have a “HIGH” ranking – two of these are associated with the Ad Duwayhi Mine. This listing includes Jibal al Hajar, the ancient Haj’r Mine, which is a completely different site from Ma’aden’s Al Hajar Mine situated 210 km to the northwest.

Table 17
Name and Location of Gold Occurrences – Tathlith Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
1454	B'ir Jarbuah	B'ir Jarbuah	Gold	43.5840280	20.8702220	Tathlith	Med	v, dd
0626	Al Gariat Awla	Gariat Avala	Gold	43.6848610	19.6641940	Tathlith	Med	v, dd
3057	Wadi Umm Salam	Wadi Umm Salam	Gold	43.6306670	19.6612780	Tathlith	Med	v, dd
3056	Bargah Sirr Al Muwashah	Bargah Sirr Al Muwashah	Gold	43.7294170	19.6276670	Tathlith	VL	v, dd
3054	Alawi Umm Markh	Shaib Umm Maarkh	Gold	43.6443060	19.6173890	Tathlith	VL	v, dd
3059	Ash Shilkhah	Ash Shilkhah	Gold	43.6627780	19.4111110	Tathlith	VL	v, dd
3052	Jabal As Sahabiyyah	Jabal As Sahabiah	Gold	43.6519440	19.3705560	Tathlith	VL	v, dd
3044	Jibal Tayyib Al Isim	Ash Shajjah	Gold-Zinc	43.6348330	19.3318610	Tathlith	VL	v, dd
3045	Wadi Riil	R'A'lel	Gold	43.6062780	19.3043060	Tathlith	VL	v, dd
3043	Alawi Wadi Riil	Aloo	Gold	43.6300000	19.2994720	Tathlith	VL	v, dd
3058	Asfar Al Bugh	Al Musfi	Gold	43.5685000	19.2512500	Tathlith	Med	v, dd
3048	Barqa Ash Shiqayb	Barqu Ash Shagib-NW	Gold	43.6338330	19.2500280	Tathlith	VL	v, dd
3047	Alawi Ghurran Al Hashim	Ala'We Ghoran Al Husheim	Gold	43.6263060	19.2346670	Tathlith	VL	v, dd
3046	Sha'la	Sha'la	Gold	43.6338330	19.2285830	Tathlith	Med	v, dd
0622	Ghurran Ar Ranah	Wadi Mushel	Gold	43.6072500	19.2085000	Tathlith	VL	v, dd
3050	Abal Al Khashba	Sirr La'Abil	Gold	43.5708060	19.1870560	Tathlith	VL	v, dd
3051	Hazm Al Khashba	Al Ghia	Gold	43.5633330	19.1825000	Tathlith	VL	v, dd
1435	Jibal Al Khashba	Al Hasbat	Gold	43.5486670	19.1681110	Tathlith	Med	v, dd
3049	Hirsh Al Khashba	Harish Al Hashba	Gold	43.5767780	19.1628890	Tathlith	VL	v, dd
1437	Wadi Mara	Al Baythat	Gold	43.3693610	18.8686110	Tathlith	VL	v, dd
3070	Al Maddah	Madha-SE-E 2	Gold	43.3741110	18.8289720	Tathlith	VL	v, dd
3069	Lasas	Madha-SE-E 1	Gold	43.3773890	18.7942220	Tathlith	VL	v, dd
1431	Wadi Miflih	Wadi Miflih	Gold	42.3888890	18.7483330	Tathlith	VL	v, dd
1461	Wadi As Sayil	Gata Al Masana	Gold	43.4448330	18.5524720	Tathlith	VL	bx, v
1455	Wadi Higan	Masana Al Masagha	Gold	43.6000000	18.4250000	Tathlith	VL	lenses
3067	Wadi Al Mafgar	Jabal Al Ar	Gold	43.3410830	18.3816940	Tathlith	VL	uncertain

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium. (2) dd = disseminated; v = veins (geometry of veins noted during WGM site visit)

The exploration of the area has been carried out mostly under the management of the USGS and has been characterized by reconnaissance-level grab sampling of ancient mine workings and mine dumps. A few of the sites, such as Bi'r Jarbuah and Al Gariat Avala, have been more carefully mapped and sampled during follow-up exploration, but prior to 2004 only one of the sites, Bi'r Jarbuah, was systematically explored using geochemistry, geophysical surveying or drilling.

At Bi'r Jarbuah, the USGS carried out a program of trenching and sampling, and geological mapping as well as systematic geochemical sampling of the surrounding area. Scout drilling core was carried out during the late 1980s which intersected economically interesting mineralization, including some visible gold. Following this initial work, a half-kilometre by 2 km grid, elongated along the local NNW-structural trend, was established to facilitate reconnaissance geophysical surveying (electromagnetic, magnetic and gravimetric). In general, data was collected on a 50 m sampling grid augmented locally with additional stations. The magnetic and gravity surveys showed features that were attributed to formational responses, including the plutonic rocks. Crone EM survey was susceptible to water-bearing layers, however a few anomalies were detected that were attributed to sulphide-bearing structures the same as or similar to the gold-bearing zones seen on surface and in drill core. The gravity survey showed low amplitude NE-striking trends and a broad low over a diorite pluton. The NE trends correspond to the direction of carbonate alteration zones and quartz veins along the southern margin of the pluton where a gravity high and corresponding magnetic high are also located. These veins also have corresponding Crone EM responses.

Based on its early work consisting of surface sampling only, the USGS estimated that the Al Gariat Avala zone contained a resource of 300,000 to 400,000 tonnes averaging 13-18 g Au/t. During 2004, the SGS instituted a comprehensive exploration program involving detailed mapping, surveying, trenching (317 m), and the completion of 12 very short diamond core holes (905.95 m). Based on six holes drilled on the Main (A) Zone and two holes drilled on its south extension, the SGS estimated that the Al Gariat Avala deposit contained resources totalling 938,250 tonnes averaging 3.88 g Au/t and containing 106,075 oz of gold (Abdulrahim et al, 2012).

Within the Tathlith Terrane, a significant amount of the exploration has been focussed on the Jibal al Hajar area for which there are 16 MODS indices within a 5 square kilometre area. The main ancient mine, formerly known as Haj'r, and the surrounding ancient mines mostly referred to as Hamdah, Haj'r or the mines of the Hamdah area, have been the catalyst for this exploration. The earliest work was carried out during the 1950s and 1960s by SAMS and the USGS. In 1976, the prospect area was mapped at 1:10,000 scale and a single 154 m diamond drill hole was completed at Wadi Al Buwaytnah (1441) formerly known as Haj'r Gharb situated 5.8 km west of the ancient mine site. The hole intersected one-metre intervals assaying 1.6 to 3.7 g Au/t. Although dumps samples at this site assayed up to 15 g Au/t, it is uncertain why this hole was drilled at this location rather than at the main minesite where mine dumps are widely distributed and approximately 200,000 tonnes of waste material was estimated to grade 3.8 g Au/t (Helaby and Worl, 1980).

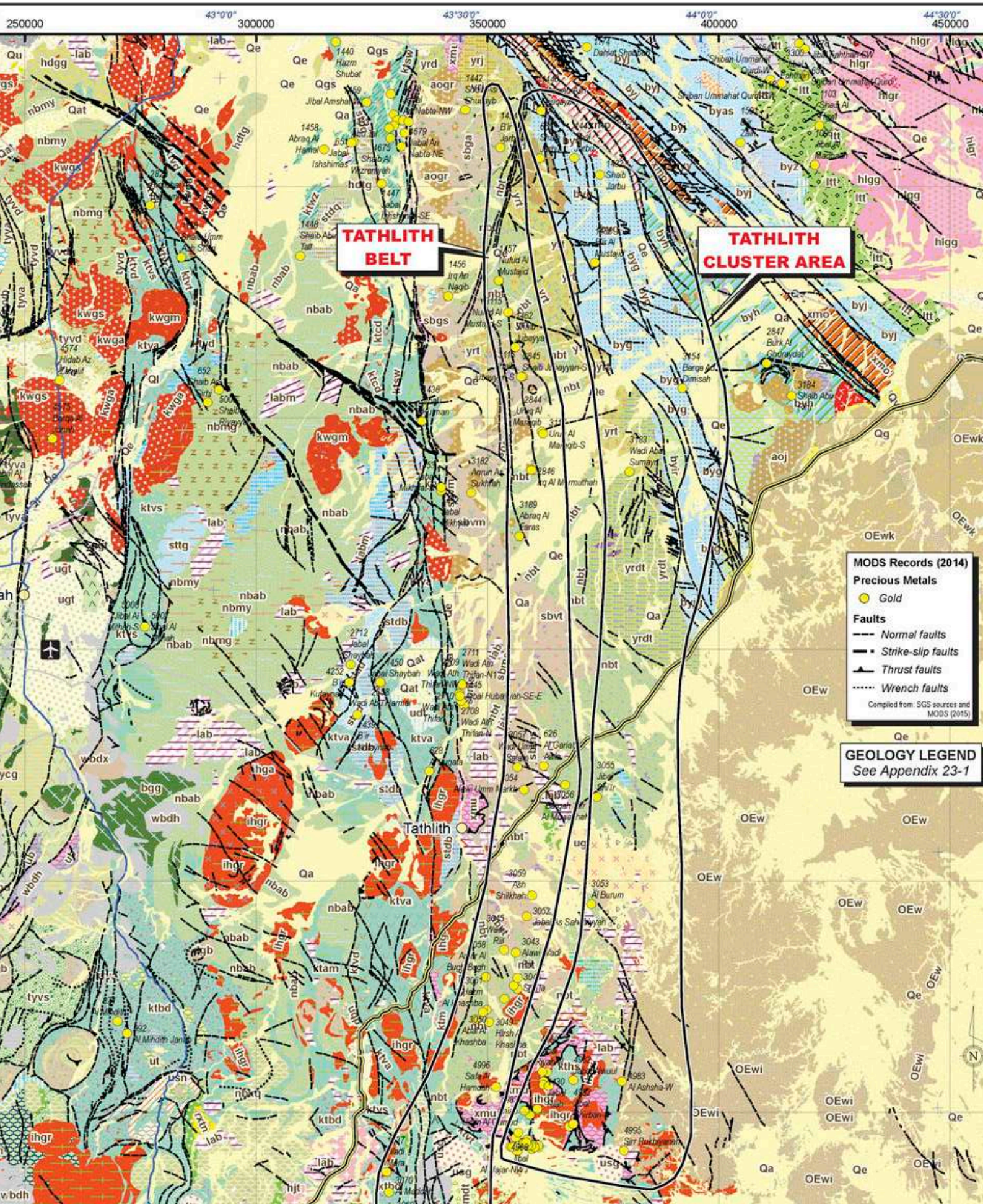

250000
43°0'0"
300000
43°30'0"
350000
44°0'0"
400000
44°30'0"
450000
TATHLITH BELT
TATHLITH CLUSTER AREA
Tathlith
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Strike-slip faults
Thrust faults
Wrench faults
Compiled from: SGS sources and MODS (2015)
GEOLOGY LEGEND
See Appendix 23-1

Table 18

Name and Location of Gold Occurrences – Cluster Within the Tathlith Terrane, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
3053	Al Burum	El Burum	Au	43.7847220	19.3950000	Tathleeth	VL	v
4960	Jibal Riyah-N	Riah	Au	43.6865000	19.0666390	Tathleeth	VL	lenses
1430	Jabal Riah	Riah	Au	43.6964440	19.0661390	Tathleeth	Med	stwk v, ribbons
4962	Jabal Alwuul	Jabal La Aual	Au	43.7502500	19.0511670	Tathleeth	VL	lenses
0623	Al Mahanide-N	Jabal Ibn Hassan	Au	43.6896670	19.0480560	Tathleeth	VL	dd, stwk v
0624	Al Mahanidh	El Hlamiya	Au	43.6892220	19.0415560	Tathleeth	Med	stwk v, ribbons
4996	Safa Al Hamdah	Sub-Tathlith-NW	Au	43.5916670	19.0361110	Tathleeth	VL	uncertain
4988	Sirr Rukbiyanah-N	Wadi As Silaym	Au	43.6771110	18.9940830	Tathleeth	VL	uncertain
4987	Shiab Umm Al Gumud	Shiab Umm Al Gumud	Au	43.6500830	18.9907220	Tathleeth	VL	uncertain
4985	Jirbat Hamid Bin Mansur	Jirbat Hamid-W	Au	43.6618060	18.9821390	Tathleeth	VL	uncertain
4982	Jibal Ghirban-N	B'ir Marwah	Au	43.7509170	18.9650000	Tathleeth	VL	uncertain
4981	Jibal Ghirban	Girban-N	Au	43.7427220	18.9601670	Tathleeth	VL	uncertain
4986	Athar Al Giayfurah	Jirbat Hamid	Au	43.6380830	18.9474720	Tathleeth	VL	uncertain
4984	Wadi Al Giayfurah	Wadi Al Giayfurah	Au	43.6333330	18.9375000	Tathleeth	VL	uncertain
4971	Jibal Al Hajar-NW10	Wadi Abu Khalid Sharq	Au	43.6565560	18.9338890	Tathleeth	VL	uncertain
4975	Jibal Al Hajar-NW11	Wadi Abu Khalid	Au	43.6544720	18.9285830	Tathleeth	VL	uncertain
4973	Jibal Al Hajar-NW7	Wadi Tathlith	Au	43.6489440	18.9283610	Tathleeth	VL	uncertain
4974	Jibal Al Hajar-NW12	Wadi Abu Khalid Gharb	Au	43.6505560	18.9280280	Tathleeth	VL	uncertain
4964	Jibal Al Hajar-NW8	Hajr Shamal Sharq	Au	43.6612500	18.9264440	Tathleeth	VL	uncertain
4972	Jibal Al Hajar-NW6	Wadi Tathlith	Au	43.6511110	18.9246940	Tathleeth	VL	uncertain
4970	Jibal Al Hajar-NW9	Hajr Shamal	Au	43.6581110	18.9231670	Tathleeth	VL	uncertain
4965	Jibal Al Hajar-NE	Hamdah-NE	Au	43.6786110	18.9230560	Tathleeth	VL	v
4967	Jibal Al Hajar-NW2	Jabal Hijrah Central	Au	43.6702780	18.9229440	Tathleeth	VL	v
4969	Jibal Al Hajar-NW3	Hamdah-NW	Au	43.6642780	18.9220830	Tathleeth	VL	v
4963	Jibal Al Hajar-NW5	Wadi Hassan	Au	43.6596940	18.9211110	Tathleeth	VL	uncertain
1463	Jibal Al Hajar-NW4	Jabal Hajr	Au	43.6704440	18.9202220	Tathleeth	VL	v, ribbons
1441	Wadi Al Buwaytnah	Hajr Gharb	Au	43.6222220	18.9200000	Tathleeth	VL	v
4959	Jabal Al Qiyya	B'ir Hamadan-N	Au	43.6263890	18.9194170	Tathleeth	VL	v
4968	Jibal Al Hajar-NW1	Hamdah-W	Au	43.6713610	18.9191390	Tathleeth	VL	v
0619	Jibal Al Hajar	Haj'R mine	Au	43.6803060	18.9190560	Tathleeth	High	dd, v
4966	Jibal Al Hajar-NW	Jabal Hijrah-SE	Au	43.6661110	18.9158330	Tathleeth	VL	v
1434	B'ir Al Qiyya	B'ir Al Hamadan	Au	43.6363890	18.9108330	Tathleeth	VL	v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium. (2) dd = disseminated; v = veins; stwk = stockwork

Following the initial regional work around Jibal Al Hajar, a number of studies were carried out in the mine area. It was quickly determined that the main area had resource potential and several diamond drilling programs were completed. An evaluation of mineralization in serpentinite in the Hamdah area was completed by Worl and Elsass (1980), and a geochemical study of the mineralization at Jabal Haj'r was reported on by Hariri (1986). Geophysical surveys comprising CEM and VLF, and geochemical surveys

of the ancient dumps were carried out following which 11 diamond drill holes totalling 1,034 m were completed. The best intersection averaged 4.87 g Au/t over 2.5 m (Bosch and others, 1989). During 1991, the USGS carried out detailed mapping, wadi-sediment sampling, rock-chip sampling, trenching, and additional diamond drilling in order to explore for gold mineralization in alluvial deposits, ancient mine dumps and oxidized bedrock. A pilot heap-leaching plant was established and a gold pour occurred on 21 July, 1991. The amount of drilling completed by the USGS is reported to have been 71 cored holes, 15 of which were on 17.5 m spacings. The fast-tracking of this project was unprecedented at the time and since. Additional drilling was carried out and an initial mineral resource estimate was made during1991 as reported by Christian and Bookstrom (1992) and as summarized below in Table 19.

Table 19
Mineral Resources for Gold Deposits at Jibal al Hajar, former Haj'r Mine Area
Tathlith Gold Belt, Arabian Shield

Deposit	Resource Type	Resource Category	Tonnes	Gold Grade (g/t)	Resource Category	Tonnes	Gold Grade (g/t)
Wadi Al Buwaytnah	Overburden-hosted	Indicated	80,000	1.88	n.a.	0	n.a.
Jibal al Hijar	Overburden-hosted	Measured	1,360,000	2.25	Proven	911,500	2.89
	Bedrock	Indicated	303,000	5.68	Probable	59,700	18.8

On the basis of the foregoing, the USGS concluded that the Jibal al Hajar ancient mine site held a reserve of >120,565 ounces (>3.75 t) of gold and an additional resource of more than 154,324 ounces (>4.8 t) of gold, yet it was also stated that the present drill hole spacing was "too wide to permit geostatistical ore-reserve estimation" according to Christian and Bookstrom. An economic model was produced by the USGS based on many assumptions, including 75% gold recovery and a gold price of US $342 per ounce, which showed the project could generate a net cash flow of US $7.4 million on an investment of $6.2 million. Gold recoveries were based on a study which showed that with a 62-day leach cycle, 62-80% of the gold could be recovered from waste dump and overburden material through heap-leaching. Column leach tests of oxidized bedrock ore showed recoveries of 91% of the gold after 24 hours of leaching (Albert and Carten, 1992). During 1992-1993, regional exploration programs were carried out in the area surrounding the deposit, including geochemical surveys and intensive alluvial and bedrock sampling programs utilizing pits and trenches. Systematic sampling was carried out at Jibal Al Hajar-NW9 (Hajar Shamal), Jibal Al Hajar-NW8 (Hajar Shamal Sharq), at 25 m and 50 m spacings, respectively. A total of 475 samples were collected at Wadi Al Buwaytnah (Hajr Gharb) most of which was grid-based sampling. Analyses were done by a variety of methods (cyanide leach and HBr/Br digestion with MIBK extraction) with some fire assaying for check purposes. Bookstrom and others (1992) noted significant variances between fire assay results and 30% lower gold values reported using the HBr/Br digestion, yet the latter method persisted for subsequent geochemical surveys rather than standard fire assaying. Following additional exploration by Ma'aden, the

details of which are unknown, an open-pit mining operation was commissioned in 2001 with a design capacity of 750,000 t per year and annularized throughput of approximately 540,000 t.

During 2005, Ma'aden commenced operations at Al Qadmah (MODS 0639), a copper prospect formerly known as Jadmah, located about 4.5 km west of Al Hajar. The resources in the Al Qadmah deposit, a gossan, was estimated to be approximately 520,000 t grading 3.1 g Au/t and 25 g Ag/t. This resource was mined out in its entirety, however production details are unavailable.

Geology

At Bi'r Jarbauh, gold mineralization occurs in ENE-trending, Fe-stained quartz and quartz-carbonate veins and stockworks within an anastomosing fracture/shear system cutting metavolcanic and metasedimentary rocks intruded by a diorite pluton. Emplacement of the diorite has caused the rotation of the layered rocks locally. Gold occasionally is seen as free gold in the veins, commonly associated with pyrrhotite and lesser arsenopyrite. NW-trending faults in the area are interpreted to be related to the Najd orogeny – these are not mineralized.

The Al Gariat Avala Prospect (MODS 0626) together with the Wadi Umm Salam (3057) prospect represent a small group of favourable ranked gold occurrences at the northern end of the belt about 110 km ESE of the town of Bishah and 180 km NE of Khamis Mushait. Ancient workings at Al Gariat Avala are distributed along two intersecting quartz-veined faults striking NNE and NNW with an aggregate total length of 1.1 km. Five separate gold-bearing structures are recognized cutting gabbro and meta-andesite, both of which are strongly affected by hydrothermal alteration. The Al Gariat Awla deposit is hosted in fractured and faulted gabbro overprinted by greenschist-amphibolite facies metamorphism. The rocks are chloritized, carbonatized, pervasively silicified and injected with white quartz stringers and veins that are consistent with a orogenic or mesothermal gold model. The chlorite-pyrite-chalcopyrite-arsenopyrite-gold mineralization is present in fissure-filling quartz veins and stockwork and alteration aureoles dipping at 35°to 50° E along the NNW-striking regional fault zone which appears to be a thrust fault associated with Tathlith-Asir suturing. The gold-bearing zone is irregular and parallels the foliation. Sulphide content is generally low (1-3%) and surface oxidation or gossan formation is generally poor. Four drill holes by the SGS gave the following results:

Drill Hole	Interval (metres)			Gold Content
	From	To	Length	(grams / tonne)
AVL-001	29.40	30.07	0.7	3.20
AVL-002	57.55	58.60	1.1	0.10
AVL-007	29.35	30.35	2.0	0.12
AVL-012	56.30	56.75	0.5	53.83

At Wadi Umm Salam, quartz veinlets failed to produce economically interesting gold value although only grab sampling was carried out on the ancient workings. Many of the samples taken at the nearby Bargah Siir Al Muwashah workings produced low values as well, however some of the quartz veins carried as much as 7.6 g Au/t. The workings at Jabal Shi'ir produced gold assays as high as 15.5 g/t from quartz veins in granodiorite. The workings at were relatively uninteresting. Gold values up to 5.6 g/t were found in veins that extended over 250 m at Ash Shilkhah where five small pits were discovered. Quartz veins at Al Barum did not produce economically interesting values and the ancient workings at Jabal as Sahabiyyah carried gold grades only as high as 3.2 g/t.

Although generally ranked as a zinc prospect, quartz veins within granitic rock at Jibal Tayyib Al Isim (3044), formerly known as Ash Shajjah, produced gold assays as high as 680 g/t = 22 ounces ! The 5 ancient workings at this site testify to the fact that the ancient miners were recovering gold. The extent of the quartz veins, which cut a granitic host rock, is reported to be "limited", however the amount of alluvial cover in this area is extensive.

The closely associated workings at Wadi Riil and Alawi Wadi Riil produced gold assays as high as 24 g/t from quartz veins in granitic rocks. Like most of the veins in the belt, they are NNW to NNE striking. A short distance to the south, vein at Asfar al Bugh assayed as high as 11 g Au/t while to the southeast, veins in granite gneiss at Barqa ash Shiqayb carried up to 3.8 g Au/t.

A cluster of workings occurs at Wadi Sha'la and Alawi Ghurran al Hashim, MODS 3046 and 3047, with the latter representing the most extensive ancient workings in the area. At both locations, the host rock is granitic gneiss. Individual pits are up to 15 m by 20 m, and samples taken from the workings assayed as high as 35 g Au/t and 41 g Au/t, respectively. The USGS still considered this to be of minor interest.

Small pits at Ghurran Ar Ranah assayed 7.5 g Au/t from quartz veins cutting biotite-hornblende granodiorite gneiss. The veins and pits were traced over a NNE strike length of 200 m. The vein systems at Abal al Khashba and Hazm al Khashba are hosted in granite and strike north to west-northwesterly - gold values were generally low at 1.6 g/t and 3.0 g/t, respectively. At Jibal al Khashba and Hirsh al Khashba, most of the veins were similarly low-grade, however at the former site sample carried as much as 11.6 g Au/t in NNW-trending quartz veins hosted by granite gneiss.

In the area surrounding Al Mahanide-N (0623) and Al Mahanidh (0624), five gold prospects with ancient workings area reported including Jabal Riah (1430) associated with north-trending carbonate alteration zones in gabbro and meta-andesite.

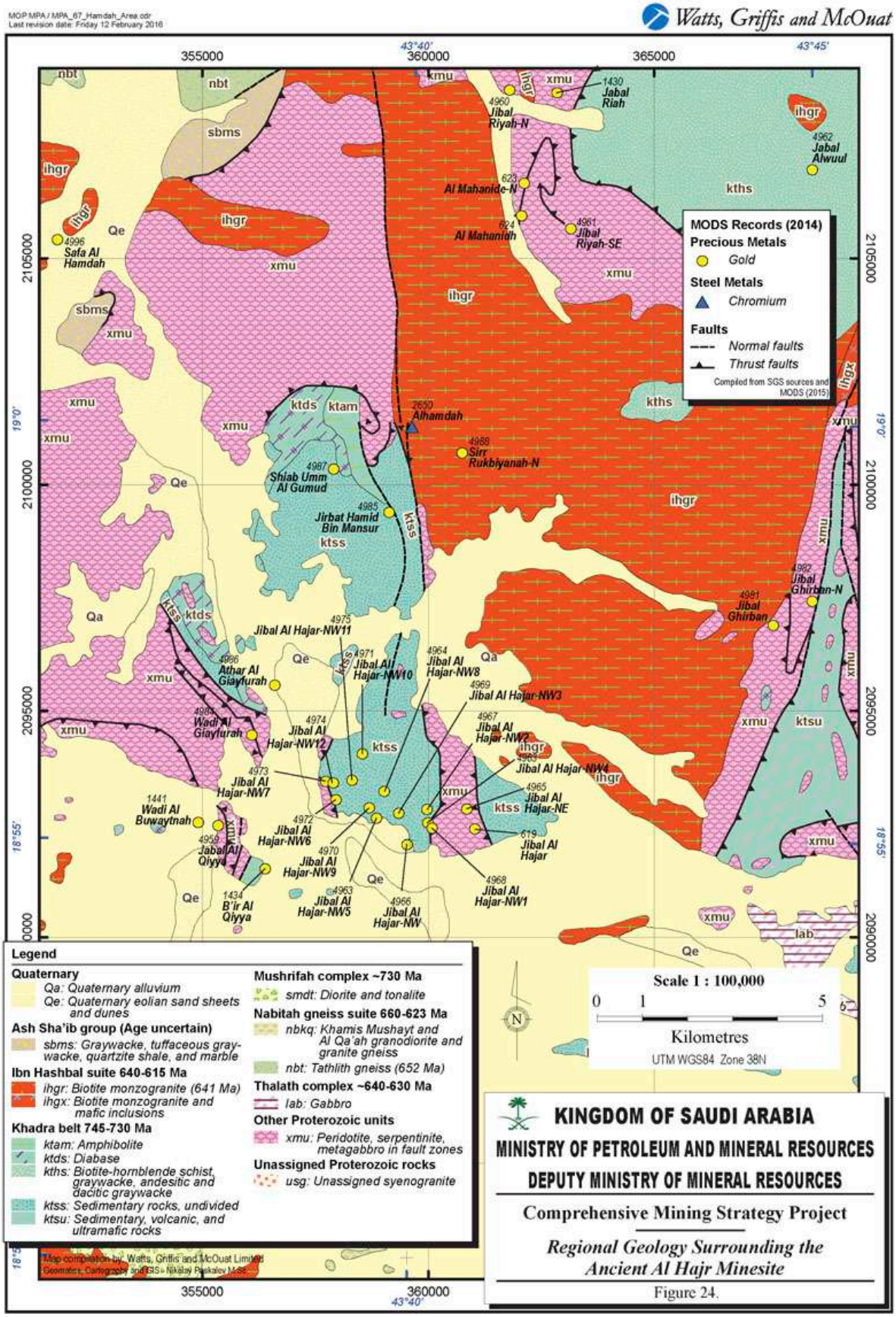
The area of the ancient Haj'r Mine (Hamdah), now known as the Jibal al Hajar prospects, is located near the southern margin of the Tathlith Terrane. According to the USGS, the area is hosted by deformed and hydrothermally altered rocks that are part of the Nabitah mobile belt (Bookstrom and others, 1992, Jannadi and El-Komi, 1993). However, the prospect area and ancient mine sites are actually east of the Nabitah structure by approximately 20 km and are close to the NNE-trending Mulha Fault which abuts the Nabitah

Fault Zone. Whether the two structures are related is uncertain. Initially, the host rocks in the prospect area were described as being an ultramafic slab (Hamdah Serpentinite) which was overlain and underlain along imbricate shears by faulted blocks of metavolcanic and metasedimentary rocks. The surrounding rocks exhibit strong ductile shearing (phyllite) and are strongly brecciated at the margins of the serpentinite. According to Bookstrom (in Jannadi and El-Komi, 1993), the thrust faulting was the result of NW-SE compression which WGM believes is unlikely to be associated with Nabitah orogenesis. The structures have deep roots as indicated by reports of additional lozenges of ultramafic rock lower within the footwall. Most recently, the geology has been re-interpreted as a classic VMS setting. The host rocks comprise predominantly rhyolites, rhyodacites, dacites, andesite and mafic/felsic tuffs and copper/zinc mineralisation is principally hosted in pyritic massive sulphides and associated stock works enclosed within the volcanic units. The site of mineralization is proximal to a felsic volcanic centre. The main elements are copper and zinc, with associated concentrations of gold and silver. Lead does not commonly occur within the mineralisation. The geology of the Jibal Al Hajar mine is shown in Figure 24.

According to the original USGS description, the ancient mines are located along foliated aplite sills that were emplaced along thrust planes. Individual prospects, such as Wadi Al Buwaytnah (Hajr Gharb) and Jibal al Hajar NW8 (Hajar Shamal Sharq) are situated where windows are eroded through the hanging wall and expose the mineralized planes. Some of these windows are located in domed sequences above plutons which give evidence of their presence by increased hydrothermal alteration and increases in the numbers of felsic intrusions. At Jibal al Hajar (0619), the ancient Hajr Mine, about 60% of the gold mineralization was reportedly is in phyllite, 25% is in serpentinite, 10% is in aplite and 5% is in hornblende schist and diorite. Gold is mostly micron-sized and is carried by quartz veins located within and adjacent to the dikes and sills. Arsenopyrite and loellingite are accessory minerals at the margins of aplite dikes and the ore contains magnetite, pyrrhotite, pyrite and traces of chalcopyrite, sphalerite and galena. Resources of the renamed Hamdah deposit (0619) were estimated at 181,000 t grading 4.5 g Au/t in the ancient mine dumps and 242,300 t grading 5.16 g Au/t in bedrock (Bosch and others, 1989). More recent work by the USGS in 1990-91 has shown that the mine dumps cover an area three times as large as previously estimated, and the dumps are estimated to contain approximately 3.5 tonnes of gold (approx. 109,000 ounces).

Recommendations

The foregoing area surrounding the Jibal Tayyib Al Isim area and extending north to Al Gariat Awla contains 40 known ancient workings which are mainly sited on quartz veins cutting granite or granitic rocks. All of the occurrences have been sampled, and a few have been mapped, but none have been subjected to extensive or systematic exploration.


Watts, Griffis and McOuat
MOP/MPA / MPA_67_Hamdah_Area.cdr
Last revision date: Friday 12 February 2016
355000
360000
365000
43°40'
43°45'
2105000
2100000
2095000
2090000
19°0'
18°55'
MODS Records (2014)
Precious Metals
Gold
Steel Metals
Chromium
Faults
Normal faults
Thrust faults
Compiled from SGS sources and MODS (2015)
Safa Al Hamdah
Jabal Riah
Jibal Riyah-N
Jabal Alwuul
Al Mahanide-N
Al Mahanidh
Jibal Riyah-SE
Alhamdah
Sirr Rukbiyanah-N
Shiab Umm Al Gumud
Jirbat Hamid Bin Mansur
Jibal Ghirban-N
Jibal Ghirban
Jibal Al Hajar-NW11
Athar Al Giayfurah
Jibal Al Hajar-NW10
Jibal Al Hajar-NW8
Jibal Al Hajar-NW3
Wadi Al Giayfurah
Jibal Al Hajar-NW12
Jibal Al Hajar-NW2
Jibal Al Hajar-NW4
Jibal Al Hajar-NW7
Jibal Al Hajar-NE
Wadi Al Buwaytnah
Jibal Al Hajar-NW6
Jibal Al Hajar
Jabal Al Qiyya
Jibal Al Hajar-NW9
Jibal Al Hajar-NW1
B'ir Al Qiyya
Jibal Al Hajar-NW5
Jibal Al Hajar-NW
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Ash Sha'ib group (Age uncertain)
sbms: Graywacke, tuffaceous graywacke, quartzite shale, and marble
Ibn Hashbal suite 640-615 Ma
ihgr: Biotite monzogranite (641 Ma)
ihgx: Biotite monzogranite and mafic inclusions
Khadra belt 745-730 Ma
ktam: Amphibolite
ktds: Diabase
kths: Biotite-hornblende schist, graywacke, andesitic and dacitic graywacke
ktss: Sedimentary rocks, undivided
ktsu: Sedimentary, volcanic, and ultramafic rocks
Mushrifah complex ~730 Ma
smdt: Diorite and tonalite
Nabitah gneiss suite 660-623 Ma
nbkq: Khamis Mushayt and Al Qa'ah granodiorite and granite gneiss
nbt: Tathlith gneiss (652 Ma)
Thalath complex ~640-630 Ma
lab: Gabbro
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
usg: Unassigned syenogranite
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 38N
N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Regional Geology Surrounding the Ancient Al Hajr Minesite
Figure 24.

The area was covered by magnetometer, INPUT and radiometric surveys during regional airborne surveying during the 1970s and numerous anomalies were defined. However the surveying was not target specific and little follow-up if any was carried out. The area was mapped by the USGS during the course of regional (quadrangle based) 1:100,000 scale geological mapping during 1978, but this also was not exploration-style mapping. The Al Gariat Avala Prospect was mapped at this time, and additional ancient workings and prospects were sampled during 1983.

Certain geophysical surveys have been shown to be effective in tracing veins and alteration zones. While subject to interference by groundwater, Crone EM showed promise in tracing veins and carbonate alteration at Bi'r Jarbuah. IP surveying might have produced similar results. Magnetic surveying was useful in outlining the subsurface extensions of intrusions in areas where only the upper portion of a larger body may be seen on surface. While these surveys do not detect the presence or absence of gold mineralization, they do have the potential to assist in providing important information which is useful in modelling the local geology.

Grab sampling of the type carried out by the USGS has a better chance of detecting no gold than economically interesting gold due to the nature of this gold mineralization which is relatively coarse and irregular in its distribution. The concentration of a large number of occurrences in a relatively small area is considered to be significant, but the potential of the area has certainly not been fully tested by the work to date. The USGS, and Worl in particular, had a tendency to over-estimate the resources in gold prospects, however, not all prospects were prone to exaggeration. Worl's estimate should be taken in the context that it indicates good potential.

The level of exploration to date at Al Gariat Avala is highly inadequate. None of the holes drilled by the SGS extended below 100 m from surface. In fact, the mineralized intersections were even closer to surface. The SGS estimate for the A Zone, which is essentially based on surface samples and the results of 4 drill holes, is probably a significant over-statement given the irregularity of most gold deposits, however it may be indicative of excellent potential. A resource of 100,000 ounces, or nearly 3 tonnes of gold, in less than 100 m of vertical is an excellent start for a project even if it is based on relatively few data points. The prospect is situated on or very close to the Tathlith-Asir suture zone and close to the southern extension of the Nabitah Deformation Zone which is known as the singular most important gold-bearing structure in the Arabian Shield. It is clear to WGM that the results to date demand follow-up exploration as strongly recommended by the authors of the SGS report, including deep drilling on a 50 m x 25 m grid (Abdulrahim et al, 2012). Lateral step-outs are also needed to test for changes to the gold-bearing structure as it crosses lithological contacts because the physical and mineralogical characteristics of the host rocks can have a major influence on the grade and thickness of the mineralized zone.

Many of the mineralized intervals in drill holes on the Jibal al Hajar deposit and surrounding prospects were analysed using laboratory techniques that were inappropriate for gold. This practice continued even after it was known that gold contents were being under-reported by as much as 30%. The historical assay database for the project is therefore likely to contain erroneous assays that do not reflect the true gold

content. WGM can only conclude that the prospects probably have higher gold contents than reported. The high ranking given to the cluster of additional workings in the vicinity of the Jibal Al Hajar (0619) ancient workings, formerly known as the Haj'r Mine, is not matched by any significant amount of exploration work apart from that focused on the Jibal al Hajar Mine. Some detailed sampling has been done of the neighbouring ancient mine sites, and 15 drill holes were completed on the various outlying sites, intersecting gold values up to 10 g/t over narrow intervals. The fact that the mineralization was irregular and never more than 5 m in thickness was seen by the USGS as a negative. The fact that mineralization was present was also seen by Bookstrom (in Jannadi and El-Komi, 1993) as proof of potential on the underside (lower margin) of the serpentinite. WGM agrees that deeper structural zones should be drilled, however it is unknown to WGM whether this potential has already been followed up with deeper drilling. The likelihood of follow-up is probably low given the performance of the Al Hajar Mine. Process through-put seldom met production targets although mine output did increase from 2004 to 2006, nevertheless at an average grade of 1.5 g Au/t, the head grade was significantly below the resource grade after 2004. This resulted in a 50% reduction in gold production and a 50% increase in cash operating costs, an outcome which might have been avoided if better assaying techniques had been used and the deposit had been drilled with an appropriate drill hole density.

The Tathlith Gold Belt should be explored systematically from north to south with routine, systematic geophysical surveying, preferably with a combination of ground based magnetometer and IP surveying, which is thought to be superior to EM surveying, especially where deeper cover is present. New developments in V-TEM or Z-TEM surveying offer additional solutions including the potential for 3D modelling, but this surveying is quite costly. Each prospect should be surveyed using a 100 m profile spacing with profile lines sufficient long to provide coverage at the deepest level to the edge of the prospect area (are of ancient workings). For each prospect, this might entail 10-15 line-kilometres of surveying for each instrument. Some surveying between prospects is also warranted to trace gold-bearing structures beneath alluvial cover. Detailed geological mapping is needed to establish structural trends such that the IP data can be properly interpreted. As the current level of sampling is completely inadequate, diamond core drilling of each prospect is required to properly assess the gold potential. A budget for 1,500 m of drilling should be allocated for each prospect. Shallow drilling (<100 m) should be used to confirm the geometry of each mineralized zone. Step-out drilling on 100 m sections should be used to assess lateral continuity.

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3.1.3.10 The Wadi Shwas Gold Belt

Location, Distribution of Occurrences and History

The Wadi Shwas Gold Belt is approximately 80 km in length and is marked by several parallel shear zones, 10-12 km apart, striking approximately north-south in the southern part of the Arabian Shield about 50-70 km west of Bishah. The belt is well populated with base metal occurrences which generally associate with a VMS model. The orogenic gold occurrences are associated with the aforementioned shears (structural zone) which has been referred to as the Tabalah Shear Zone (Figure 25).

The northern end of the gold belt is not well populated with gold occurrences and the structural zone passes below Harrat al Buqum in the vicinity of the town of Jarab. The most northerly prospect is Shaib al Khid (MODS 1105). At the southern end of the zone, the zone bifurcates with one prominent shear (fault) zone passing immediately west of the town of Al Bashayer and another structure striking to the southeast passing through the Al Hajar Minesite (not to be confused with the former Haj'r Mine at Jibal al Hajar). Beyond Al Bashayer, the two structures continue separate traces for more than 100 km. The western branch, coinciding with the Umm Farwah Shear Zone, passes over the edge of the escarpment at the edge of the Shield near Al Bashayer. South of Al Hajar, the eastern branch (deformation zone) deflects around the Nimas Batholith, first striking to the southeast and then to the south-southwest, probably merging with SSW-trending structures originating in the Bishah Area such as the Tarj Shear Zone. The southern part of this zone can be traced into the vicinity of Tanomah where it also passes over the edge of the escarpment.

This eastern branch of the belt contains seven gold occurrences, six of which are in a 26 km long section of the structure. These are shown in the lower part of the following table as Wadi Shwas South Belt, but the structure was probably a single deformation zone before emplacement of the Nimas Batholith (Table 20).

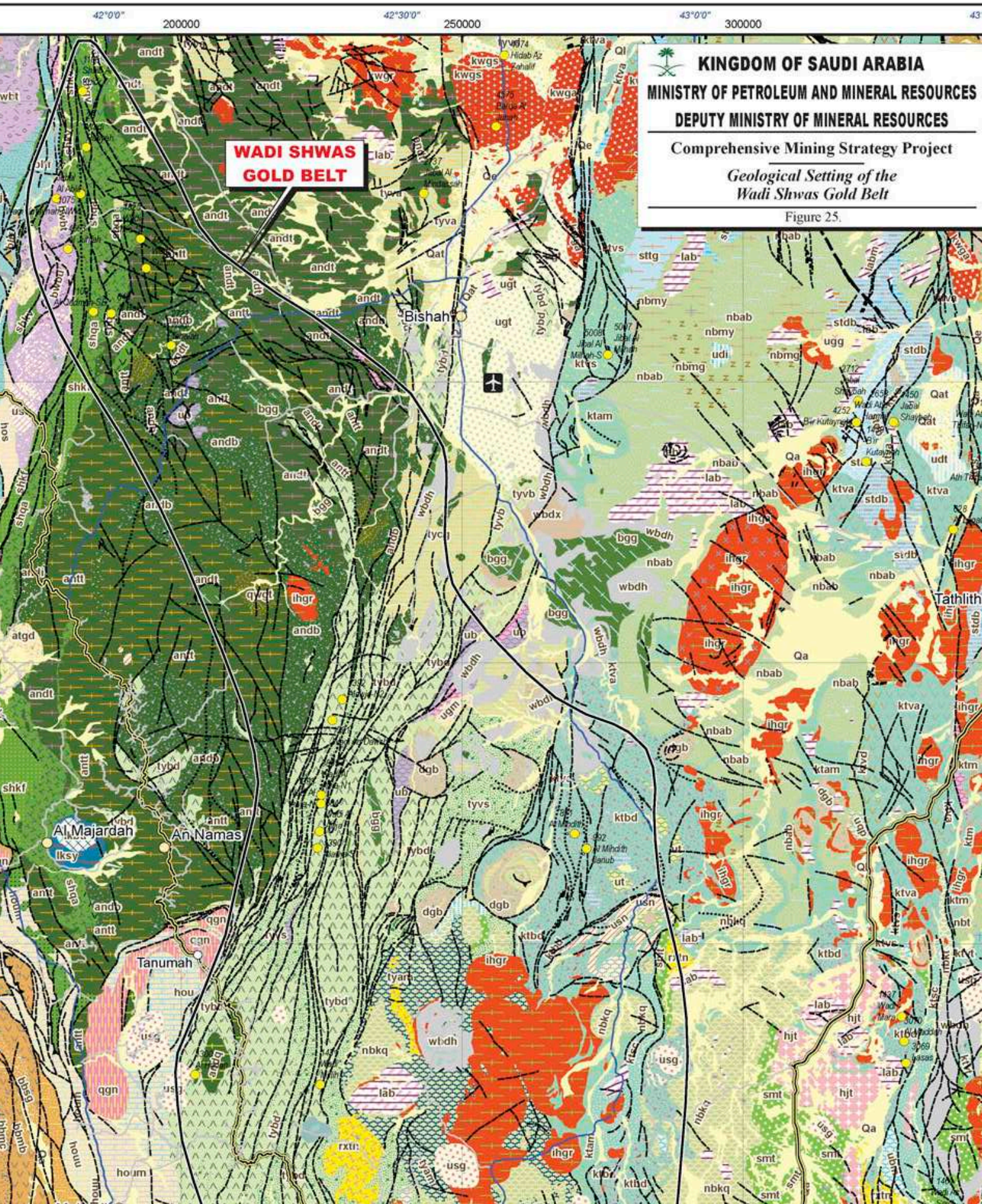
The Shaib Al Khidr prospect (MODS 1105) is located at the northern end of the belt, but little is known of this gold occurrence. The Wadi Ranyah prospect (MODS 0020) sampled by the BRGM during 1988 produced three high grade silver values (98 to 208 g/t) which correlate positively with high lead and zinc contents. Gold values were generally less than 1 g/t (Donzeau and Beziat, 1989).

Table 20
Name and Location of Gold Occurrences – Wadi Shwas Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
1105	Shaib Al Khidr	Al Mukaisrah	Gold	41.9581940	20.3375000	Al Aqiq	Med	Structural
0020	Wadi Ranyah	Wadi Ranyah	Gold	41.9662220	20.2475560	Al Aqiq	Low	Uncertain
1075	Wadi Kutaynah-NW	Assous	Gold	41.9580560	20.1722220	Al Aqiq	VL	Shear zone
0027	Jabal Al Abla	Ablah Breccia Pipe	Gold	41.9171670	20.1647780	Al Aqiq	Med	Sub-massive, v
4825	Wadi Shirs-S	Wadi Sorgah	Gold	42.0616670	20.1016670	Al Aqiq	VL	Structural
4663	Al Juhfah	Al Gohafa	Gold	41.9380560	20.0838330	Al Aqiq	Med	Shear zone
4824	Wadi Surum	Wadi Surum	Gold	42.0716670	20.0550000	Tabalah	VL	Structural
1100	Al Qadmah-SE	Sahlam	Gold	41.9833330	19.9833330	Tabalah	VL	Uncertain
0649	Al Hajar	Al Hajar	Gold	42.0136110	19.9810560	Tabalah	VH	Uncertain
2722	Wadi Tabalah	Wadi Tabalah	Gold	42.1166940	19.9311670	Tabalah	Med	Shear zone
Wadi Shwas – Southern Extension								
1392	Alawja-N2	Al Oja0	Gold	42.4166670	19.3666670	An Namas	VL	Structural
1391	Wadi Ad Dawsh	Al Farah	Gold	42.4000000	19.3333330	An Namas	Med	Structural
3895	Wadi Al Awja-N1	Lorelon-N	Gold	42.3833330	19.2138890	An Namas	VL	Structural
1393	Wadi Al Awja-N	Lorelon	Gold	42.3833330	19.2000000	An Namas	Med	Uncertain
0684	Wadi Al Awja	An Nimas	Gold	42.3816670	19.1555560	An Namas	Med	Uncertain
1390	Alawja-S	Farshat Al Harban	Gold	42.3783330	19.1283330	An Namas	VL	Uncertain
1300	Al Hadan	Jabal Qal-NE	Gold	42.1777780	18.7611110	An Namas	VL	Structural

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins; Strata = stratigraphic control

The Jabal Al Abla prospect (0027), formerly known as the Ablah Breccia Pipe, has attracted attention on several occasions. According to the DGMR, the earliest visit in modern times was by Larken in 1936 (Kemp, 1972). On behalf of SAMS, the area was then sketch mapped during the 1950s and sampled across the area of the ancient workings (Schaffner, 1957c). His samples indicated local copper enrichment, as well as low-grade gold values over broad intervals: 1.37 and 1.71 g/t over 6.1 m across the main workings and a breccia zone, respectively. Other workings contained gold values as high as 3.1 g/t over 61 cm. After visiting the prospect during 1966 and not taking samples, the USGS suggested that fluorite had been mined to provide smelter flux (Goldsmith, 1966a). A reconnaissance visit made by the Japan Geological Mission in the late 1960s and the feldspar, silica and fluorite potential were considered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250000
43°0'0"
300000
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Wadi Shwas Gold Belt
Figure 25.
WADI SHWAS GOLD BELT
Bishah
Al Majardah
An Namas
Tanumah
Tathlith

promising (Igarashi, 1975). A resource of 7,000 tons of fluorite was estimated, and 1:2,000-scale geologic mapping and drilling recommended. During 1969, the USGS drilled one 207 m hole "AB-1" under the main fluorite lens. At a vertical depth of about 125 m, the drill hole cut several zones of fluorite mineralization with elevated values of Cu, Zn, Ag, Pb, Mo (2.2% Mo over 0.4 m), and gold values of 0.7-5.49 g/t over 0.8-1.8 m (Allcott, 1970b). The USGS mapped the prospect at 1:2,500 scale and described the mineralization in detail, estimating that about 20,000 tons of acid grade fluorite (97% CaP_2) was present to a depth of 50 m (Kemp). Samples from a gossan on the fluorite zone contained as much as 17.15 g Au/t, as well as elevated silver and base-metals values, indicating a possibility that ancient miners exploited the zone for precious metals and abandoned the workings when the oxidized mineralization was depleted. Kemp suggested geophysical investigations prior to additional drilling. Subsequent work by the BRGM included regional wadi sediment geochemical sampling which identified base metal anomalies (Cartier, 1983a). In the mid 1980s, the USGS carried out rock chip sampling and an audio-magnetotelluric survey which showed an apparent resistivity low at the mine site, and a possible alteration zone at a depth of 150-300 m (White and Samater, 1987; Tippens and others, 1987). The BRGM remapped the prospect at 1:2,000 scale during the late 1980's, sampled the ancient workings, and collected 478 channel samples (1-3 m long) along seven traverses spaced at intervals of approximately 50 m. The following gold contents were reported from the mine area (Donzeau and Beziat):

- 2.20 g/t in massive fluorite;
- 1.30 to 15.55 g/t in pockets of iron oxides (gossan);
- 6.30 g/t in quartz associated with massive fluorite;
- 3.11 to 4.97 g/t in greisens; and,
- 9.64 g/t in brecciated pegmatite.

Renewed channel sampling at Jabal Al Abla revealed a geochemical gold background of 0.15 g/t, and a spatial correlation of anomalous gold (>0.5 g/t) with the greisen; the maximum gold value was 7.61 g/t. The zone was also geochemically anomalous in Ba, As, Sb, Mo, W, Nb and Y as well as base metals. The BRGM completed a 3-hole, 629 m diamond drilling program designed to intersect the zone at 80 to 100 m below surface (Donzeau and Beziat). Drill hole CO-O2 intersected four widely spaced gold assays of 1-2 g/t. Drill hole CO-03, beneath the ancient workings, did not intersect massive fluorite but cut a 20 m section averaging 1.08 g Au/t as well as 1.29 g Au/t over 8 m in breccias. Drill hole CO-04 cut two zones in the fluorite breccia pipe containing from 1 to 5.4 g Au/t - one of the zones included a 1 m quartz vein assaying 16.23 g Au/t. The BRGM disapproved the results and recommended that no further work was justified.

The occurrences in the Wadi Shirs area (formerly known as Wadi Sorgha), including Wadi Tabalah (2722), Wadi Surum (4824) and Wadi Shirs-S (4825), are viewed as being in the An Nimas Batholith. Most of these were discovered by the USGS as a result of 1:100,000-scale geologic mapping during the 1970's. A few consist of rediscovered ancient workings. The presence of gold mineralization was first reported from the Hazim occurrence, but neither sampling nor mapping was undertaken at the time Cornwall (1973). During 1990, the BRGM made a preliminary evaluation of mineral occurrences in the Bishah region, and two

samples of quartz veins at Hazim (0035) in the Wadi Bidah Belt gave gold values of 14.90 and 8.59 g/t - sample type and analytical method were not stated (BRGM, 1990). This gave some impetus to further exploration in the area.

At Al Juhfah (4663 – formerly Al Gohafa), the BRGM collected samples from a 300 by 800 m area of ancient workings on a quartz vein swarm. The results are not recorded and no geological sketches were made of the sample locations. The gold occurrences at Wadi Sarum (4824) and Wadi Shirs-S (4825 – formerly Wadi Sorgha) were discovered in 1988 by the BRGM during an evaluation of the Wadi Shwas district. At Wadi Surum, two samples contained 3.6 and 4.8 g Au/t, and at Wadi Sorgha one gold value of 3.5 g/t was obtained (Donzeau and Beziat).

The USGS sampled several occurrences in 1973. Two chip samples at Wadi Talabah (2722) returned 1.20 ppm Au across an unreported width, and 8.80 ppm Au over approximately 1.5 m (Anderson, 1977).

The major gold occurrence in the Wadi Shwas belt is the Al Hajar deposit (0649). The USGS is thought to have been at Al Hajar during 1965 when an unsuccessful attempt was made to locate airborne EM conductors (Cheeseman and Poloni, 1980). The first systematic exploration by the DGMR in 1973 comprised a 20 m x 40 m SP survey and a small amount of Turam EM surveying which defined a long SP anomaly associated with the gossans. Follow-up IP and/or more Turam-EM were recommended prior to drilling (Gazzaz, 1974). The Japan Geological Survey ("**JGS**") completed 1:2,000 scale geological mapping, extensively sampled the gossans and drilled three diamond drill holes (562 m). The primary focus of this work was base metal exploration. Several types of gossan were identified in four zones, including an opaline variety. Metal contents as high as 1.33% Cu, 1.25% Pb and 0.27% Zn were detected, however 36% of the samples contained anomalous gold values as great as 7.70 g/t as well as silver contents as high as 19.5 g/t (Fujii, N. and others, 1978). Follow-up work remained focused on base metals with the DGMR completing additional detailed geophysical surveys (magnetometer and IP) (ARGAS, 1978). During 1975 to 1980, DGMR remapped the prospect and undertook a small drainage geochemical program, gossan and other rock sampling, the deepening of JGS drill hole RAJ-3, and the drilling of a new hole for a total of 406.35 m (Cheeseman and Poloni). Petrographic studies of drill core were completed (Loubat, 1980). Chip samples were taken across the base of the weathered profile in gossan zones and the focus seemed to shift to gold. A 5.5 m interval averaged 3.9 g Au/t and 51 g Ag/t. The mineralization was, however, predominantly base metal with RAJ-3 intersecting 1.98% Cu, 0.14% Zn and 12.1 g Ag/t over 1.5 m. Drill hole RAJ-4 intersected two 1.5 m intervals containing copper and zinc mineralization up to 1.58% Cu and 1.71% Zn. These results were insufficient to generate significant interest immediately. During 1987 and 1989, the BRGM completed a major exploration program to evaluate the gold potential of the near-surface oxidized zone. This included a significant amount of surface sampling (900 samples) and trench samples (4,637 samples) as well as geophysical surveying (SF, misse-a-la-masse, magnetic, resistivity, and IP) and diamond drilling (44 holes / 3,850 m at Al Hajar North and 37 holes / 2,308 m at Al Hajar South) resulting in approximately 6,000 drill core samples. Metallurgical testing was carried out to investigate the leachability of the gold mineralization - 1,500 t of material from Al Hajar North yielded 6,224.5 g of gold and 2,634.5 g of silver. The Al Hajar North deposit was estimated to contain a "reserve" of 2.37 Mt grading 2.5

g Au/t with recoverable reserves of 1.54 Mt grading 3.45 g Au/t using a 1 g/t cut-off. The Al Hajar South deposit was estimated to contain reserves of 5.73 Mt grading 1.44 g Au/t with recoverable reserves of 2.69 Mt grading 2.6 g Au/t. A preliminary feasibility study was favorable at a throughput of 400,000 t per year at an average grade of 2.88 g Au/t or 500,000 t per year at 2.53 g Au/t. The BRGM proposed 3,500 m of additional drilling at both deposits, additional metallurgical testwork, hydrogeological studies and a final feasibility study (BRGM, 1989). The BRGM holes at Al Hajar North penetrated as much as 110 m into unoxidized, locally massive sulfide mineralization and at Al Hajar South sulfides up to 40 m thick were intersected. This exploration suggested the presence of an E-dipping massive sulfide body beneath Al Hajar North and a deep massive sulfide target 100-200 m south of Al Hajar South. A new BRGM resource estimate was prepared for the zones at Al Hajar North and South below the gold bearing gossan as follows:

sulphate-enriched rock at the base of the gossan	300,000 t grading 6.82% Cu
primary massive sulphides	1.85 Mt grading 2.13% Zn
stockwork sulphides	904,500 t grading 1.30% Cu

Beginning in 2000, the supergene (oxidized) zone at Al Hajar was successfully mined for gold by Ma'aden. For the years 2004 through 2008 inclusive, Al Hajar produced a total of 136,000 ounces of gold and 912,000 ounces of silver (SRK, 2007). The development included two open pits, North and South, which were excavated between 2000 and 2006, and a heap leach operation. The North pit is 82 m deep in classic massive sulphides. The South pit is in a stockwork zone, and is actually three interconnecting open pits on the side of a hill up to120 m from top of upper pit to base of lower pit. When mining ceased, the heap leach operation continued through the re-crushing of processed ore and tailings which contained approximately 1.3 g Au/t (SRK), and through importing additional ore by road from two satellite pits. With an understanding that the massive sulphide deposit represented a potentially viable resource, 131 HQ- and NQ-sized diamond drill holes were completed by Ma'aden during 2006-07, and from 2008 onwards another 65 holes were completed. The heap leach pads ceased operation at the end of 2012. Since that time, the deposit has been re-evaluated by Ma'aden for its potential to produce base metals. During 2013, a feasibility study was completed on the potential to produce a flotation concentrate. Initial results were not overly favourable in respect to metal recoveries, especially for zinc, however recoveries improved as tests continued. The consultant concluded that marketable copper concentrates could be produced however a new more representative composite was needed for both copper and zinc ores as the existing sample was not truly representative given the variability of the ore. The current Mineral Resources, estimated without the application of a cut-off grade, are summarized in Table 21 (GBM, 2013).

Table 21
Al Hajar Mineral Resources Estimated in 2012

Area	Classification	Tonnes	Cu		Zn		Au		Ag	
			%	Tonnes	%	Tonnes	g/t	ounces	g/t	ounces
North Pit Area	Oxide									
	Measured	-	-	-	-	-	-	-	-	-
	Indicated	265,600	0.84	2,236	0.12	311	0.04	363	2.78	23,774
	Inferred	224,000	0.56	1,262	0.19	425	0.08	554	4.64	33,427
	Sulphide									
	Measured	1137045	2.93	33,360	0.71	8,094	0.44	15,916	8.15	297,794
	Indicated	2,726,340	1.23	33,535	0.74	20,197	0.43	37,449	17.95	1,573,408
	Inferred	1,290,410	0.83	10,749	0.34	4,391	0.2	8,344	15.54	644,757
South Pit Area	Oxide									
	Inferred	259,200	0.66	1,712	0.18	469	0.18	1,483	10.3	85,841
	Sulphide									
	Inferred	2,091,200	1.17	24,415	0.47	9,738	0.21	13,911	12.5	840,250

The mineral resources were re-estimated in accordance with the JORC Code (2004) focusing on copper and based on drilling carried out between 2006 and 2010 that totalled 196 diamond drill holes: 175 NQ-sized and 21 HQ-sized subdivided as 64 holes (5,952 m) in the South Pit area and 132 holes (15,601 m) in the North Pit area. On the basis of the foregoing resource estimate, an open pit mine was designed to extract approximately 3.32 Mt or copper ore (700,000 tpa) at a stripping ratio of 3.1 to 1 (waste to ore) with a 5-year mine life. According to GBM (2013), Ma'aden brought one additional project in the Jibal al Hajar area into production during the post-2010 period. Referred to as the "Sherss Gossan" deposit, it is located 15 km north of the Al Hajar project, it is reported to contain a minor resource of 300,000 tonnes grading 1.55 g Au/t and 14 g Ag/t. The name is found in the current MODS database, and its current name is Wadi Ar Ruhub.

Located about 100 km SSE of Al Hajar, the Wadi Al Awja-Wadi Ad Dawsh area contains significant precious metal-copper occurrences on the eastern splay of the gold belt. The USGS visited the occurrences during 1972-73 and recorded brief descriptions without detailed sketches. Few analyses were reported - one grab sample at Wadi Al Awja (formerly known as Lorelon) contained 35.2 g Ag/t, 0.19 g Au/t and 3,825 ppm Cu. At Al Awja South, formerly known as Farshat Al Harban, six samples contained as much as 0.58 g Au/t, 21.2 g Ag/t and 20,750 ppm (2.1%) Cu (Greenwood, 1979a). During 1979-80 Riofinex mapped the geology on widely spaced traverses at 1:50,000 scale and each mineral occurrence was grab sampled giving maximum assays of 13.8 g Au/t at Wadi Ad Dawsh; 5.2 g Au/t, 60 g Ag/t and 13.61% Cu at Wadi Al Awja North; and 17.5 g Au/t, 17.5 g Ag/t and 7.06% Cu at Al Awja South (Ransom, 1981). Follow-up work during 1980-81 included 1:1,000 scale geological mapping and extensive channel and grab sampling at Wadi Ad Dawsh, Wadi Al Awja North, and Wadi Al Awja N1 (Morfett, 1982). At Wadi Al Awja, the pyrite-bearing halo contained a maximum of 1.5 g Au/t over 3 m. Samples of gossan and quartz from the mine dump returned

gold values of 9 g/t and 2 g/t, respectively, but no significant values were obtained along strike from the workings. The occurrence was considered to have little potential. At Wadi Al Awja N1, gold is enriched with values as high as 19.85 g/t across a 2 m section of carbonate-altered, serpentinized rock within shears. At Wadi Ad Dawsh the quartz vein contains less than 4 g Au/t and the wall rocks are unmineralized. Mine dump samples averaged 3.8 g Au/t and 42.6 g Ag/t. No further work was recommended at any of these sites (Morfett, 1982).

Geology

The structure controlling mineralization in the Wadi Shwas Gold Belt is a series of north-south trending deformation zones which separate the Bahah, Ablah and Tayyah tectonic belts within the Asir Terrane (Johnson, 2000). The deformation zone wraps around the An Nimas Batholith Complex which is composed of mafic to intermediate rocks (diorite, gabbro and tonalite). The batholith apparently acted as a lozenge in the deformation zone, causing it to bifurcate around the margins of the plutonic rocks. Consequently, to the south, the individual limbs of the deformation zone are quite far apart, so to an extent conflicting with the concept of this being a single gold belt. However, the continuation of the deformation zone from the north to areas south of the An Nimas Complex is very clear in satellite imagery.

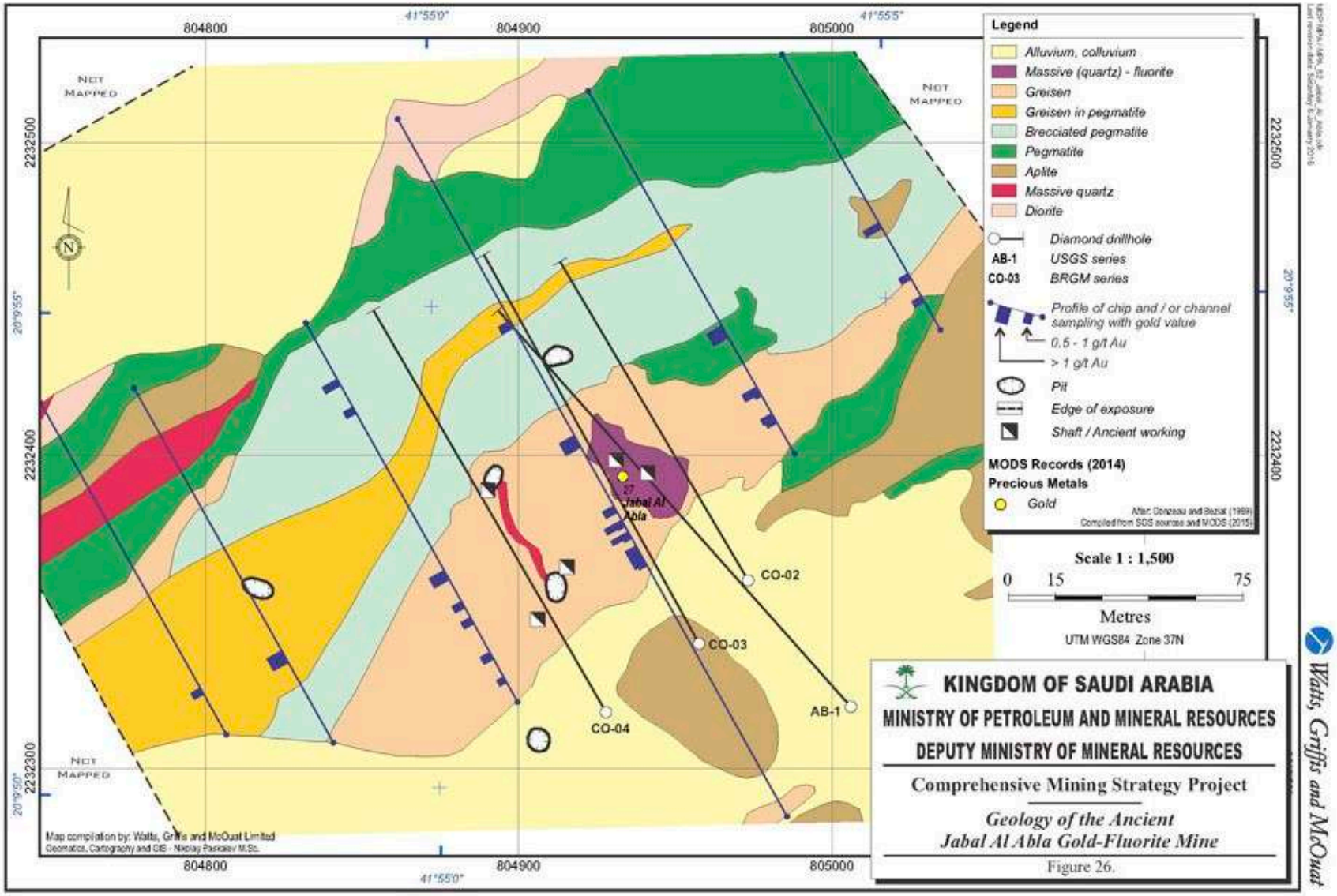
The Wadi Shwas area is primarily known for its stratabound VMS-type base-metal mineralization and associated supergene gold-enriched gossans, however it also contains several epigenetic gold-silver prospects. Gold and base metal mineralization is commonly co-existent however this should not imply a single metallogenic event. Many of the gold occurrences are associated with quartz veins that are structurally controlled and which have no direct connection with the stratabound base metals mineralization.

The Jabal Al Abla prospect consists of a composite body of diorite, syenite and locally pegmatitic microgranite dikes of the Shuwas pluton, a member of the younger "diorite and tonalite" suite (Figure 26). These rocks were deformed and intruded by a northeast-trending swarm of pegmatite/aplite dikes, including the large pegmatite hosting the Ablah fluorite prospect. This pegmatite is an east-west elongated body, much of which has been affected by brecciation, quartz veining in three dominant orientations and greisenization (Kemp, 1972; Donzeau and Beziat, 1989). The brecciated pegmatite contains a fluorite/quartz-fluorite breccia pipe measuring approximately 35 m by 22 m. A northern exposure of the system is covered by massive limonitic gossans. No sulfides have been identified at surface, but the presence of limonite indicates that they were locally abundant. Chalcopyrite, sphalerite, pyrite, galena, silver, tetrahedrite, bismuth-boulangerite and molybdenite occur in drill core (Allcott, 1970b; BRGM, 1990). Minor quartz-fluorite veins exist beyond the main pipe. Ancient workings at the site consist of two shafts greater than 50 m deep, a collapsed adit and numerous surface workings on the main fluorite zone as well as underground and surface workings on minor veins.

Mineralization occurs within the margin of the An Nimas batholith at Wadi Talabah (2722) where a shear zone associated with a major north-south structural lineament cuts diorite, and gives gold assays as high

as 9 g/t (Anderson, 1977). A similar setting is found at the Jabal Hate copper prospect (3109) where ancient workings consist of malachite-stained gossans associated with a 200 m long and 10 m wide diorite dike emplaced in sheared tonalite (Greene, 1982a). There is no report of gold values. The Wadi Surum (4824) and Wadi Shirs South gold occurrences (4825) are hosted by granodiorite near the western margin of the An Nimas batholith - ancient workings are situated on discontinuous quartz-carbonate stringers adjacent to a north-trending fault/shear zone (Donzeau and Beziat). The occurrence of gold in these settings where major shear zones cut through country rock and the An Nimas batholith are ideal settings for mineralization. The length and strength of these features in satellite imagery suggests that they are deeply rooted and therefore likely to act as major hydrothermal conduits.

The Al Hajar VMS deposit is composed of two mineralized areas, north and south, and is hosted by steeply dipping, moderately folded volcanic rocks including rhyodacitic pyroclastic rocks and flows, rhyolite, and mafic flows and dikes (Figure 27). Disseminated, veinlet and massive sulfide mineralization is hosted predominantly within hydrothermally altered (chloritized) rhyodacite. At Al Hajar North, a 160 m long by 40-90 m thick massive sulfide body occurs within a talcose and chlorite-rich zone. It, as well as the altered rocks, is cut by a stockwork sulfide zone. At Al Hajar South, the massive sulphides are less well defined - pyrite and pyrrhotite predominate with minor chalcopyrite, sphalerite, arsenopyrite and magnetite together with minor sulfide minerals and sulfosalts. The two gold deposits (Al Hajar North and Al Hajar South) comprise one of the most significant gold resources in the southern Arabian shield. The mineralization is very fine-grained, between 5 and 45 microns, and is subhorizontal and occurs in the near-surface oxidized zone above 80 m. The deposits are zoned laterally from an exterior bleached facies (including volcanic rocks) to a ferruginous facies, and an innermost siliceous facies. This layering is documented in the VMS base metals chapter of this report in Figure 59. There is a vertical zonation from a 2 to 15 m-thick layer of sulfates overlying the protore sulfide mineralization, a 35 to 45 m-thick leached and residual oxidized zone, and a 0.5 to 10 m-thick surface zone comprising ferricrete, silcrete, and calcrete. As a zone of supergene gold enrichment overlying a VMS protore, the deposits is not orogenic in origin, however it does speak to the need to assess all gossans in the belt for significant gold enrichments irrespective of the geological setting. As also can be seen from the example of the Al Amar deposit, VMS deposits have the potential for late-stage epithermal or mesothermal gold-rich veins that may be separated in time from the original VMS system.


804800
804900
805000
41°55'0"
41°55'5"
2232500
2232400
2232300
20°9'55"
20°9'50"
NOT MAPPED
Legend
Alluvium, colluvium
Massive (quartz) - fluorite
Greisen
Greisen in pegmatite
Brecciated pegmatite
Pegmatite
Aplite
Massive quartz
Dionite
Diamond drillhole
AB-1 USGS series
CO-03 BRGM series
Profile of chip and / or channel sampling with gold value
0.5 - 1 g/t Au
> 1 g/t Au
Pit
Edge of exposure
Shaft / Ancient working
MODS Records (2014)
Precious Metals
Gold
After: Gonzeau and Bezat (1989)
Compiled from SGS sources and MODS (2015)
Jabal Al Abla
CO-02
CO-03
CO-04
AB-1
Scale 1 : 1,500
0 15 75
Metres
UTM WGS84 Zone 37N
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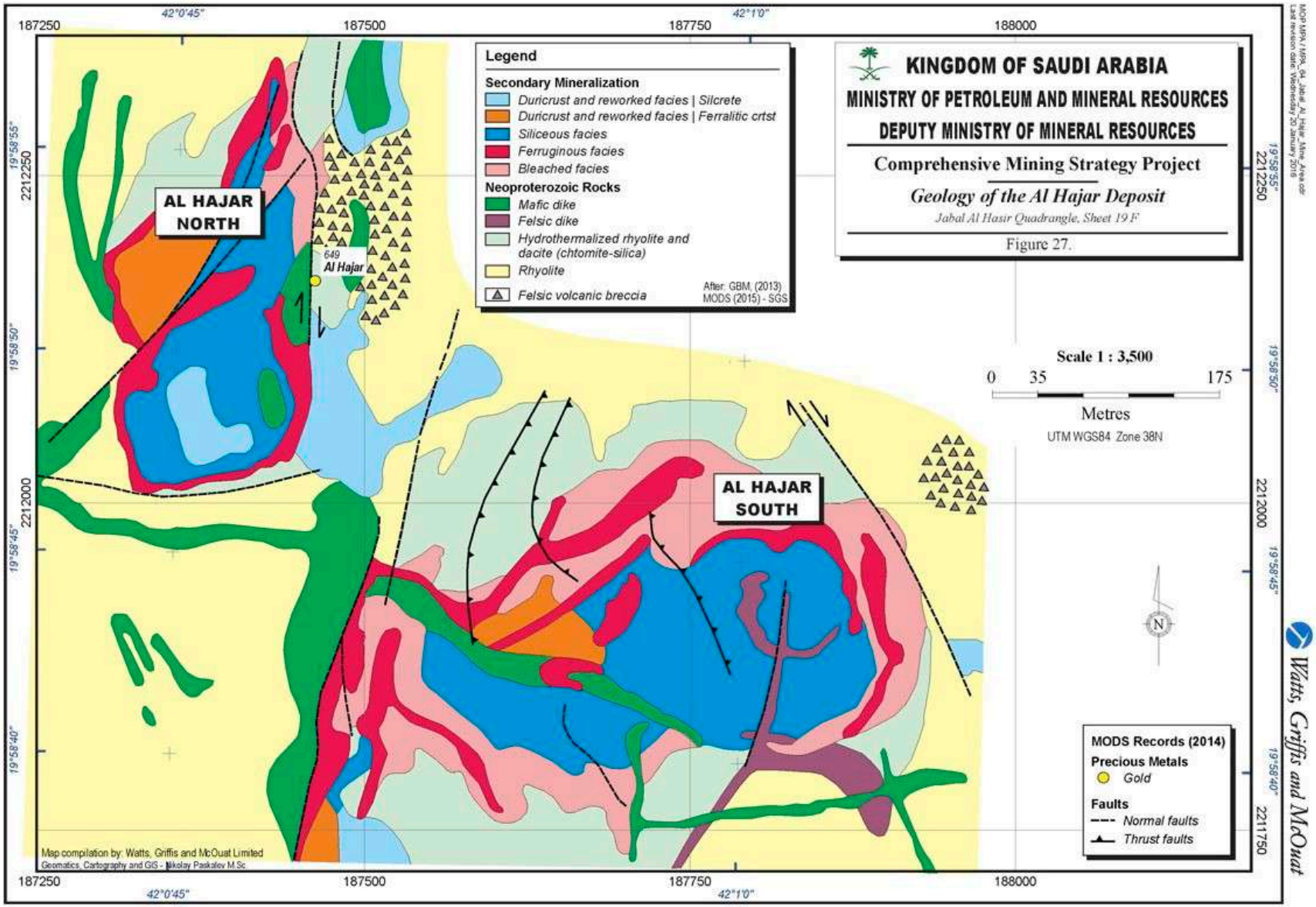
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Ancient Jabal Al Abla Gold-Fluorite Mine
Figure 26.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
Watts, Griffis and McOuat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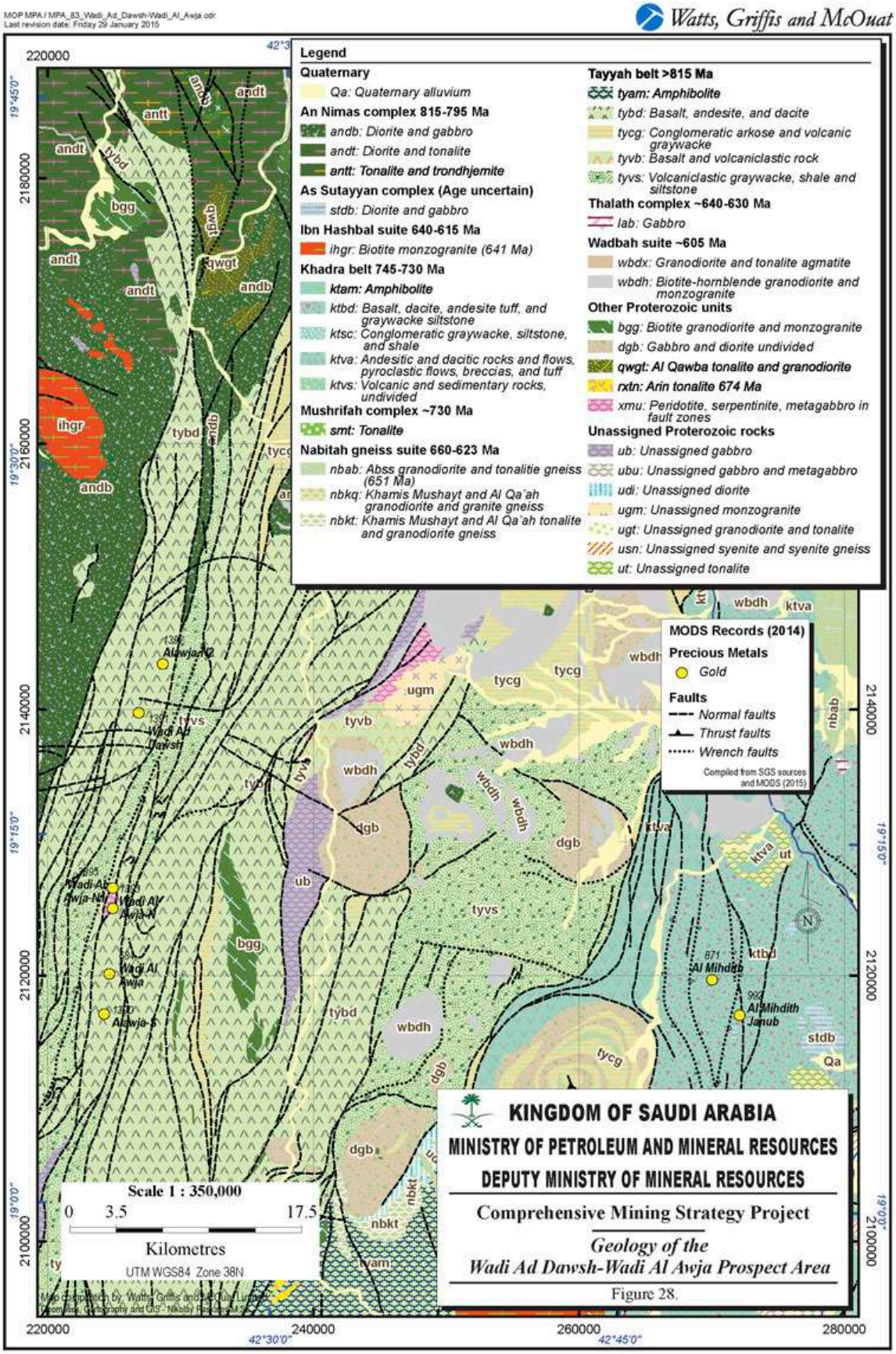
Comprehensive Mining Strategy Project
Geology of the Al Hajar Deposit
Jabal Al Hasir Quadrangle, Sheet 19 F
Figure 27.
Legend
Secondary Mineralization
Duricrust and reworked facies | Silcrete
Duricrust and reworked facies | Ferralitic crtst
Siliceous facies
Ferruginous facies
Bleached facies
Neoproterozoic Rocks
Mafic dike
Felsic dike
Hydrothermalized rhyolite and dacite (chtomite-silica)
Rhyolite
Felsic volcanic breccia
After: GBM, (2013)
MODS (2015) - SGS
AL HAJAR NORTH
AL HAJAR SOUTH
649
Al Hajar
Scale 1 : 3,500
0 35 175
Metres
UTM WGS84 Zone 38N
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc
187250
187500
187750
188000
42°0'45"
42°1'0"
19°58'55"
19°58'50"
19°58'45"
19°58'40"
2212250
2212000
2211750
Watts, Griffis and McOuat

The Al Awja South and Al Awja N2 prospects are situated in the splay of the Wadi Shwas belt that wraps around the eastern margin of the An Nimas Batholith (Figure 28). Most of the orogenic gold occurrences also have silver and copper associations. The mineralization is hosted a belt of metavolcanic and metasedimentary rocks with serpentinite and talc-carbonate rock outcrop locally outcropping in the belt. The exception is the Al Farah occurrence which is hosted by plutonic rocks belonging to the An Nimas batholith near its contact with metavolcanic rocks. In detail, the Al Awja South, Wadi Al Awja North, Wadi Al Awja N1 and Wadi Al Awja N2 gold occurrences are hosted by a variety of mafic and ultramafic schists. Ancient workings are arranged along a strike of 15-20 km, on or in proximity to the major north-trending fault zone which can be traced for approximately 70km to the north and 100 km to the south (Ransom, 1981; Greenwood and others, 1986). At Al Awja N2, massive quartz veins in chlorite schist are approximately north-striking and dip westerly. One gossanous and locally copper-stained quartz vein is 200 m long, up to 10 m wide and carries pyrite and chalcopyrite. Ancient mine workings are present along the margin of the vein.

Four kilometers to the south at Wadi Ad Dawsh, a series of quartz veins generally striking NNW dip westerly at the contact between granophyre and An Nimas diorite. Quartz spoil, some containing pyrite, chalcopyrite, galena, tetrahedrite and sphalerite, is scattered over a distance of 800 m. At Wadi Al Awja N1, 13 km south of Wadi Al Awja N2, the main mine working is situated on a 50 m wide shear zone containing secondary copper mineralization and iron-rich altered wall rocks in an ultramafic lens with carbonatized, sheared contacts (Morfett, 1982). The Al Awja gold occurrence is located 4.8 km to the south and the Alawja-S prospect is another 3 km beyond that. Copper oxide-stained narrow shears and quartz-siderite zones are present in chlorite-sericite-siderite schists. Ancient workings are in zones up to 100 m long and 1-metre wide (Ransom, 1981). Pyrite, chalcopyrite and native gold are reported in narrow (1-12 cm) veins at Alawja-S, and pyrite-chalcopyrite mineralized shears at Wadi Al Awja. At the Wadi Al Awja North occurrence (Luqah, Luqan - MODS 1393), a large open mine working measuring 110 m by 4 m by 7 m was worked at a sheared contact between peridotite and andesite. The sheared hydrothermally altered peridotite is schistose, serpentinized, talcose, chloritized and/or carbonatized with local ankerite veining and potassic feldspathization. Copper and iron oxides, chalcocite, and asbolite (wad) are present. The zone is surrounded by a pyritic halo less than 3 m wide (Morfett, 1982).


MOP MPA / MPA_83_Wadi_Ad_Dawsh-Wadi_Al_Awja.odr
Last revision date: Friday 29 January 2015
Watts, Griffis and McOuat
Legend
Quaternary
Qa: Quaternary alluvium
An Nimas complex 815-795 Ma
andb: Diorite and gabbro
andt: Diorite and tonalite
antt: Tonalite and trondhjemite
As Sutayyan complex (Age uncertain)
stdb: Diorite and gabbro
Ibn Hashbal suite 640-615 Ma
ihgr: Biotite monzogranite (641 Ma)
Khadra belt 745-730 Ma
ktam: Amphibolite
ktbd: Basalt, dacite, andesite tuff, and graywacke siltstone
ktsc: Conglomeratic graywacke, siltstone, and shale
ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
ktvs: Volcanic and sedimentary rocks, undivided
Mushrifah complex ~730 Ma
smt: Tonalite
Nabitah gneiss suite 660-623 Ma
nbab: Abss granodiorite and tonalitie gneiss (651 Ma)
nbkq: Khamis Mushayt and Al Qa'ah granodiorite and granite gneiss
nbkt: Khamis Mushayt and Al Qa'ah tonalite and granodiorite gneiss
Tayyah belt >815 Ma
tyam: Amphibolite
tybd: Basalt, andesite, and dacite
tycg: Conglomeratic arkose and volcanic graywacke
tyvb: Basalt and volcaniclastic rock
tyvs: Volcaniclastic graywacke, shale and siltstone
Thalath complex ~640-630 Ma
lab: Gabbro
Wadbah suite ~605 Ma
wbdx: Granodiorite and tonalite agmatite
wbdh: Biotite-hornblende granodiorite and monzogranite
Other Proterozoic units
bgg: Biotite granodiorite and monzogranite
dgb: Gabbro and diorite undivided
qwgt: Al Qawba tonalite and granodiorite
rxtn: Arin tonalite 674 Ma
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubu: Unassigned gabbro and metagabbro
udi: Unassigned diorite
ugm: Unassigned monzogranite
ugt: Unassigned granodiorite and tonalite
usn: Unassigned syenite and syenite gneiss
ut: Unassigned tonalite
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Wrench faults
Compiled from SGS sources and MODS (2015)
Al Awja-N2
Wadi Ad Dawsh
Wadi Al Awja-N1
Wadi Al Awja-N
Wadi Al Awja
Al Awja-S
Al Mihdith
Al Mihdith Janub
Scale 1 : 350,000
0 3.5 17.5
Kilometres
UTM WGS84 Zone 38N
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the
Wadi Ad Dawsh-Wadi Al Awja Prospect Area
Figure 28.
220000
240000
260000
280000
2180000
2160000
2140000
2120000
2100000
19°45'0"
19°30'0"
19°15'0"
19°0'0"
42°30'0"
42°45'0"

Recommendations

The Jabal Al Abla detailed study by Kemp (1972), the drilling by the USGS reported by Allcott (1970) and other sampling studies have generally been satisfactory, however a substantial amount of the exploration results are missing from the records, especially detailed drill logs, which makes the outcome difficult to interpret. Exploration by the BGRM resulted in a good quality geological map, and its detailed sampling showed that gold mineralization was widely distributed in the greisens even if the assays were not by the optimum method. The gold potential of the Jabal Al Abla prospect was further tested by a more recent diamond drilling program (BRGM, 1990) but the amount of drilling was insufficient. The breccia pipe appears to decrease in diameter with depth, and partial assay values reported by the BRGM indicate that high-grade gold values do not continue down dip. Nevertheless, economically interesting gold values could easily extend down plunge to the east or west of the more recent drill holes. As much of the focus of previous exploration was directed towards base metals, the BRGM wadi-sediment geochemical sampling program should be reassessed and perhaps redone with a focus on gold and the use of an analytical method that is appropriate for gold (i.e. fire assaying).

The gold mineralization at Wadi Shirs South, Wadi Surum and Wadi Tabalah is associated with the An Nimas Batholith has been subjected to insufficient work to evaluate their potential. Neither geologic maps nor locations of samples were presented, and many of the occurrences are poorly described. No follow-up work has been done. Initial results from several of the occurrences, however, provide justification for further exploration. The gold mineralization at Wadi Tabalah is particularly interesting because the shear zones are devoid of sulfide mineralization. The occurrence and its surrounding area should be investigated in detail. It should be noted that all USGS gold analyses were by AA techniques, presumably following acid dissolution. Although gold contents of the occurrences are generally low (with the exception of Wadi Thlabah), more detailed sampling with fire assaying for gold is needed. The Wadi Surum and Wadi Shirs South gold occurrences lie on a fault zone which should be prospected along its entire length to identity targets for follow-up exploration.

The BRGM analysis of the supergene gold deposit at Al Hajar is thorough and well presented. All sample analytical data from trenches and diamond drill holes are given, and the presentation of geologic plans and drill hole sections is very good. In its original review in 1992, WGM recommended some additional exploration but agreed with the BRGM that the deposit had excellent mine-making potential and warranted additional exploration. WGM recommended continuing geophysical surveying to define targets at depth and additional drilling to the north and northeast down plunge from the defined deposit.

Although Ransom (1981) recommended additional work at Wadi Al Dawsh, Wadi Al Awja North and Wadi Al Awja N2, he dismissed the potential of the belt. Morfett (1982) concluded that the Wadi Al Awja North, Wadi Al Awja N2 and Wadi Al Dawsh occurrences had little potential, and recommended no further work. Despite these conclusions, WGM believes the area warrants further evaluation. The work to date appears to have vacillated between base metal and gold potential, and each must be addressed with appropriate exploration programs given that gold and base metals are controlled by two very different metallogenic

models. The presence of ultramafic rocks at Wadi Al Awja North and Wadi Al Awja N2, as well as metagabbro south of Al Awja South, indicate that the regionally extensive faults are deep-seated and probably favorable sites for hosting gold mineralization. As most of the ancient workings are copper-oxide stained, copper-free precious-metals mineralization may have been overlooked by both "ancient" and modern workers. A systematic approach to determining the gold potential is needed. The most interesting gold value in the region, 19.85 g/t across 2 m at Wadi Al Awja N2, has not been adequately investigated because most of the main stope was inaccessible due to debris. This mineralization will require careful structural mapping supported by geochemical sampling and geophysical surveying (IP) and then by diamond drilling for a proper evaluation. Other occurrences have not been thoroughly explored: only two samples were taken at Wadi Al Dawsh, and only eight grab samples were collected at Al Awja South. The analytical technique employed for gold is uncertain. Morfett (1982) refers to gold values as "assay values", but the standard Riofinex technique of acid digestion with an AA finish may have been used. Re-analysis of archived samples by fire assay procedures would be desirable but these samples have probably been long lost.

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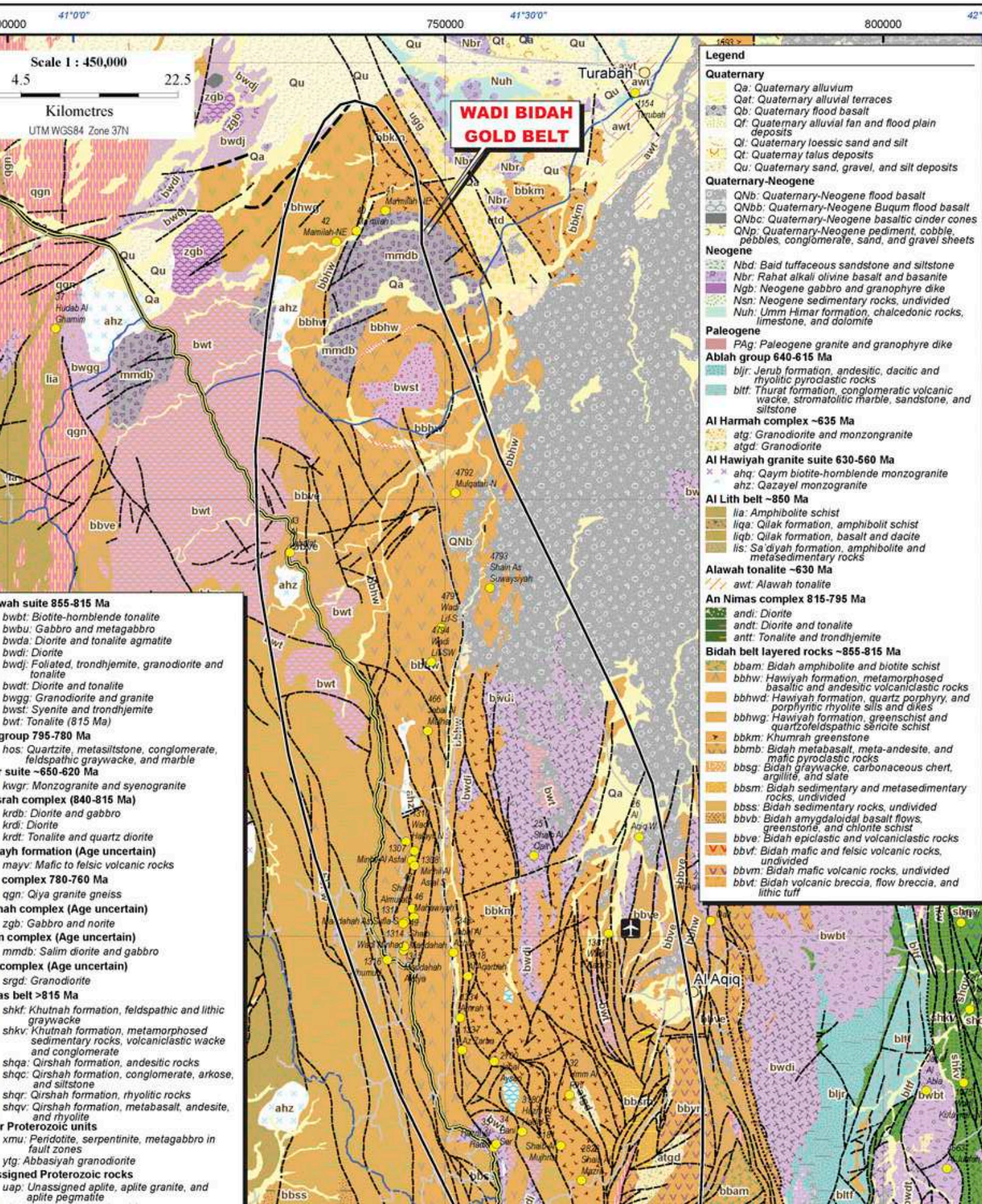
3.1.3.11 The Wadi Bidah Gold Belt

Location, Distribution of Occurrences and History

The northern end of the Wadi Bidah Gold Belt lies below thick aeolian sand cover on the western margin of Harrat Hadan. The most northerly gold occurrences are the three sites at Ma'milah and Ma'milah NE (MODS 0040-0042). The gold prospects are distributed along a NNW-SSE trending structural lineament with the Mulqatah-N occurrence 33 km to the south. The belt continues through the Al Qihab (formerly Gehab) and Shaib At Tayr area and through a cluster of prospects near Mahawiyah (formerly Abu al Maadan). The belt then deflects to the southeast, possibly as a result of Najd faulting, with a southern terminus near the city of Al Karra at the Wadi Al Mazra gold occurrence. The belt may rotate to the southwest at this point before passing over the escarpment south of Al Bahah. Its total length is estimated at 130-140 km. The gold belt parallels Wadi Bidah, but is offset approximately 5 km or more to the west. The structural complexity of the belt is evident in Figure 29.

Most are sites of ancient workings and consist mainly of quartz veins or stringers cutting cherty iron formation, metavolcanic rocks, or intrusions. The occurrences have been visited, sampled, and/or mapped by several exploration teams but few have been adequately tested by diamond drilling. A listing of the occurrences and their salient characteristics is given in Table 22. The highest gold value obtained was 314 g/t in a grab sample from the Bajila occurrence.

The earliest sampling of the Ma'milah prospects (0040-0042) was carried in the early 1930s. Schaffner, on behalf of SAMS, obtained values of up to 50.1 g Au/t from grab samples taken at ancient mine workings during the mid-1950s. The prospects were geologically mapped in the mid-1960s and samples of vein quartz were assayed producing gold values as high as 20.2 g/t (Smith, 1986). Following this, the USGS drilled two diamond drill holes totalling 335 m on the Central prospect, however the results were not encouraging and it was concluded that the veins pinch out along strike and down-dip (Kiilsgaard, 1976). Riofinex visited the prospects in the mid-1970s as part of a shield-wide mineral assessment, and produced a detailed assessment of the three prospects in the early 1980s (Gaukroger, 1983). A program of 1:1000-scale geological mapping of the prospects and 1:10,000-scale reconnaissance mapping was completed along with channel sampling and a review of the USGS drilling. Three follow-up diamond drill holes totalling 608 m were completed at Ma'milah Central. The best intersection was 2.6 g Au/t over 25 cm and no further work was recommended. During 1986, the BRGM carried out a program of channel sampling, percussion drilling (17 holes totalling 934 m) and diamond core drilling (4 holes totaling 157 m) to test the near-surface potential of Ma'milah Central (Coumoul, Beziat, and others, 1989). Measured resources to a depth of 50 m were estimated at 237,041 tonnes grading 4.11 g Au/t, however the results of this work did not meet the BRGM objectives of defining 1.5-2.0 t of gold exploitable by open pit methods and consequently the site was abandoned.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WADI BIDAH
GOLD BELT
Turabah
Al Aqiq
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qb: Quaternary flood basalt
Qf: Quaternary alluvial fan and flood plain deposits
Ql: Quaternary loessic sand and silt
Qt: Quaternay talus deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
QNbb: Quaternary-Neogene Buqum flood basalt
QNbc: Quaternary-Neogene basaltic cinder cones
QNp: Quaternary-Neogene pediment, cobble, pebbles, conglomerate, sand, and gravel sheets
Neogene
Nbd: Baid tuffaceous sandstone and siltstone
Nbr: Rahat alkali olivine basalt and basanite
Ngb: Neogene gabbro and granophyre dike
Nsn: Neogene sedimentary rocks, undivided
Nuh: Umm Himar formation, chalcedonic rocks, limestone, and dolomite
Paleogene
PAg: Paleogene granite and granophyre dike
Ablah group 640-615 Ma
bljr: Jerub formation, andesitic, dacitic and rhyolitic pyroclastic rocks
bltf: Thurat formation, conglomeratic volcanic wacke, stromatolitic marble, sandstone, and siltstone
Al Harmah complex ~635 Ma
atg: Granodiorite and monzongranite
atgd: Granodiorite
Al Hawiyah granite suite 630-560 Ma
ahq: Qaym biotite-hornblende monzogranite
ahz: Qazayel monzogranite
Al Lith belt ~850 Ma
lia: Amphibolite schist
liqa: Qilak formation, amphibolit schist
liqb: Qilak formation, basalt and dacite
lis: Sa'diyah formation, amphibolite and metasedimentary rocks
Alawah tonalite ~630 Ma
awt: Alawah tonalite
An Nimas complex 815-795 Ma
andi: Diorite
andt: Diorite and tonalite
antt: Tonalite and trondhjemite
Bidah belt layered rocks ~855-815 Ma
bbam: Bidah amphibolite and biotite schist
bbhw: Hawiyah formation, metamorphosed basaltic and andesitic volcaniclastic rocks
bbhwd: Hawiyah formation, quartz porphyry, and porphyritic rhyolite sills and dikes
bbhwg: Hawiyah formation, greenschist and quartzofeldspathic sericite schist
bbkm: Khumrah greenstone
bbmb: Bidah metabasalt, meta-andesite, and mafic pyroclastic rocks
bbsg: Bidah graywacke, carbonaceous chert, argillite, and slate
bbsm: Bidah sedimentary and metasedimentary rocks, undivided
bbss: Bidah sedimentary rocks, undivided
bbvb: Bidah amygdaloidal basalt flows, greenstone, and chlorite schist
bbve: Bidah epiclastic and volcaniclastic rocks
bbvf: Bidah mafic and felsic volcanic rocks, undivided
bbvm: Bidah mafic volcanic rocks, undivided
bbvt: Bidah volcanic breccia, flow breccia, and lithic tuff
wah suite 855-815 Ma
bwbt: Biotite-hornblende tonalite
bwbu: Gabbro and metagabbro
bwda: Diorite and tonalite agmatite
bwdi: Diorite
bwdj: Foliated, trondhjemite, granodiorite and tonalite
bwdt: Diorite and tonalite
bwgg: Granodiorite and granite
bwst: Syenite and trondhjemite
bwt: Tonalite (815 Ma)
group 795-780 Ma
hos: Quartzite, metasiltstone, conglomerate, feldspathic graywacke, and marble
suite ~650-620 Ma
kwgr: Monzogranite and syenogranite
srah complex (840-815 Ma)
krdb: Diorite and gabbro
krdi: Diorite
krdt: Tonalite and quartz diorite
ayh formation (Age uncertain)
mayv: Mafic to felsic volcanic rocks
complex 780-760 Ma
qgn: Qiya granite gneiss
hah complex (Age uncertain)
zgb: Gabbro and norite
n complex (Age uncertain)
mmdb: Salim diorite and gabbro
complex (Age uncertain)
srgd: Granodiorite
as belt >815 Ma
shkf: Khutnah formation, feldspathic and lithic graywacke
shkv: Khutnah formation, metamorphosed sedimentary rocks, volcaniclastic wacke and conglomerate
shqa: Qirshah formation, andesitic rocks
shqc: Qirshah formation, conglomerate, arkose, and siltstone
shqr: Qirshah formation, rhyolitic rocks
shqv: Qirshah formation, metabasalt, andesite, and rhyolite
r Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
ytg: Abbasiyah granodiorite
ssigned Proterozoic rocks
uap: Unassigned aplite, aplite granite, and aplite pegmatite

Table 22
Name and Location of Gold Occurrences – Wadi Bidah Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
0041	Ma'milah-NE	Ma'milah-NE	Gold	41.3402500	21.0822500	Turbah	Med	Dd, v
0040	Ma'milah	Ma'milah	Gold	41.3084720	21.0616940	Turbah	Med	Dd, v
0042	Mamilah-NE	Ma'Malah-SE	Gold	41.2860000	21.0508890	Turbah	Med	Dd, v
4792	Mulqatah-N	Mulgatah-W	Gold	41.4126110	20.7893890	Turbah	Low	Uncertain
0043	Al Jabalat	Bajila	Gold	41.2301940	20.7302780	Turbah	Low	Uncertain
4793	Shain As Suwaysiyah	Abu Sulal	Gold	41.4490000	20.6907780	Turbah	VL	Uncertain
0468	Al Qihab	Al Qihab	Copper-Gold	41.3928890	20.6827500	Al Aqiq	Low	Lenses
4791	Wadi Lif-S	Southeast Wadi Laif	Gold	41.3945280	20.6502500	Al Aqiq	Undefined	Uncertain
4794	Wadi Lif-SW	North Shaib At Tair	Gold	41.3833330	20.6150000	Al Aqiq	Med	Uncertain
0464	Shaib At Tayr	Sha'Ab At Tare	Copper-Gold	41.3894440	20.5966670	Al Aqiq	Med	Lenses
0466	Jabal Al Malha	Mulhal	Gold	41.3784720	20.5439720	Al Aqiq	Undefined	Structural
1310	Wadi Halayil N	Khayal Al Masna'Ah	Gold	41.3527780	20.4305560	Al Aqiq	VL	Shear zone
1309	Wadi Halaiyil	Umm Al Janadal	Gold	41.3616670	20.4208330	Al Aqiq	VL	Structural
1307	Minhil Al Asfal	Bal Maadan	Gold	41.3591670	20.4111110	Al Aqiq	VL	Structural
1308	Minhil Al Asfal S	Shiab Al Wial	Gold	41.3616670	20.4055560	Al Aqiq	Undefined	Structural
0047	Shaib Almurath	Asswada	Gold	41.3583330	20.3611110	Al Aqiq	Low	Uncertain
0046	Mahawiyah	Abu Al Maadan	Gold	41.3605560	20.3522220	Al Aqiq	Low	Shear zone
1313	Mandahah As Sufla-S	Abu Suddra	Gold	41.3502780	20.3475000	Al Aqiq	Undefined	Strata
1314	Wadi Minhad	Argub	Gold	41.3486110	20.3458330	Al Aqiq	Undefined	Shear zone
1315	Mandahah Alulya	Jabal Al Ahmar	Gold	41.3491670	20.3222220	Al Aqiq	Undefined	Structural
0049	Shaib Mandahah	Wadi Mandahah	Copper	41.3486110	20.3180560	Al Aqiq	Med	Structural
1343	Jabal Al Azhar	Jabal Al Azhar	Gold	41.4027780	20.3152780	Al Aqiq	Undefined	Shear zone
1316	Alhumud	Al Bannan	Gold	41.3305560	20.3086110	Al Aqiq	Undefined	Shear zone
1318	Al Aqarbah	Sh'ab Anhal	Gold	41.4183330	20.2905560	Al Aqiq	Undefined	Structural
1334	Amrah	Al Arwaq	Gold	41.4091670	20.2477780	Al Aqiq	Undefined	Strata
1337	Az Zarba	Jabal Isan	Gold	41.4108330	20.2141670	Al Aqiq	Med	Shear zone
2700	Jabal Aysan	Haffa Abith	Gold	41.4455560	20.2022220	Al Aqiq	Undefined	Structural
3180	Hazm Al Hadid-E	Waiss	Gold	41.4750000	20.1291670	Al Aqiq	Undefined	Uncertain
0035	Hazm Al Hadid	Hazim Al Hadid	Gold	41.4466670	20.1166670	Al Aqiq	Low	Shear zone
3181	Shaib Al Mujhris	Jabal Gahab	Gold	41.5172220	20.1136110	Al Aqiq	Undefined	Structural
0034	Bani Sar	Bani Sar	Gold	41.4441670	20.1130560	Al Aqiq	Med	Shear zone
2826	Shaib Al Mazra	Shaib Al Mazra	Gold	41.5392220	20.0778330	Al Aqiq	Undefined	Uncertain

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins; Strata = stratigraphic control

The same course of action occurred over the ancient workings at Al Qihab (also "Gehab") where gossans were first noted in the early 1960s (0468), and where the site was abandoned after a protracted period of investigation. During the early work, a l:l,000 scale geological map of the prospect was created by the BRGM and the workings and gossans were grab sampled. This program also included five diamond drill holes (total 808 m) to test the base-metal potential (Earhart and Mawad, 1970). Two holes intersected massive and disseminated sulfides, with the best section assaying 1.54% Cu, 1.18% Zn, 1.37 g Au/t and 5.66 g Ag/t over 12.2 m. During the mid-1970s, exploration continued by the USGS with limited programs of geological mapping and geophysical surveying (Turam) as well as four additional diamond drill holes

totalling 728 m. Subsequently, the base-metal potential of the Wadi Bidah district was reassessed and the Gehab gossans were sampled by Riofinex which downgraded the prospect and recommended no further work (Riofinex, 1979a). Nevertheless, a program of mapping, trenching (295 m), geophysical surveying (IP and SP), geochemical surveying and drilling was carried out in an effort to evaluate the gold potential of the gossans (Roubichou and others, 1989). Forty-seven very short percussion drill holes (2,339 m) were completed with recoveries ranging from 8% to 181% giving clear evidence of how this technique is unsuitable for sampling purposes. Samples were analyzed for gold by the AA method, and an inferred resource of 293,000 t grading 4.02 g Au/t was estimated to a depth of 30 m.

During a regional evaluation of the Wadi Bidah area, the Shaab at Tayr prospect (0464) and surrounding area were first mapped in detail by Earhart and Mawad, at 1:1,000 scale. During 1967, three holes totaling 228.5 m were diamond core drilled in to test the down dip potential of the surface gossan. Two of the holes stopped short of the target for technical reasons. Core recovery was generally poor, averaging 58.4% in the successful hole. A follow-up EM survey over the prospect detected several anomalous responses coincident with the mineralization (Kazzaz, 1969). Additional SP surveying located anomalies that were coincident with the sulfide mineralization. Subsequently, two holes totalling 250 m were diamond drilled to test the geophysical anomalies down dip from surface gossans. The best intersection assayed 0.61% Cu and 2.13% Zn over 11.8 m. Subsequent sampling of the gossans for gold detected values as high as 6.8 g/t and the BRGM chip sampled the gossans during 1986 after excavating 1,212 m of trenches. Shallow percussion drilling (18 holes totalling 697 m) and core drilling (26 holes totaling 1,168 m) demonstrated that the zone was subeconomic (Coumoul, Abdulhay, and Roubichou, 1989).

The Jabal Al Malha (formerly Mulhal) prospect (0466) was mapped during the early 1960s at 1:12,500 scale with additional EM surveys over parts of the prospect which failed to detect any significant conductors. Several subsequent exploration programs included detailed mapping down to 1:500 scale. As part of a regional geochemical survey targeted at assessing gold potential, the Mulhal prospect was sampled, the results of which showed that high precious-metal values up to 29.6 ppm Au were associated with barite-bearing rocks. Roubichou and others (1989) conducted an exploration program over the prospect to assess the gold potential of the gossan. Detailed mapping, trenching and IP surveying followed outlining anomalous gold values over widths of up to 25.6 m along an explored strike length of approximately 250 m. No clearly defined anomalies were outlined by the IP surveys and the resource potential was estimated at 100,000 t grading 4-5 g Au/t to a depth of 5 m (Coumoul, Abdulhay and Roubichou). Follow-up mapping and EM surveying by the USGS gave a few anomalies and low gold values resulting in the prospect being downgraded in respect to its potential.

As a result of site visits during the 1960s and ‘70s, the Shaib Mandahah (formerly Wadi Mandahah) prospect area (0049) and its ancient workings were described in a number of documents. Mawad (1980) mapped the prospect at 1:2,500 scale, chip sampling the gossan, and completing SP and EM (Turam) and rock geochemical surveys. Four diamond drill holes totalling 887.4 m were completed. The drilling demonstrated that the gossan was developed on a zone of disseminated pyrite, chalcopyrite, sphalerite,

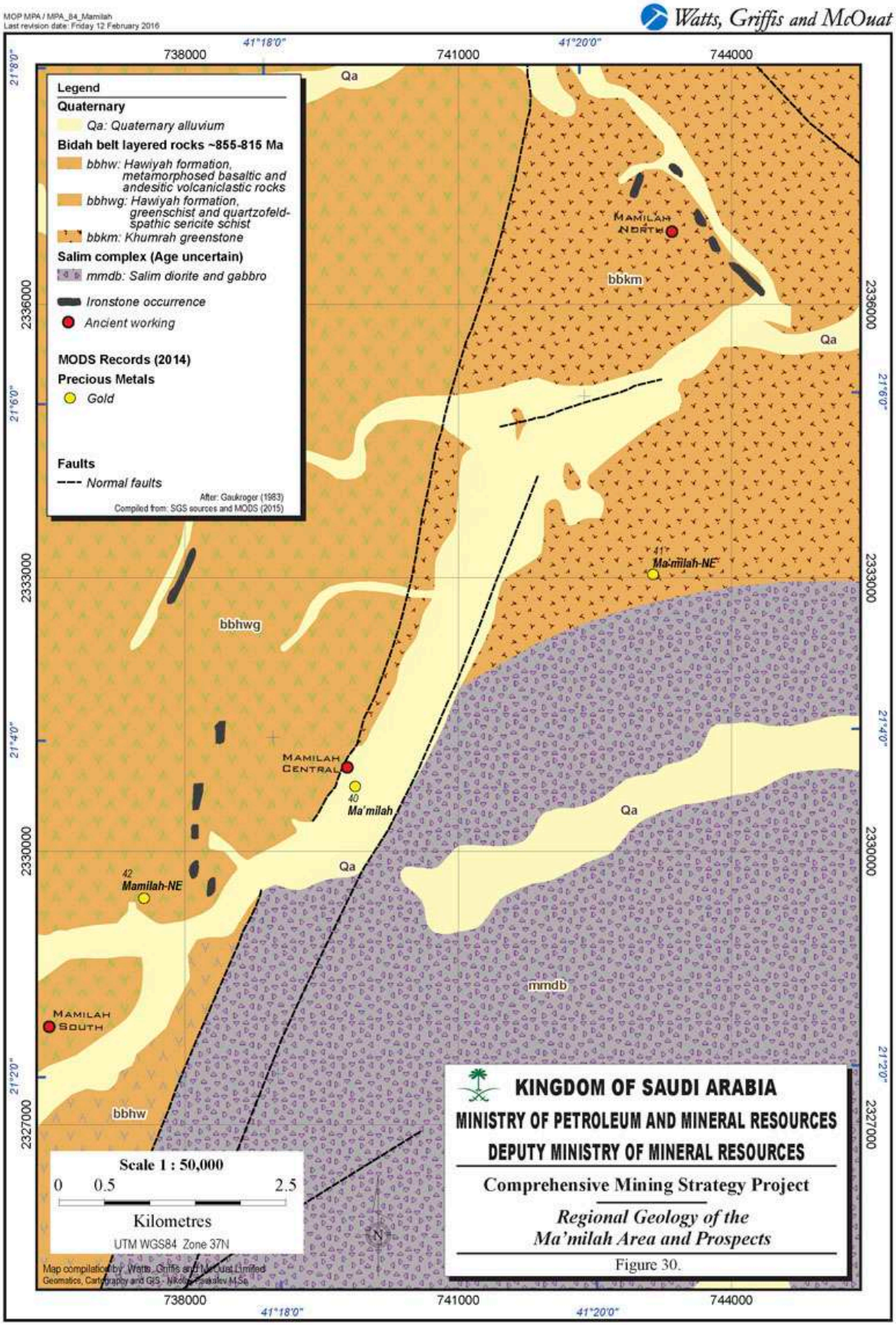
and galena. The best drill hole intersection was 2.05 m averaging 0.30% Cu and 4.6% Zn. Gold values were not reported.

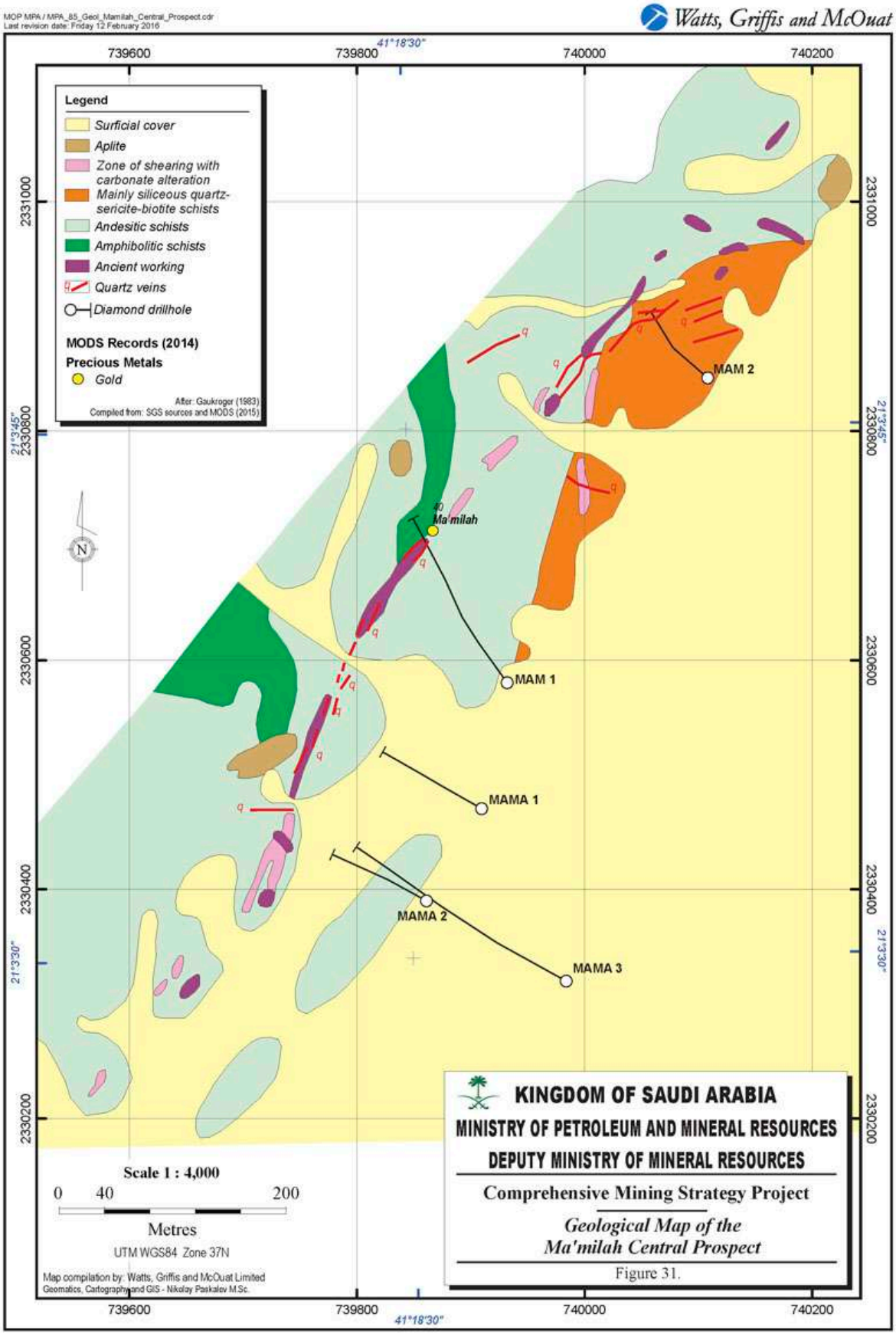
The other prospects distributed along the southern part of the gold belt have received little or no attention except for chip sampling. Gold was found in all occurrences except for the Jabal Gahab site (3181) where no gold values were detected. The Bani Sarr prospect (0034), located near the southern end of the belt, was explored. Sixty channel samples were collected across the mineralized zone and contained grades as high as 22 g Au/t with an average of 2 g Au/t (Goldsmith, 1971). The mapping of a 275 m section of the zone, the collection of five dump samples and 20 traverse samples is reported by Worl and Smith (1982). Dump samples produced gold assays as high as 13.8 g/t, and the traverse samples produced assays up to 11.4 g Au/t over 25 m. Further work was recommended but there is no record available to WGM to indicate that any additional work was completed.

Geology

Ancient workings at Ma'milah occur in three groups on single or multiple quartz veins cutting metasedimentary and metavolcanic rocks. A shallowly dipping, 1-metre wide quartz vein at Mamilah North (0041) can be traced for about 240 m (Figure 30). Ancient mine dump samples contain disseminated chalcopyrite and covellite. The Central workings (Figure 31) are sited on a massive quartz vein up to 12 m wide containing disseminated chalcopyrite with minor pyrite, covellite, and malachite. The vein is traceable for 920 m, striking NNE parallel to the cleavage and foliation of the host amphibolite schists. The host rocks are chlorite altered and the prospect is thought to be located on a major, N-trending shear zone characterized by strong pervasive carbonate alteration. The South prospect (0042) has mineralization very similar to that at the Central prospect, and it is spatially associated with the same structure. The ancient mine workings are located on a quartz vein approximately 3 m wide that crops out intermittently for about 1.2 km. Coumoul, Beziat and others (1989) estimated that the Mamilah Central prospect contains measured resources of 237,041 t averaging 4.11 g Au/t.

The Al Qihab prospect (0468) is located about 10 km north of the Shaib at Tayr prospect in an area where conformable gossans as wide as 5 m are present over a strike length of about 700 m. The gossans are hosted by a sequence of intercalated intermediate to felsic pyroclastics, flows and volcanogenic sediments. Riofinex estimated that the prospect contained a mineral resource of 1.0-1.9 Mt grading 0.64-1.26% Cu and 1.45% Zn (Riofinex (1979). Roubichou and others (1989) evaluated the gold potential of the gossans, and calculated the geologic potential to be 293,059 t grading 4.02 g Au/t. The geology is such that there exists potential for either a polymetallic, gold-bearing deposit or a structurally controlled gold deposit.

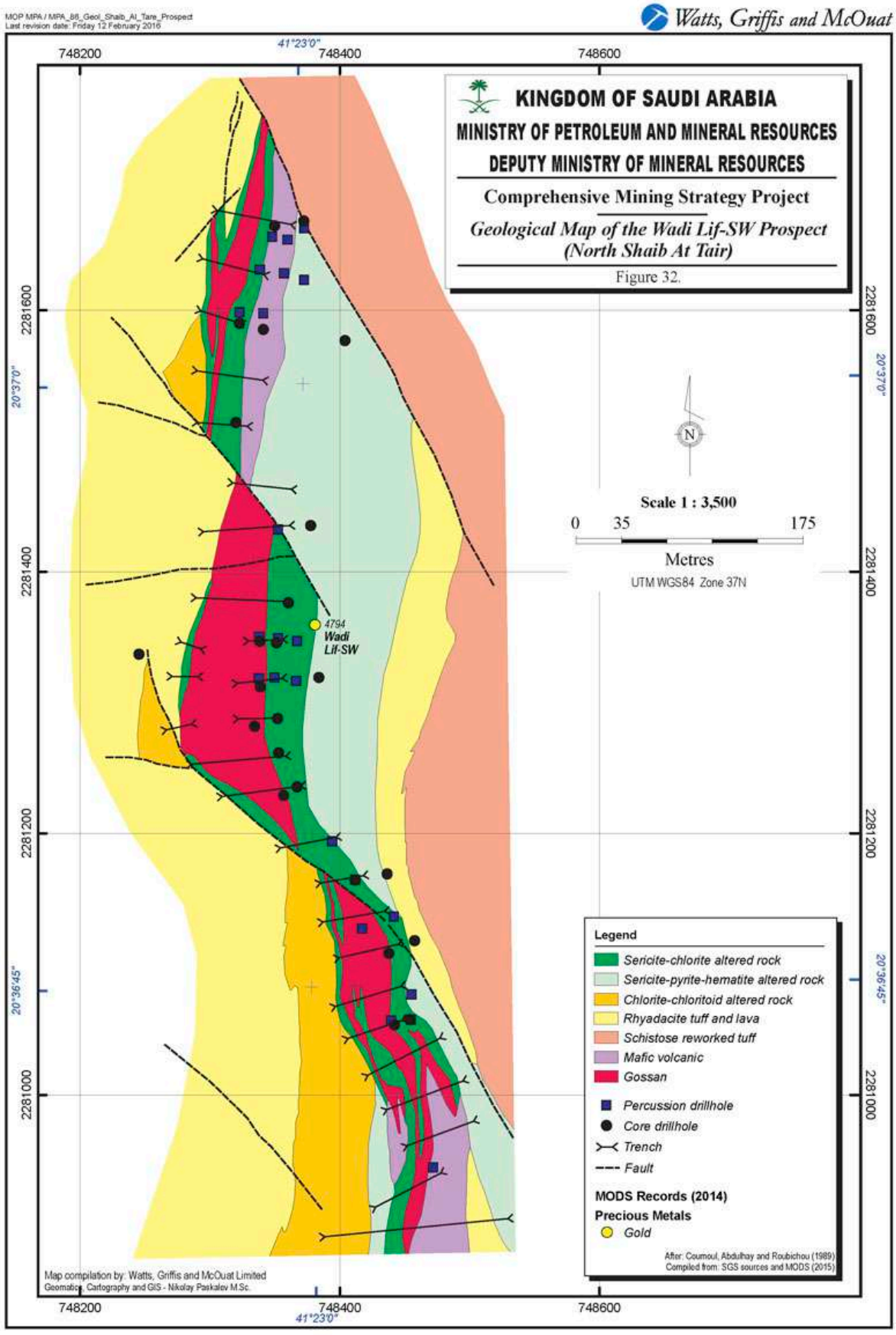

MOP MPA / MPA_84_Mamilah
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
738000
741000
744000
41°18'0"
41°20'0"
21°8'0"
21°6'0"
21°4'0"
21°2'0"
2336000
2333000
2330000
2327000
Legend
Quaternary
Qa: Quaternary alluvium
Bidah belt layered rocks ~855-815 Ma
bbhw: Hawiyah formation, metamorphosed basaltic and andesitic volcaniclastic rocks
bbhwg: Hawiyah formation, greenschist and quartzofeldspathic sericite schist
bbkm: Khumrah greenstone
Salim complex (Age uncertain)
mmdb: Salim diorite and gabbro
Ironstone occurrence
Ancient working
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
After: Gaukroger (1983)
Compiled from: SGS sources and MODS (2015)
Qa
bbkm
bbhwg
bbhw
mmdb
MAMILAH NORTH
MAMILAH CENTRAL
MAMILAH SOUTH
41 Ma'milah-NE
40 Ma'milah
42 Mamilah-NE
Scale 1 : 50,000
0 0.5 2.5
Kilometres
UTM WGS84 Zone 37N
N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Poussaliev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Regional Geology of the Ma'milah Area and Prospects
Figure 30.


MOP MPA / MPA_85_Geol_Mamilah_Central_Prospect.cdr
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
739600
739800
41°18'30"
740000
740200
2331000
2330800
2330600
2330400
2330200
21°3'45"
21°3'30"
Legend
Surficial cover
Aplite
Zone of shearing with carbonate alteration
Mainly siliceous quartz-sericite-biotite schists
Andesitic schists
Amphibolitic schists
Ancient working
Quartz veins
Diamond drillhole
MODS Records (2014)
Precious Metals
Gold
After: Gaukroger (1983)
Compiled from: SGS sources and MODS (2015)
N
Ma'milah
MAM 2
MAM 1
MAMA 1
MAMA 2
MAMA 3
Scale 1 : 4,000
0 40 200
Metres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Map of the
Ma'milah Central Prospect
Figure 31.

At Shaib al Tayr, three separate limonite-hematite gossans up to 34 m wide extend along strike for a distance of approximately 600 m (Figure 32). Lesser minerals include jarosite, malachite, barite and carbonates. The gossans developed from massive to disseminated sulfides, including pyrite, chalcopyrite, sphalerite and galena, with minor sulfosalts, tellurides and oxides. The mineralization is primarily stratabound and is hosted by a northerly trending intercalated series of meta-rhyolite, quartz-sericite schist and chlorite schist. These rocks are sheared and folded along a north-trending axis. A mineral resource of 2.4 Mt grading 0.37% Cu and 0.5% Zn, with minor Pb and Ag was estimated by Riofinex. The gold potential of the gossan was re-assessed by the BRGM which estimated the measured resources to be 299,530 t at 6.27 g Au/t (Coumoul, Abdulhay and Roubichou, 1989).

The Jabal al Malha gold prospect (0466), which was previously known as Mulhal, comprises a group of ancient workings developed on a series of stratiform gossans hosted in a sequence of NE-trending intermediate to felsic flow and pyroclastic rocks. The host rocks have been sheared and extensively silicified, sericitized and pyritized (with associated arsenopyrite), and they contain irregularly distributed lenses of rock rich in chromium mica (Smith and others, 1983). The main gossan, which composed mainly of goethite and hematite and minor malachite, barite, galena, pyrite, and chalcopyrite, is intermittently exposed over a strike length of about 200 m and averages 8 m in width. The shear zone can be traced approximately 8 km north from the Jabal al Malha prospect. Intense deformation has resulted in tight, north-trending folds with amplitudes of a few metres. Samples of gossanous material returned gold values of 10.3 to 42.50 g/t (up to 1.24 oz/ton !) with 0.16% to 2.3% Cu. Subsequent sampling returned similar values (Smith and others). The Jabal Mohr copper prospect (2827) is located about 3.6 km north-northeast of the Jabal al Malha prospect on the northern extension of the zone that hosts the gold mineralization. A gossan is exposed intermittently for a distance of about 500 m along strike and it is partially exposed in outcrop widths up to 20 m. The gossan is composed of hematite, goethite, and jarosite with minor secondary copper minerals and is hosted by altered felsic tuff. Gold is associated with gossanous material as well as pyritic, hydrothermally-altered felsic volcanic rock.

The Wadi Mandahah copper prospect (0049) is located on a north-striking, west-dipping limonite gossan about 300 x 10 m in size. The ancient workings are as much as 70 m deep and are developed on malachite and chrysocolla mineralization in relatively soft chlorite ± sericite ± quartz schist. The gossan is composed of limonite, with variable amounts of malachite and chrysocolla. Chip samples returned values up to 48,500 ppm Cu, 6,500 ppm Zn, and 780 ppm Pb. Gold values are not reported although the heavily sheared character of the host rock suggests a potential for gold.


MOP MPA / MPA_86_Geol_Shaib_Al_Tare_Prospect
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Map of the Wadi Lif-SW Prospect
(North Shaib At Tair)
Figure 32.
Scale 1 : 3,500
0 35 175
Metres
UTM WGS84 Zone 37N
4794
Wadi
Lif-SW
Legend
Sericite-chlorite altered rock
Sericite-pyrite-hematite altered rock
Chlorite-chloritoid altered rock
Rhyadacite tuff and lava
Schistose reworked tuff
Mafic volcanic
Gossan
Percussion drillhole
Core drillhole
Trench
Fault
MODS Records (2014)
Precious Metals
Gold
After: Coumoul, Abdulhay and Roubichou (1989)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
748200
748400
748600
41°23'0"
2281600
2281400
2281200
2281000
20°37'0"
20°36'45"

The Bani Sarr gold prospect (0034) is composed of a cluster of ancient workings that are developed along quartz veins over a distance of 2.5 km. The quartz veins are hosted by a dioritic intrusion which locally exhibits strong north-trending shearing of a type that probably associates with Nabitah tectonics. The vein system consists of two parallel quartz veins 1-5 m apart and apparently following older mafic dikes. A zone of alteration and quartz veining separates the two veins. Channel samples across the mineralized zone gave assays as high as 22 g Au/t although average values were much lower at 2 g/t. Dump samples produced gold assays as high as 13.8 g/t. Importantly, however, more systematic traverse (trench?) samples produced assays up to 11.4 g Au/t over 25 m. Further work was recommended but there is no record available to WGM to indicate that any additional work was completed.

Recommendations

The prospects in the belt have generally been well prospected and there are no apparent short-comings in the general level of sampling or mapping by the BRGM and the USGS. For example, the three Ma'milah prospects have been well mapped at a variety of scales and some of the mapping is quite detailed although in some cases the mineralized zone extends beyond the area of the mapping such that the full extent of the gold-bearing zones has not been adequately covered. The geophysical surveying used techniques that were probably considered appropriate at the time, but have since fallen out of use in favour of more effective techniques. For example, in respect to gold exploration, SP and Turam surveying has largely been superseded by IP surveying. The IP surveying that was completed was reconnaissance scale, and probably lacked the power generation and penetration capabilities of modern day equipment. Reflecting the fact that the exploration was oriented towards shallow targets, the drilling programs were inadequate for many reasons in addition to the fact that they were highly focused and tested only very shallow targets. Percussion drilling is completely unacceptable as a means of exploring for gold. The heavy reliance on such drilling at Ma'milah, Al Qihab and Shaib At Tayr means that large portions of these prospects are essentially untested even though some diamond drilling was completed.

The BRGM drilled 19 percussion holes at Mamilah Central and even where the percussion holes were redrilled using core drilling methods (2 holes), significant differences in grade, width, and number of intersections were recorded (Coumoul, Beziat and others, 1989). Variations of up to 87% were noted which is unacceptable by any measure. In addition to this, there is little or no work between the Ma'milah prospects and so additional work is needed to further evaluate the gold potential of the ancient site. None of the Riofinex or BRGM resource estimates are considered to be compliant with existing international standards.

At the Al Qihab prospect, the USGS diamond drilling program successfully intersected base and precious-metal sulfide mineralization in two holes however the reliance on percussion drilling means that the gossan mineralization was not adequately tested. WGM is also uncertain whether the samples were fire assayed or simply digested prior to the instrumental AA analysis, a common problem with gold assaying in the Kingdom up to the mid-1990s.

At Shaib at Tayr, the favorable alteration zone extends beyond the mapped area, both to the north and south and the coverage of the IP surveying is insufficient to properly delineate the gold-bearing zone. The effectiveness of the diamond core drilling by the USGS was severely degraded by poor core recovery. Percussion drilling by BRGM tested mainly the oxidized gossan mineralization at very shallow depths. This work confirmed the trace of the gossans for approximately 600 m, and demonstrated that the supergene zone extends to a depth of about 45 m. Due to poor recoveries and possible cavitation, the BRGM concluded that this program was a failure and the results unreliable. The core drilling program provided better results with calculated recoveries ranging between 33% and 100% but the adequacy is questionable due to the probably loss of mineralized sections, the probably presence of coarse nuggety (irregularly distributed) gold and the BRGM's practice of selecting only one quarter of the core for analysis. The BRGM demonstrated that some of the gold is encapsulated in silica grains which could isolate it from the aqua regia digestion employed with the atomic absorption analytical method. This has the potential to introduce substantial bias into the results. For resource calculations a density of 2.25 was assumed for the auriferous sugary facies gossan material. However, this contrasts with the measured density of 2.50 for similar material at Al Hajar and suggests that the resource calculation may be understated. Further work is required to fully define the extent of both the sulfide and oxide mineralization at Shaib at Tayr.

Exploration by the USGS and BRGM established Jabal al Malha (Mulhal) as a significant gold and base metal prospect. The results of the IP survey were not available for review. Most of the gold analyses were carried out using the atomic absorption method, which may be inadequate given the siliceous nature of some of the gossans, with probable encapsulation of gold particles and thus incomplete digestion. At Jabal Mohr, a base metals prospect nearby, the USGS outlined a gossan anomalous in metals and coincident with geophysical anomalies. The gossan is hosted by a hydrothermally altered sequence of volcanic rocks known to host massive sulfide mineralization in the general area. Additional exploration is needed to more fully assess the gold and base metal potential of the area.

At Shaib Mandahah, geochemical and geophysical anomalies extend beyond the mapped area, and the strongest EM conductor and coincident geochemical response remain untested by any of the drill holes. One of the drill holes lost 1.2 m of core, probably within the mineralized zone. The work carried out did not adequately test many of the favorable targets, and so further exploration drilling is warranted.

At Bani Sarr, the work by the USGS defined a large gold-bearing structure. The limited exploration so far has not been sufficient to outline the geology and nature of the mineralized system. Additional exploration involving geophysical or geochemical surveys, and drilling to evaluate the subsurface extent of the zone is warranted.

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3.1.3.12 Al Wuhayti-Umm Ash Shalahib Belt

Location, Distribution of Occurrences and History

The Al Wuhayti-Umm Ash Shalahib gold belt is located in the Arabian Shield near its most easterly exposed extent. The belt includes a large number of gold occurrences and a few silver occurrences (e.g. Jabal Al Wuhayti – MODS 0164) which are situated along or adjacent to the Al Amar-Idsas Fault zone (Figure 33). This gold-bearing structural zone can be traced for approximately 165 km and represents the suture formed during the collision of the Ar Rayn and Ad Dawadimi Terranes. The structural break is marked by a series of hills, locally a NNW-trending scarp which is clearly visible on satellite imagery, however the major structure is not well exposed and is generally buried by alluvial fans. The gold occurrences are found along the entire trace of the fault zone extending from the northern margin of the exposed Shield, beyond which it is covered by Phanerozoic strata, to its southern margin where it is similarly hidden. Individual occurrences are summarized in Table 23.

A few of the major occurrences in the gold belt were the sites of ancient mining activities such as Jabal Al Wuhayti (MODS 0164), previously known as Jabal al Utaybi or simply At Taybi. Initially, the prospect was known as a base metal occurrence due to the presence of ancient mine workings. The early exploration was carried out by the BRGM during the late 1970s and comprised detailed 1:5,000 scale geological mapping, ground geophysical surveying (magnetometer, IP, mise a la masse), lithogeochemical sampling and percussion drilling (523 m). Geophysical and geochemical anomalies were outlined in the vicinity of the ancient workings, and three out of the five percussion holes drilled into the prospect encountered significant mineralization. The intersection averaged 1.30% Cu and 3.87% Zn over 3 m. For some unknown reason, the BRGM did not test the gold potential at this time even though gold prices were relatively high. It was not until the late 1990s that the BRGM concluded that "re-investigation of the At Taybi and Umm ad Dabah occurrences appears warranted on the base of the Al Amar deposit-model" (Nehlig and Salpeteur, 1999). This was an interesting observation considering Vadala et al (1994) documented the "new discovery" of gold in the At Taybi prospect. In 1992, WGM had recommended 1:5,000 scale geological mapping at At Taybi combined with extensive lithogeochemical sampling, IP surveys to trace the extend of sulphides (and gold) mineralization, and 2,000 m of diamond drilling (WGM, 1992).

Based on approximately 48 bedrock samples collected during 1994 in two lithogeochemical programs, Vadala described the precious-metal mineralization as located at the western margin of a body of carbonate enclosed within rhyolitic tuff. These horizons are composed of massive barite or of barite crystals disseminated in a matrix of variably barite-mineralized brown carbonate. Gold was detected in the barite and in an associated siliceous breccia. At the edge of the barite, a jasperoid siliceous facies is in places associated with locally silicified mudstone. Half of the first 12-sample set showed gold contents ranging from 1 to 3 g/t and silver contents ranging from 16 to 215 g/t, with a geochemical signature of Ba-Zn-Sb-(As-Pb-Mo). Vadala recommended 1:2,000 scale geological mapping, reconnaissance chip sampling of hydrothermal facies, carbonates and siliceous horizons together with the identification, mapping, and sampling of all types of breccia; systematic grid-based soil geochemistry designed to determine the extent of hydrothermal alteration; trenching to evaluate the area, distribution, and grade of surface mineralization, ground geophysics designed to test the presence of hidden mineralization on the west flank of the carbonate mass and to detect any resistant (stockwork) and/or polarizable (sulphide) bodies at depth, and reconnaissance diamond core drilling. Despite all of these positive recommendations, going back to WGM's original favourable assessment, it seems that little actual progress have been made on this prospect which has been controlled by Ma'aden since the late 1990s. The geochemical signature of the mineralization seems to be epithermal. Some have drawn similarities between it and the Umm ash Shalahib gold prospect as well as certain similarities with the Al Amar deposit. It is possible that an interesting gold-bearing structure may exist in the prospect area that is only coincidentally associated spatially with base metals mineralization.

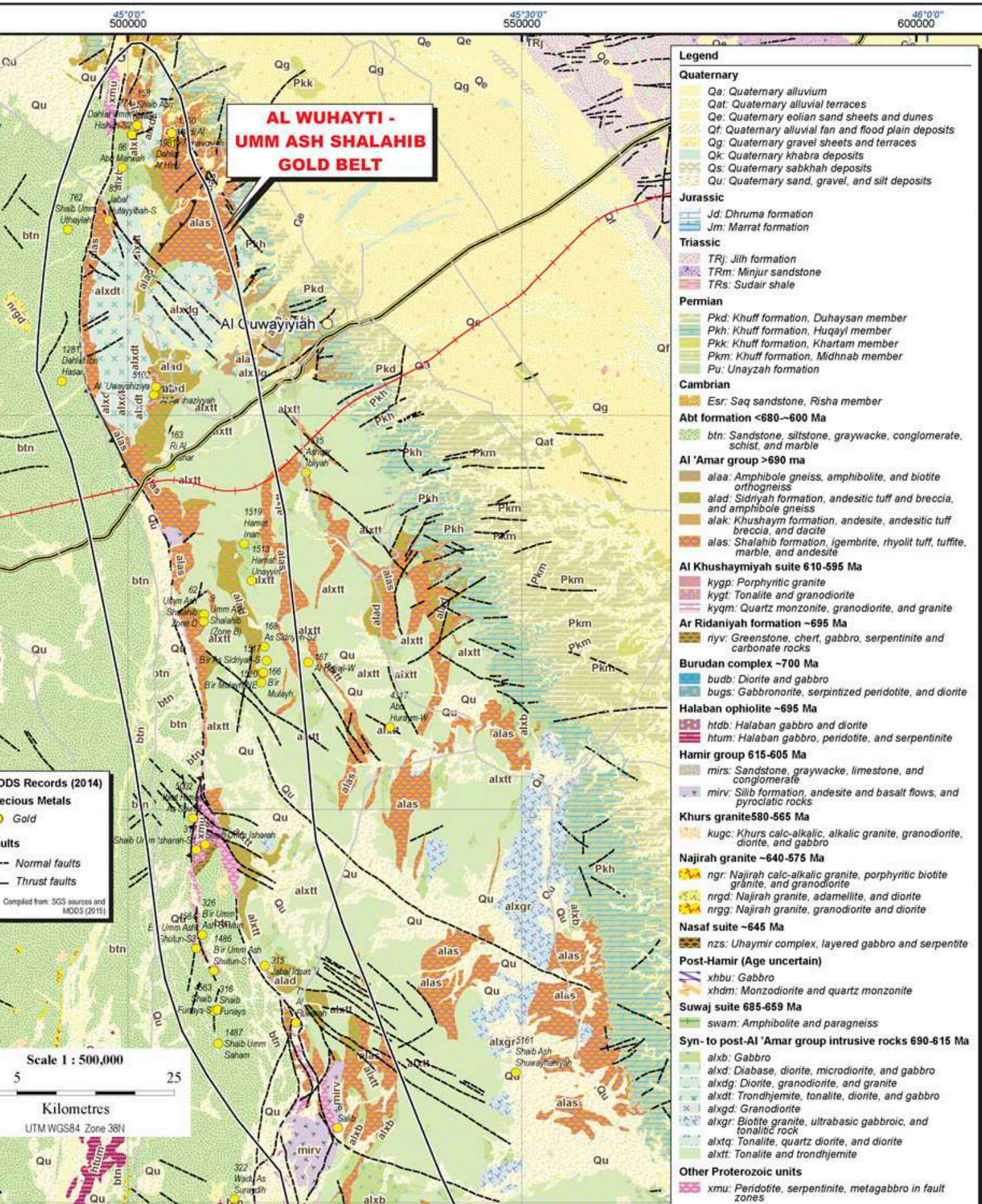

45°0'0"
500000
45°30'0"
550000
46°0'0"
600000
AL WUHAYTI -
UMM ASH SHALAHIB
GOLD BELT
Al Uwayyiyah
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Jurassic
Jd: Dhruma formation
Jm: Marrat formation
Triassic
TRj: Jilh formation
TRm: Minjur sandstone
TRs: Sudair shale
Permian
Pkd: Khuff formation, Duhaysan member
Pkh: Khuff formation, Huqayl member
Pkk: Khuff formation, Khartam member
Pkm: Khuff formation, Midhnab member
Pu: Unayzah formation
Cambrian
Esr: Saq sandstone, Risha member
Abt formation <680-~600 Ma
btn: Sandstone, siltstone, graywacke, conglomerate, schist, and marble
Al 'Amar group >690 ma
alaa: Amphibole gneiss, amphibolite, and biotite orthogneiss
alad: Sidriyah formation, andesitic tuff and breccia, and amphibole gneiss
alak: Khushaym formation, andesite, andesitic tuff breccia, and dacite
alas: Shalahib formation, igembrite, rhyolit tuff, tuffite, marble, and andesite
Al Khushaymiyah suite 610-595 Ma
kygp: Porphyritic granite
kygt: Tonalite and granodiorite
kyqm: Quartz monzonite, granodiorite, and granite
Ar Ridaniyah formation ~695 Ma
riyv: Greenstone, chert, gabbro, serpentinite and carbonate rocks
Burudan complex ~700 Ma
budb: Diorite and gabbro
bugs: Gabbrononite, serpintized peridotite, and diorite
Halaban ophiolite ~695 Ma
htdb: Halaban gabbro and diorite
htum: Halaban gabbro, peridotite, and serpentinite
Hamir group 615-605 Ma
mirs: Sandstone, graywacke, limestone, and conglomerate
mirv: Silib formation, andesite and basalt flows, and pyroclatic rocks
Khurs granite580-565 Ma
kugc: Khurs calc-alkalic, alkalic granite, granodiorite, diorite, and gabbro
Najirah granite ~640-575 Ma
ngr: Najirah calc-alkalic granite, porphyritic biotite granite, and granodiorite
nrgd: Najirah granite, adamellite, and diorite
nrgg: Najirah granite, granodiorite and diorite
Nasaf suite ~645 Ma
nzs: Uhaymir complex, layered gabbro and serpentite
Post-Hamir (Age uncertain)
xhbu: Gabbro
xhdm: Monzodiorite and quartz monzonite
Suwaj suite 685-659 Ma
swam: Amphibolite and paragneiss
Syn- to post-Al 'Amar group intrusive rocks 690-615 Ma
alxb: Gabbro
alxd: Diabase, diorite, microdiorite, and gabbro
alxdg: Diorite, granodiorite, and granite
alxdt: Trondhjemite, tonalite, diorite, and gabbro
alxgd: Granodiorite
alxgr: Biotite granite, ultrabasic gabbroic, and tonalitic rock
alxtq: Tonalite, quartz diorite, and diorite
alxtt: Tonalite and trondhjemite
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
ODS Records (2014)
ecious Metals
Gold
ults
Normal faults
Thrust faults
Compiled from: SGS sources and MODS (2015)
Scale 1 : 500,000
5
25
Kilometres
UTM WGS84 Zone 38N

Table 23
Name and Location of Gold Occurrences - Al Wuhayti-Umm ash Shalahib Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential	Geometry
				Longitude	Latitude			
0086	Abu Marwah	Abu Marwah	Au	44.9924720	24.2463330	Nkheelan	Low	dd, v
0085	Jabal Hutayyibah-S	Jabal Al Ajair	Au	44.9754640	24.1861190	Nkheelan	Very low	dd
1281	Dahlat Ibn Hasan	Jabal Eitaby	Au	44.9170000	24.0009170	Nkheelan	Very low	v
5102	Al `Uwayshiziya	Auchiziya	Au	45.0347220	23.9944440	Nkheelan	Low	v, 160° Az
0175	Al Awshaziyyah	Aussagiyah	Au	45.0321690	23.9858530	Nkheelan	Very low	uncertain
0164	Jabal Al Wuhayti	Jabal Al Utaybi (At Taybi)	Ag-Au	45.0177780	23.9238330	Ar [illegible]	Medium	v, 070° Az
0163	Ri Al Mishar	Ar Ramadiah	Au	45.0522000	23.9028000	Ar [illegible]	Low	uncertain
1519	Hamat Inan	Jabal Meharek	Au	45.1443610	23.8145000	Ar [illegible]	Very low	dd, v
0009	Umm Ash Shalahib (Zone B)	Umm Ash Shalahib (Zone B)	Au	45.0944140	23.7333000	Ar [illegible]	Medium	v, [illegible]
0062	Umm Ash Shalahib Zone D	Umm Ash Shalahib Zone D	Au	45.0939000	23.7253000	Ar [illegible]	Medium	v
1520	B'ir Mulayh-NE	Hammat Umm Shobrom (Bl 17)	Au	45.1683060	23.6667220	Ar [illegible]	Very low	dd
0166	B'ir Mulayh	Hammat Umm Shobrom	Au	45.1657500	23.6550830	Ar [illegible]	Low	v
5002	Iblat Himam As Sawail	Al Ublah	Au	45.0802780	23.5000830	Ar [illegible]	Medium	v, 360°/80°W
0069	Shaib Umm Isharah	Jabal Bitran	Au	45.0956940	23.4698060	Ar [illegible]	Medium	massive
0317	Shaib Umm Isharah-S1	Jabal Bitran West)	Au	45.0845000	23.4638890	Ar [illegible]	Very low	v, 005°/80°W
1485	Shaib Umm Isharah-S2	Jabal Bitran 15 Km East	Ag	45.0749720	23.4462780	Ar [illegible]	Low	sericite schist
0326	B'ir Umm Ash Shutun	B'ir Umm Ash Shodden	Au	45.0917780	23.3663060	Ar [illegible]	Medium	v, 320°/80°W
4564	B'ir Umm Ash Shutun-S3	Umm Ash Shaddon West	Au	45.0839440	23.3505830	Ar [illegible]	Medium	uncertain
0315	Jabal Idsas N	Deposit C	Au	45.1693970	23.3307970	Ar [illegible]	Low	dd, v
1486	B'ir Umm Ash Shutun-S1	B'ir Umm Ash Shodden	Au	45.1058610	23.3249720	Ar [illegible]	Undefined	v, [illegible]
4563	Shaib Funays-S	Bi'r Umm Ashaddon	Au	45.1111110	23.2802780	Ar [illegible]	Undefined	v, 350°/65°W
0316	Shaib Funays	B'ir Umm Ash Shaddon-SE	Au	45.1058610	23.2786670	Ar [illegible]	Low	v, 350°/80°W
0007	Al Fawarah	Al Fawarah	Au	45.2083060	23.2651940	Ar [illegible]	Medium	v, 360°/80°W
1487	Shaib Umm Saham	Fawarah-W	Au	45.1119440	23.2411110	Ar [illegible]	Undefined	v
0006	Salib	Selib	Au	45.2598890	23.1443890	Ar [illegible]	Medium	v, 340°/70°W
0106	Shaib Marqan	Marjan	Au	45.3998060	22.9170000	Ar [illegible]	Low	dd
4316	Shaib Ash Shalikh	Sumakh	Au	45.4060830	22.9161670	Ar [illegible]	Undefined	v
0108	Shaib Marqan-SE	Wadi Chabaniyah	Au	45.4042500	22.9067780	Ar [illegible]	Low	v
6002	Al Malqa	Al Malqa	Au	45.3725000	22.8822780	Ar [illegible]	Undefined	uncertain
0107	Hishshat Umm Abal	Wadi Marjan	Au	45.4028060	22.7636110	Ar [illegible]	Very low	v
0010	As Sakhin	As Sakhin	Au	45.2020000	22.7291670	Ar [illegible]	Medium	v, uncertain

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium; (2) dd = disseminated; v = veins (reported geometry of veins as noted during WGM site visit)

B'ir Umm Ash Shutun (MODS 0326) was also a site of ancient mining activities although these are smaller than those at Jabal Al Wuhayti. The largest centre of mining in the belt was in the Umm Ash Shalahib area (MODS 0009 and 0062). It is uncertain to what degree the ancient miners were influenced by the mineralization being exploited at that time in the area of the present Al Amar Mine, located only about 8 km to the NNW of Umm Ash Shalahib. Recent work has culminated the drill-definition of three mineralized bodies, one of which (A1) contains 110,000 tonnes averaging 10.6 g Au/t, 55.5 g Ag/t and 5.2% Zn. The additional bodies are D1 (60,000 t at 4 g Au/t, 4 g Ag/t and 4% Zn) and the E1 and E2 bodies which total 900,000 tonnes grading 7.2% Zn and 3 g Ag/t (Sangster and Abdulhay, 2005).

Many of the mineral occurrences in the belt have been explored by the BRGM and to a lesser degree by the USGS. Despite its significance, it is surprising that very little work was done in the Umm Ash Shalahib area until the 1990s. This is in contrast to the other prospects at Jabal Al Wuhayti (formerly known as Al Utaybi), Hishshat Umm Abal (formerly known as Wadi Merjam, MODS 0106), Al Farawah (MODS 0007) and Salib (MODS 0006). Recent work at Hishshat Umm Abal, referred to as "Merjan" by the SGS, has identified diorite that is intruded by granite and then dissected by faults/shears trending 360° that are probably associated with orogenic processes such as the cratonization of the shield, as well as 050° and 090° which may be stress release features, and 320° which is probably related to Najd tectonics. Gold-bearing quartz veins are mostly hosted in granite, assaying 1-15 g/t, and rarely as high as 40 g/t. Up to 5.9% Cu occurs locally. The presence of such major structures in this area needs to be confirmed and geologically mapped in detail, and explored by follow-up diamond drilling if warranted. The Umm ash Shaddon prospects have similar geological setting as Wadi Merjian, located on a fault splay that trends south off the Al Amar suture. Similar trends/associations are seen in some of the gold prospects in the adjoining Ad Dawadimi Terrane, only a few kilometres to the west.

Geology

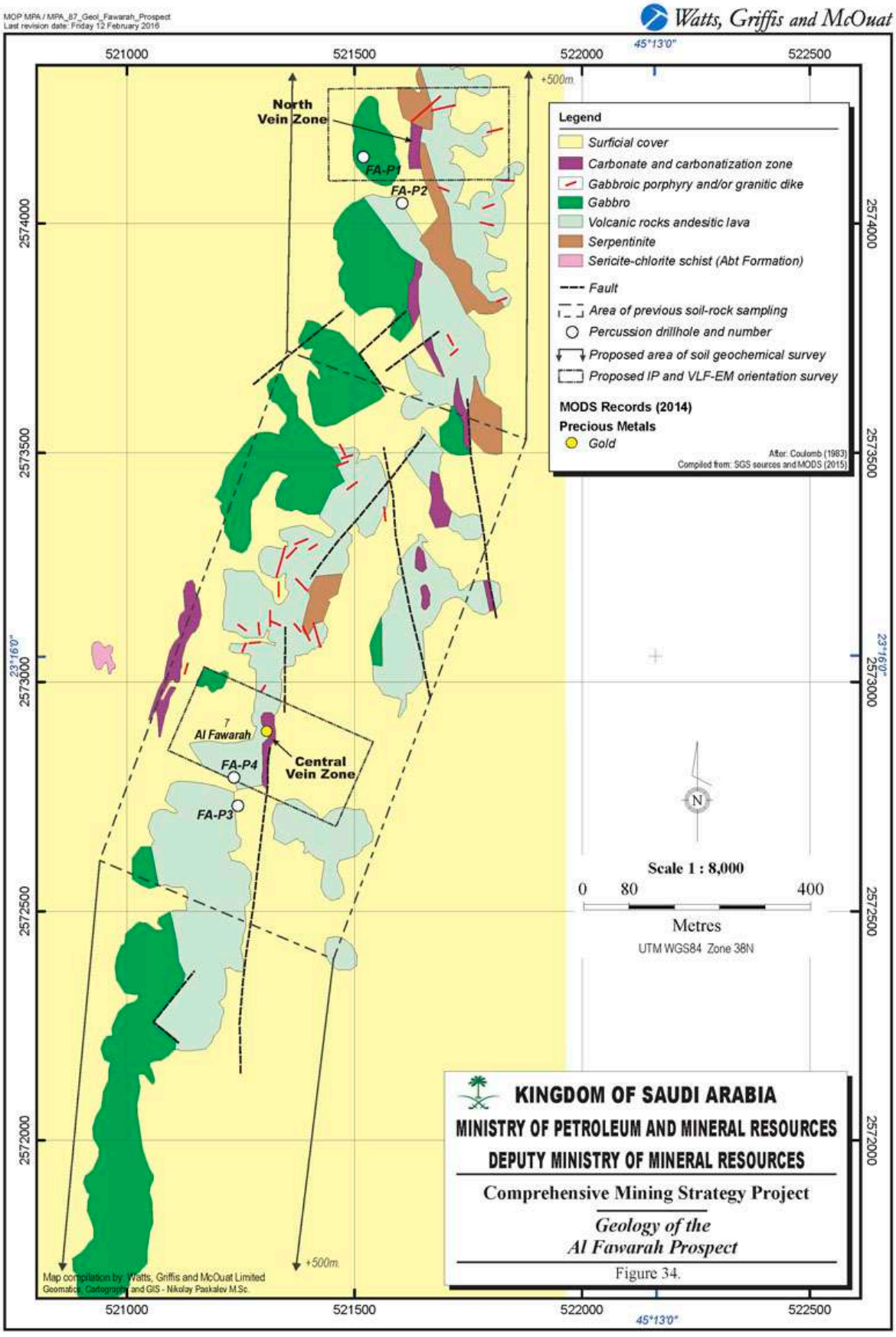
At Wadi Merjam, gold occurrences consist of groups of workings on quartz veins along a north-trending structural zone, characterized by strong foliations and mylonitization of the granite-diorite and metavolcanic rocks over a distance of at least 25 km. Mineralization consists of pyritic quartz veins up to 200 m long and 10 m wide surrounded by variably silicified and chloritized wall rocks. Initial exploration included grab which was followed by detailed mapping, chip sampling across the deformation zone and altered wallrocks, and detailed wadi-sediment sampling in the prospect area. Together this outlined what was considered to be a major deformation zone flanked by strongly anomalous gold mineralization in quartz veins. It is uncertain what follow-up exploration has been completed as even not the MODS database shows no record of this prospect being drilled.

At the Al Fawarah prospect (Figure 34), two main areas of ancient workings are developed on quartz-carbonate veins that are up to 150 m long and 4-6 m wide that are spatially and (probably) genetically related to the Al Amar-Idsas Fault (suture). The veins are hosted by volcano-sedimentary rocks and altered gabbro and contain disseminated pyrite and malachite. Work in the early 1980s consisted of geological mapping, channel sampling, soil geochemical sampling, magnetometer surveying and the completion of four percussion drill holes to average depths of approximately 200 m. At the main prospect, the North Vein is a quartz-carbonate vein 4-5 m wide and 60 m long which is 1 km north of the South Vein, a 4-6 m wide vein that is 160 mm long. Both are spatially and structurally related to the Al Amar-Idsas Suture Zone. The vein is hosted in greenstones and altered gabbro. The presence of highly altered (carbonatized) rocks is reported that were mineralized as far as 60 m away from the veins. Like Selib, 10 km to the south, the main suture at Fawarah contains bodies of ultramafic and listwaenite. It is interesting that Ma′aden uses the presence of listwaenite as a major indicator of gold potential in the Nabitah suture zone to the west.

Two percussion holes were drilled by the BRGM into each of the occurrences for a total of 420 m of drilling. The best intersection was 6.8 g Au/t over 3 m in the northern zone. Evidence supports WGMs view that percussion drilling is a poor exploration method which is generally not capable of returning representative samples for analysis. The intersection reported is of uncertain validity, however, as a first attempt to drill the zone usually fails, this result is very significant. Percussion drilling is especially inadequate for structurally-controlled, vein-type gold deposits because of the strong possibility of coarse, irregularly distributed gold mineralization. Despite the favourable outcome of the initial work, it is uncertain if any follow-up diamond drilling has been completed.

In the Salib area, mineralization is located along the Al Amar-Idsas Fault Zone comprising two mineralized quartz-carbonate vein/stockwork systems (north and south), which are approximately 1,200 m apart and apparently localized along the contact between serpentinite and a carbonate-silica altered gabbro/diorite unit. The provenance of the ultramafic rock is uncertain, however given the magnitude of the fault zone, these rocks could be of ophiolite affinity (note that similar rocks occur along the suture on which the Mansourah and Masarah deposits are hosted). The gold-bearing veins are up to 450 m long and 15 m wide. They carry variable amounts of pyrite, malachite and chrysocolla. During the early to mid-1980s, the BRGM carried out a program of detailed mapping, mine dump sampling, soil sampling, ground magnetometer surveying and percussion drilling (16 holes totalling 1,784 m). The dump sampling returned values of up to 17.8 ppm Au. The best drill hole intersection was 8.43 g Au/t over 1.5 m. Like with the Fawarah prospect, it is uncertain whether any definitive follow-up diamond drilling was completed.

The Wadi Merjiam, Al Fawarah and Salib prospects are cited as typical examples of the work carried out to date which has not progressed beyond the most basic exploration programs. This is typical of the gold prospects in this belt.


MOP MPA / MPA_87_Geol_Fawarah_Prospect
Last revision date: Friday 12 February 2016
Watts, Griffis and McOuat
45°13'0"
521000
521500
522000
522500
2574000
2573500
2573000
2572500
2572000
23°16'0"
+500m
North Vein Zone
FA-P1
FA-P2
Al Fawarah
FA-P4
Central Vein Zone
FA-P3
Legend
Surficial cover
Carbonate and carbonatization zone
Gabbroic porphyry and/or granitic dike
Gabbro
Volcanic rocks andesitic lava
Serpentinite
Sericite-chlorite schist (Abt Formation)
Fault
Area of previous soil-rock sampling
Percussion drillhole and number
Proposed area of soil geochemical survey
Proposed IP and VLF-EM orientation survey
MODS Records (2014)
Precious Metals
Gold
After: Coulomb (1983)
Compiled from: SGS sources and MODS (2015)
N
Scale 1 : 8,000
0 80 400
Metres
UTM WGS84 Zone 38N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the
Al Fawarah Prospect
Figure 34.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

The Ri al Mishar prospect (MODS 0163), formerly known as the Ar Ramadiah prospect, is located about 12 km north of the Al Amar Mine in an area underlain by metavolcanic and metasedimentary rocks. The site is approximately 4.1 km NE of the Al Amar-Idsas Fault zone, and near the margin of a large intrusion of tonalite and trondjhemite that dominates the area immediately to the east creating a large circular feature seen on satellite imagery. The mineralization is described as hematite and malachite hosted by a NW-trending, 40^{o} west-dipping quartz-filled shear zone which measures 110 m long and 1-10 m wide. The wall rocks to the structure are reported as migmatized andesite which is probably a chlorite-rich schist. Ancient mine workings were discovered during regional geological mapping at 1:100,000 scale. Initial sampling of the waste dumps surrounding the ancient workings assayed 4 g Au/t, 0.35% Zn, and 0.2% Cu. WGM is uncertain whether any other work has been done in this area, and the metallogenic model for this mineralization is far from clear.

At Al Wuhayti, the overall geological setting is very similar to that of the Ri al Mishar prospect mentioned in the foregoing paragraph. Several prospects are known in the area: Jabal Al Wuhayti-NE (MODS 1530), Jabal Al Faqisah (0531), Jabal Al Wuhayti-NE1 (1532), Shaib Muhayriqah (1533) and Shaib Umm Raqabah (1534), Jabal Al Utaybi-S (1538) all of which are copper occurrences as well as Durayb As Sayyah (3657), a graphite occurrence which is interesting for gold as it is hosted in sericite-chlorite schist and sheared trondjhemite (leucotonalite) either within or adjacent to the Al Amar-Idsas Fault Zone. The main gold prospect at Al Wuhayti is located very close to a strong 030^{o}-trending structural lineament seen on satellite imagery which appears to be a very young feature, cutting across the Al Amar-Idsas Fault Zone. This structure may be the cause and the host for gold mineralization in this area. WGM noted strong shearing striking 070^{o} at the prospect during a recent site visit. These general northeast trends differ somewhat from other prospects in the area, but approximately the same trend was noted by WGM at Umm ash Shalahib (060^{o}).

The Al Wuhayti prospect was primarily explored for base metals using percussion drilling, however the samples returned to surface for chemical analysis were of low quality due to poor recoveries. None of the samples was analyzed for gold. The best intersections included: 12 m averaging 0.51% Cu and 1.69% Zn; 3 m averaging 1.30% Cu and 3.87% Zn; and, 12 m averaging 0.24% Cu and 1.88% Zn.

The BRGM drilling showed that the mineralization extends to a vertical depth of approximately 120 m. No deeper exploration was done. Work by the BRGM ceased in 1991 when the area was acquired by Ma'aden's predecessor company "Petromin". The BRGM ranked Marjan, At Taybi and Umm ash Shalahib as the best prospects for precious metals mineralization in the belt and recommended detailed mapping, geochemical sampling, trenching, ground geophysics and core drilling. At Taybi was eventually sampled for Au and Ag – a large barite-carbonate body in rhyolite was found to contain high silver values - up to 199.5 g Ag/t. Siliceous breccias and a jasperoid siliceous facies are associated with the carbonate. According to Vadala of the BRGM, these are gold-bearing and are similar to Umm ash Shalahib. The prospect was included in SGS-USGS review in 2005 but no new data added. The prospect was subsequently reclassified as an epithermal occurrence similar to Mahd adh Dhahab.

At this time, the ancient workings at Umm ash Shalahib represent the best explored prospect in the Al Wuhayti-Umm ash Shalahib Belt gold belt. The prospect area is 2,500 m in length and is up to 600 m wide and is dominated by a rhyo-dacite flow dome, and older pyroclastic unit and a younger epiclastic sedimentary formation. The trenches show strong shearing and quartz stockworking on a 060° strike and dipping 70° NW, however the main trend of the zone is reported by the BRGM to be 140°. The mineralization occurs as (1) disseminated (< 6 µm) gold in exhalative barite lenses (+/-localized siliceous sinters), with gold values as high as 45 g/t associated with pyrite, sphalerite, galena, chalcopyrite and traces of silver sulphosalts; (2) gold disseminated in siliceous alteration / quartz stockwork zones along 070°-070° striking faults with gold values in the range of 0.5 to 10 g/t associated with pyrite, chalcopyrite, covellite, chalcocite and rutile; and, (3) gold mineralization localized along structural contacts or at the edge of dikes (Vadala et al, 1992). While gold mineralization is the most widespread, copper-zinc mineralization is found in VMS-type rhyolite breccia at the site. Magnetite-bearing skarns are also present. Given the strong base metal presence at Umm ash Shalahib, the metallogenic model probably favours epithermal gold rather than conventional orogenic gold. The prospect was first explored between 1966 and 1976 when a variety of geological, geochemical and geophysical surveys were completed. This work culminated in 1972 with the completion of 12 drill holes totalling 3,710.5 m of diamond core drilling. Several years of desk-top studies and additional mapping programs followed. Drilling continued in 1980-81 with 5 percussion holes (610 m) and then Shell Minerals completed 7 cored holes (1,029.6 m) the following year. The BRGM continued work in 1990 with detailed geological mapping at 1:2,000 scale, systematic chip sampling, trenching on 20-100 m profiles, geochemical surveys and gravity surveying as well as lithogeochemical analysis and petrographic studies. Subsequent to this the BRGM recommended the drilling of 10 holes, a mixture of percussion and diamond drill holes, and completed this work in 1996-97, actually completing 15 cored holes totalling 2,352.15 m (Leistel et al, 2000).

At the Jabal Bitran prospect, listwaenite-filled fault zones in the Abt Schist gave values as high as 10.8 g Au/t in samples reported by the BRGM to have been taken from ancient workings. No other information is available.

Recommendations

The At Taybi area was situated on an exploration licence owned by Ma'aden for many years. It is completely unknown what exploration work may have been completed by Ma'aden at At Taybi, however it seems that the area may have relinquished, possibly in about 2005, as a means of reducing Ma'aden's overall carrying costs of its large land position. Reports concerning the work carried out my Ma'aden at At Taybi, and other related sites, should be acquired by the SGS and evaluated to determine the exploration potential remaining. This is a vital step in advancing the exploration of the prospect such as to ensure that new exploration work does not repeat the work already done in terms of both the type of survey and/or the way it was implemented. If no significant work has been done in this area, then the recommendations previously made by WGM in 1992 and by the BRGM in 1994 and 1999 should be implemented. This work comprised detailed geological mapping, lithogeochemical sampling, IP surveying and diamond drilling.

Although some interesting intersections were returned from the most recent work at Umm ash Shalahib, including a 1.65 m intersection of 40.7 g Au/t, 51 g Ag/t, 0.16% Cu, 0.45% Zn and 0.05% Pb, the recent exploration was carried out for stratabound base metals and did not focus on cross-cutting structures likely to be gold-bearing. The two approaches are not mutually compatible. While the exploration on Umm ash Shalahib has been relatively comprehensive, the prospect could benefit from a reassessment from two perspectives:

1) The results to date need to be reassessed in whole to determine the extent to which potential gold-bearing structures, as distinct from the sulphide-bearing horizons, have been adequately explored for gold, recognizing the likelihood that:
    a. the potential for gold mineralization may be associated with a regional-scale structure; and,
    b. the potential may extend well beyond the limits of the base metals mineralization even though these structures are weak relative to those at Al Amar.

    and,
2) Modern geophysical equipment and surveying techniques need to be applied to Umm ash Shalahib because no surveying relevant to the VMS-type base metals model (e.g. EM surveying) has been carried out since the early 1970s and the early 1980s. The BRGM's microgravity survey carried out in the 1990-92 exploration program was ineffective. At the end of its program, the BRGM concluded that there is untested potential for larger and more economically interesting mineralization at depth. Many drill holes were poorly oriented in respect to the exploration model, and many did not effectively test the prospective zone below 100 m. Such mineralization may be spatially associated with EM conductors.

The exploration work in the Al Wuhayti-Umm ash Shalahib Belt has been insufficient at best. No other prospect has been explored to the level of Umm ash Shalahib, yet even its exploration level is less than desirable when examined in detail. With the notable exception of this prospect and Al Wuhayti, there has been a tendency to expect positive result too quickly, and to walk away from projects when initial results were not encouraging. This has certainly been the case with many of the prospects assessed previously by WGM in 1992 (WGM, 1992c). In fact, most of the prospects in the belt have been subjected to no more than surface sampling. Gold has a tendency to hide, and the potential inherent in a major structural belt, such as the Al Amar-Idsas Fault Zone, cannot be so simply dismissed. The gold potential will be best in or adjacent to the major planes of faulting which may not be well exposed. Nevertheless, systematic exploration based on detailed geological mapping, geochemical sampling and geophysical surveying is vital to success. The need for detailed geological assessment is obvious given the lack of follow-up exploration at occurrences like the Jabal Bitran prospect where values as high as 10.8 g Au/t in the BRGM's samples have apparently failed to encourage additional exploration work. Geochemical sampling has clear limits in areas of deep alluvial cover and eolian deposits, and under such conditions the lack of geochemical anomalies cannot reduce or eliminate mineral potential. Geophysical surveying using appropriate IP equipment does have the potential to detect disseminated sulphides which are commonly associated with gold deposits as well as detecting structural breaks that can represent major faults or deformation zones. It is vital that comprehensive exploration data be collected such that true anomalies in a regional context can be identified for drilling rather than localized anomalies that may not necessarily be associated with mineralization.

The approach to exploration of the belt is not necessarily served by assembling an ad hoc mixture of exploration programs, some with geochemistry and some without; some with geophysical surveying and most without. Only through a systematic regional approach can risk be reduced and the chances of success increased.

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3.1.3.13 The Wadi Khiyam Gold Belt

Location, Distribution of Occurrences and History

The Wadi Khiyam Gold Belt is located in the eastern shield south of and offset slightly from the Shalahib Gold Belt. It is approximately 55 km in length and it is marked by several parallel northerly striking shear zones and cross-structures that may comprise a conjugate fracture system (Figure 35). The northern end is marked by the Umm Ma'amal S2 gold prospect (MODS 0103) north of which the zone passes under alluvial cover near the town of Al Hafirah (Hulayfah). The belt contains two main clusters of gold prospects, Wadi Khiyam NW and SE (MODS 0097 and 0098) and the Wadi Khasabi area (formerly known as Wadi Arakah) (MODS 0427-0432 and 0444). The gold occurrences are summarized in Table 24.

Little is known in respect to the previous work and geology at the most northern occurrence. The occurrences in the Wadi Khiyam area consist of sulfide-bearing quartz veins within amphibolites gneiss and diorite, southwest of a major Najd transcurrent fault. They were first mapped and sampled by the BRGM as part of a regional exploration program. Ancient mine workings are developed on quartz-carbonate veins in sheared amphibolite (Lacombe and Letalenet, 1970). Chip sampling of pit walls at MODS 0097 and 0098 returned gold values as high as 3.5 g/t. Compilations of gold potential by Riofinex and BRGM have listed the occurrence but no detailed exploration work has been recorded (Viland and others, 1987).

The group of Wadi Khashabi occurrences located near the southern end of the belt comprise Al Khashabi NW (0444), Al Khashabi NE2 (0428), Al Khashabi NE (0430), Al Khashabi NE1 (0429), Al Khashabi E (0432), Al Khashabi (0427) and Al Khashabi SE (0431). These ancient mine sites were mapped and sampled by the BRGM during 1973. Six ancient workings within Hulayfah Group volcanic rocks and associated diorite intrusions returned gold values ranging from 1.0 g/t to 10 g/t in grab samples. Anomalous copper and lead were noted in locations where quartz veins contained appreciable pyrite. Chip and grab sampling of the prospects has been adequate to indicate anomalous gold but there has been no prospect-scale exploration. Detailed follow-up is warranted to determine the extent and gold tenor of the vein systems.

Table 24
Name and Location of Gold Occurrences – Wadi Khiyam Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
0103	Umm Ma'amal-S2	Umm Ma'amal-S2	Gold	44.9768330	22.8129440	Al Hafirah	Med	v
2266	Umm Ma'amal-S1	Jabal Za'En-N	Gold	44.9868330	22.7995560	Al Hafirah	VL	dd, v
0094	Jabal Shuwaymah	Jabal Shuwaymah	Gold	44.9734170	22.7884720	Al Hafirah	Low	dd, v
0096	Wadi Khiyam-N	Wadi Khiyam-N	Gold	44.9628610	22.7407780	Al Hafirah	Low	dd, v
0097	Wadi Khiyam-NW	Wadi Khiyam-NW	Gold	44.9361110	22.7319440	Al Hafirah	Med	dd, v
2269	Wadi Khiyam-NE	Jabal Za'En	Gold	44.9805560	22.7263890	Al Hafirah	Med	dd, v
0095	Wadi Khiyam	Wadi Khiyam	Gold	44.9569440	22.7180560	Al Hafirah	Low	dd, v
2268	Shaib Umm Maamil	Jabal Za'En	Gold	44.9638890	22.7111110	Al Hafirah	VL	dd, v
0098	Wadi Khiyam-SE	Wadi Khiyam-SE	Gold	44.9736110	22.7055560	Al Hafirah	Low	dd, v
3626	Jabal Umm Surayhah	Jabal Za'En-SE	Gold	44.9619440	22.6933610	Al Raqmiah	Med	dd, v
0104	Jabal Umm Surayhah	Jabal Za'En-SE	Gold	44.9913890	22.6294440	Al Raqmiah	VL	dd, v
1974	Shaib Ar Ruqumayah-SE	Jabal Zaen	Gold	44.9893330	22.6200830	Al Raqmiah	VL	dd, v
1617	Shaib Umm Maru	Wadi Ar Roghwa	Gold	45.0194720	22.5591110	Al Raqmiah	VL	v
1616	Shaib Ar Ruqmiyah-S	Shaib Ar Ruqmiyah-S	Gold	45.1013890	22.5405280	Al Raqmiah	VL	v
0444	Al Khashabi-NW	Wadi Arakah	Gold	45.0410830	22.4813890	Al Raqmiah	VL	dd, v
0428	Al Khashabi-NE2	Wadi Arakah	Gold	45.0604440	22.4678330	Al Raqmiah	VL	v
0430	Al Khashabi-NE	Wadi Arakah	Gold	45.0678060	22.4620560	Al Raqmiah	VL	dd, v
0429	Al Khashabi-NE1	Wadi Arakah	Gold	45.0705830	22.4570280	Al Raqmiah	VL	v
0432	Al Khashabi-E	Wadi Arakah	Gold	45.0968330	22.4432500	Al Raqmiah	VL	dd, v
0427	Al Khashabi	Wadi Arakah	Gold	45.0584720	22.4416670	Al Raqmiah	VL	uncertain
0431	Al Khashabi-SE	Wadi Arakah	Gold	45.1052220	22.4240830	Al Raqmiah	VL	dd, v
4481	Wadi Ar Rabwah	Wadi Ar Rabwah	Gold	45.0127500	22.3862500	Al Raqmiah	VL	v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium, VH = Very High; (2) dd = disseminated; v = veins; Strata = stratigraphic control

Geology

Very little is reported that is specific to these gold occurrences. At the northern end of the belt, there is virtually nothing in the literature. In the Wadi Khiyam area, which is close to the northern end, sulfide-bearing quartz veins are hosted within amphibolites gneiss and diorite, and located southwest of a major Najd transcurrent fault. Gold is apparently hosted in these veins however the relationship between the veins and the plutonic rocks is not investigated. In the Wadi Khashabi area, a northwest-trending fault cuts the volcanic units adjacent to the gold occurrences. The presence of Najd faults is thought by WGM to be irrelevant to the occurrences of gold, but this is not known with certainty. The single geological factor that appears to be controlling mineralization is the north-south shears/faults in the belt. It is possible that late tectonic intrusions, such as the diorite, have acted as heat engines for hydrothermal systems that introduced gold into favourable host rocks.

Recommendations

This belt would benefit from systematic exploration comprising initial 1:20,000 geological mapping followed by more detailed 1:2,500 scale mapping of mineral prospects and ancient workings. Systematic sampling across mineralized zones using 1-metre sample intervals is also needed to properly relate gold mineralization to geology. If disseminated sulphides are present in quartz veins or alteration zones, then induced polarization (IP) geophysical surveying would be a useful means of identifying targets at depth for drill-testing. All favourable gold prospects should be diamond core drilled with a minimum budget sufficient for three shallow holes (50-100 m from surface) and three deeper holes at 100-200 m from surface (1,000 m total).

References

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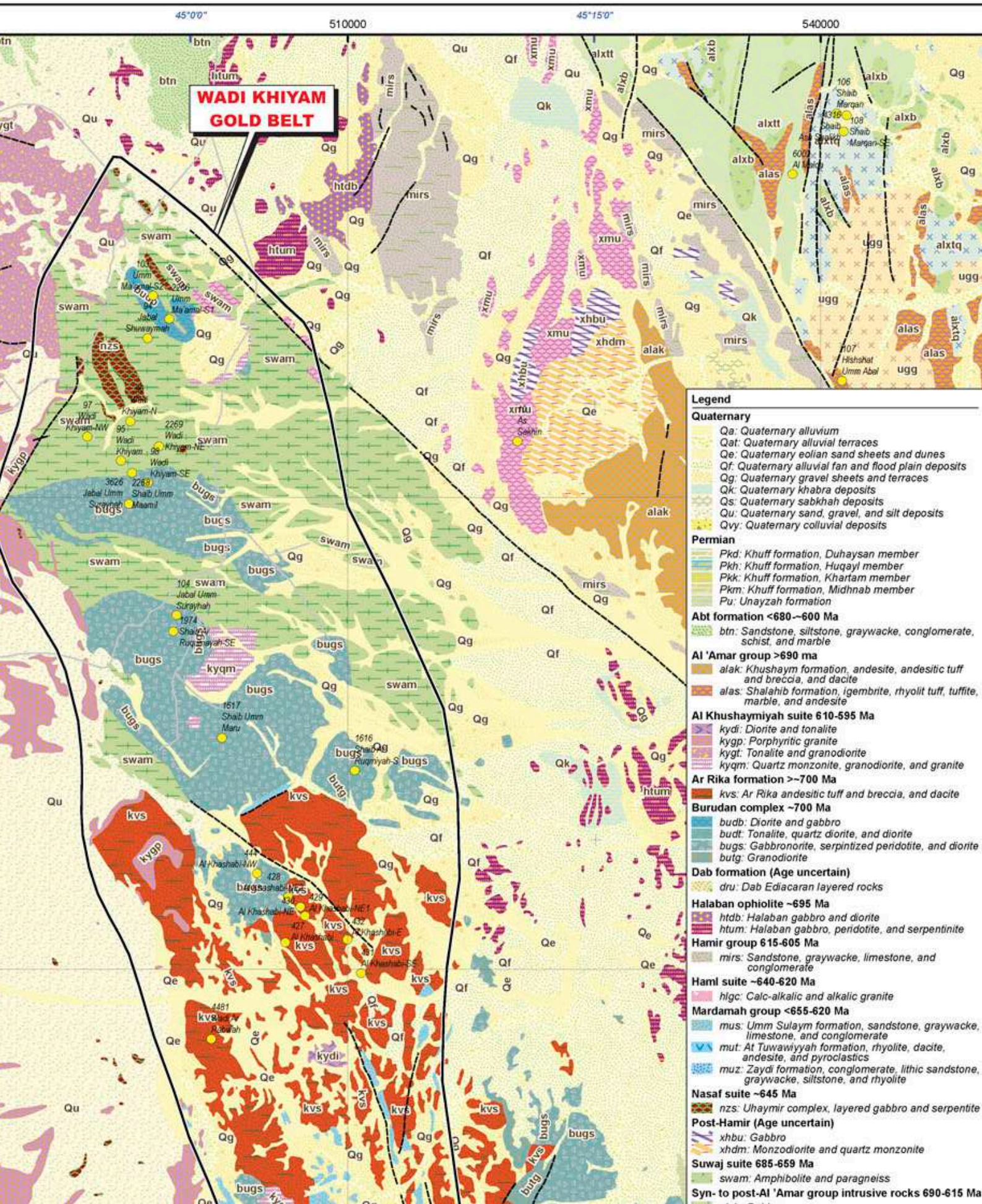
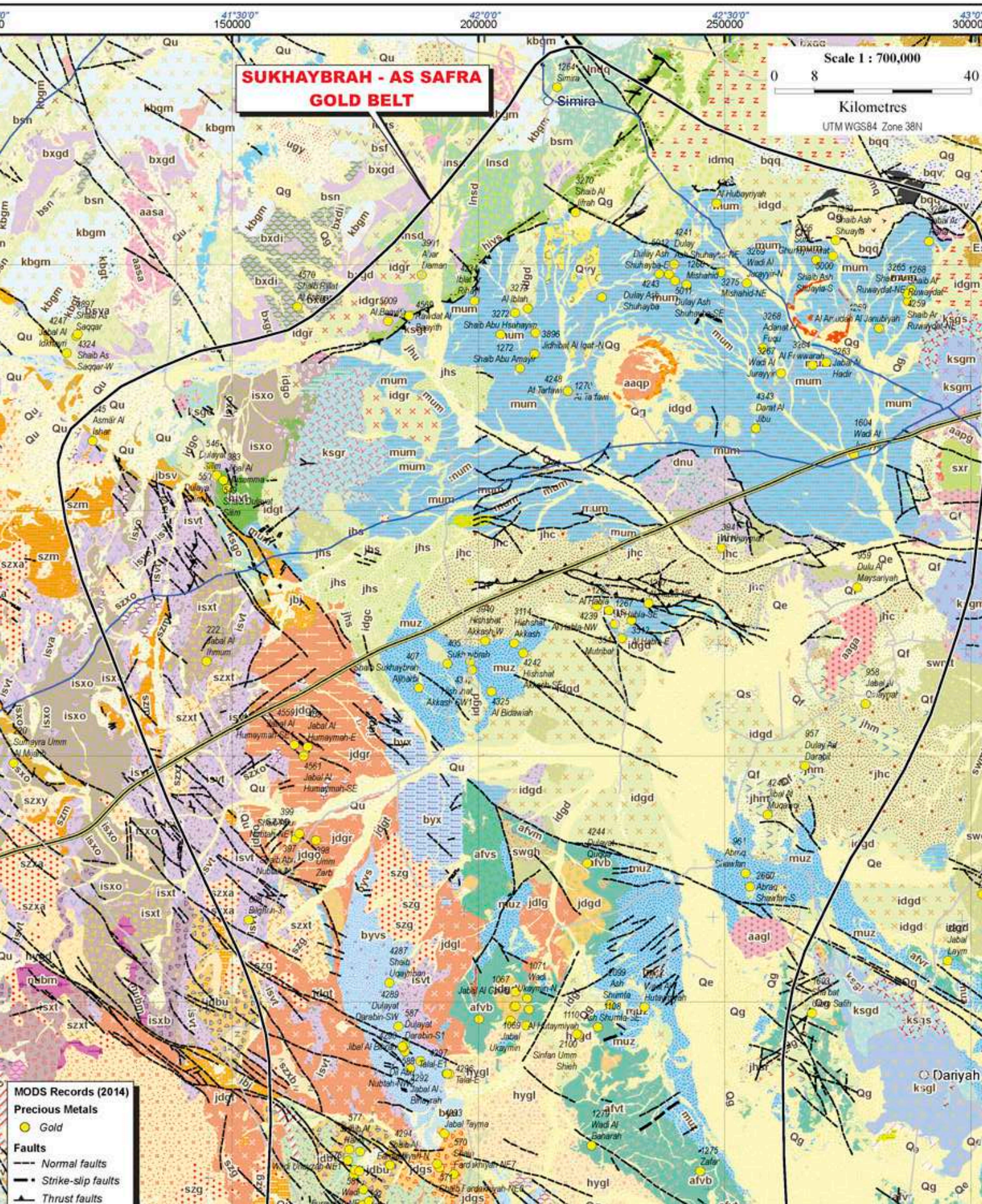

45°0'0"
510000
45°15'0"
540000
WADI KHIYAM
GOLD BELT
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Qvy: Quaternary colluvial deposits
Permian
Pkd: Khuff formation, Duhaysan member
Pkh: Khuff formation, Huqayl member
Pkk: Khuff formation, Khartam member
Pkm: Khuff formation, Midhnab member
Pu: Unayzah formation
Abt formation <680-~600 Ma
btn: Sandstone, siltstone, graywacke, conglomerate, schist, and marble
Al 'Amar group >690 ma
alak: Khushaym formation, andesite, andesitic tuff and breccia, and dacite
alas: Shalahib formation, igembrite, rhyolit tuff, tuffite, marble, and andesite
Al Khushaymiyah suite 610-595 Ma
kydi: Diorite and tonalite
kygp: Porphyritic granite
kygt: Tonalite and granodiorite
kyqm: Quartz monzonite, granodiorite, and granite
Ar Rika formation >~700 Ma
kvs: Ar Rika andesitic tuff and breccia, and dacite
Burudan complex ~700 Ma
budb: Diorite and gabbro
budt: Tonalite, quartz diorite, and diorite
bugs: Gabbronorite, serpintized peridotite, and diorite
butg: Granodiorite
Dab formation (Age uncertain)
dru: Dab Ediacaran layered rocks
Halaban ophiolite ~695 Ma
htdb: Halaban gabbro and diorite
htum: Halaban gabbro, peridotite, and serpentinite
Hamir group 615-605 Ma
mirs: Sandstone, graywacke, limestone, and conglomerate
Haml suite ~640-620 Ma
hlgc: Calc-alkalic and alkalic granite
Mardamah group <655-620 Ma
mus: Umm Sulaym formation, sandstone, graywacke, limestone, and conglomerate
mut: At Tuwawiyyah formation, rhyolite, dacite, andesite, and pyroclastics
muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
Nasaf suite ~645 Ma
nzs: Uhaymir complex, layered gabbro and serpentite
Post-Hamir (Age uncertain)
xhbu: Gabbro
xhdm: Monzodiorite and quartz monzonite
Suwaj suite 685-659 Ma
swam: Amphibolite and paragneiss
Syn- to post-Al 'Amar group intrusive rocks 690-615 Ma


SUKHAYBRAH - AS SAFRA
GOLD BELT
Scale 1 : 700,000
0 8 40
Kilometres
UTM WGS84 Zone 38N
41°30'0"
150000
42°0'0"
200000
42°30'0"
250000
43°0'0"
300000
Simira
Dariyah
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Strike-slip faults
Thrust faults

3.1.3.14 The Sukhaybrah – As Safra Gold Belt

Location, Distribution of Occurrences and History

Unlike other gold belts which are aligned along a dominant fault/shear structure or structural zone, the Sukhaybrah–As Safra Gold Belt might be better described as an ore field with the term "ore" being used in its most general sense. The term "gold district" might be a more appropriate term to describe this area. These gold deposits and prospects are largely associated with intermediate composition plutons that belong to the Idah Suite. These granodiorite, diorite and tonalite intrusions were emplaced during the Neoproterozoic (625-615 Ma) into layered metasedimentary and metavolcanic rocks of the Murdama and Hulayfah Groups in the eastern Arabian Shield. The members of this group of deposits are found in the Afif Terrane and within the Murdama Basin, a large extensional feature that formed at a time when accretion of the Arabian Shield was largely complete. The Idah Suite Intrusions likely developed as a natural consequence of crustal loading under the weight of accumulating sedimentary and volcanic rocks in the basin. Because of the irregular spatial distribution of the intrusions in the basin, these gold deposits and prospects lack the spatial alignments found in the other more structurally controlled gold belts found in the Kingdom. The lack of a singular structural control is evident from the wide geographical distribution of the gold occurrences in this group (Figure 36). In addition to proximity to an Idah Suite intrusion, a geological setting common to nearly all the prospects, each of the prospects is also controlled by a shear or fault zone that has acted as a permeable conduit along which gold-bearing hydrothermal fluids have been channelled. The favoured sites for hosting mineralization include fractured and brecciated rocks situated along the contact zone between the pluton and country rocks. In many, but not all cases, quartz veins are the prominent carrier of gold, however lower grading mineralized halos containing disseminated gold are common in both layered and plutonic rocks.

The Sukhaybrah-As Safra gold district extends approximately 275 km south-southwesterly through the Shaib abu Hashayim, Al Habla and Humaymah areas, the Sukhaybarat and Bulghah Mines and covers the Jabal Mawan and At Taybi areas. In total, the Sukhaybarat-As Safra Belt takes in 122 prospects as listed in Table 25, however many others might also be included at the fringes of the zone. The belt ends just south of the Al Safra gold-base metals prospect where it is cut off by the Al Hissu Fault, a major Najd structure. The gold belt continues, potentially, south of the Al Hissu Fault, however the gold occurrences in this area are more strongly influenced by north-south shearing associated with Nabitah orogenic structures. WGM has identified two gold belts to the south which could be an extension of the Sukhaybarat-As Safra Belt: the Jidhib-Ghuzayyilat Belt and the As Siham-Az Zeraib Belt.

Table 25
The Sukhaybrah – As Safra Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
1264	Simira	Samirah	Gold	42.1500000	26.5166670	Sumaira'a	VL	v
1265	Al Hubayriyah	Hebairiah	Gold	42.4793890	26.3096110	Sumaira'a	VL	v
3270	Shaib Al Jifrah	Khidar	Gold	42.1931110	26.2879170	Sumaira'a	Med	v
3266	Jabal Ar Raha	Jabal Ar Raha	Gold	42.9120830	26.2469440	Sumaira'a	Med	v
1383	Shaib Ash Shuayla	Shaib Ash Shuayla (Shiaila)	Gold	42.7224440	26.2457220	Sumaira'a	Med	v
5000	Shaib Ash Shuayla-S	Shiailah Center	Gold-Silver	42.7176110	26.2171670	Sumaira'a	Med	dd, v
5156	Sumr Ghunaymuwat	Sumr Ghunaymuwat	Gold	42.6841940	26.2092500	Sumaira'a	Low	uncertain
4241	Dulay Ash Shuhayba-NE	Jabal Al Khiraysha-SW	Gold	42.3955830	26.1965560	Sumaira'a	Med	v
4251	Jabal ar Rukayb	Ar Rokaib (Shaila)	Antimony-Gold	42.8578890	26.1956670	Sumaira'a	VL	v
3275	Mishahid-NE	Asha-N	Gold	42.4916670	26.1833330	Sumaira'a	Undefined	v
4243	Dulay Ash Shuhayba	Wadi Alawiin-E	Gold	42.3655830	26.1779440	Sumaira'a	VL	v
5012	Dulay Ash Shuhayba-E	Meshaheed Pluton W/Sw	Gold	42.3855280	26.1776110	Sumaira'a	Med	v
3901	Abar Daman	Tulqah	Gold-Silver	41.8833330	26.1666670	Sumaira'a	Med	v
5011	Dulay Ash Shuhayba-SE	Meshaheed Pluton Se	Gold	42.3975830	26.1656940	Sumaira'a	Med	v
3269	Wadi Al Jurayyir-N	Jurrayir-N	Gold	42.5437220	26.1640280	Sumaira'a	VL	v
1266	Mishahid	Mishahid	Gold	42.4215280	26.1593330	Sumaira'a	Med	v, stockwork
3265	Shaib Ar Ruwaydat-NE	Rouydat-N	Gold	42.8781940	26.1584720	Sumaira'a	VL	v
4259	Shaib Ar Ruwaydat-NE	Rouydat-N	Gold	42.8700000	26.1499440	Sumaira'a	VL	v
1268	Shaib Ar Ruwaydat	Jerayer	Gold	42.8716390	26.1361670	Sumaira'a	VL	v
1599	Ash Shabbakiyah	Niece	Gold	42.2500000	26.1333330	Sumaira'a	VL	v
4234	Iblat Ar Rihayl	Wadi Sha'Bah-NE	Gold-Silver	41.9916940	26.1215000	Sumaira'a	Med	v
3273	Al Iblah	Wuday	Gold	42.1003330	26.1093330	Sumaira'a	Med	v
4235	Iblat Ar Rihayl-S	Wadi Sha'Bah-E	Gold	41.9983330	26.1091670	Sumaira'a	Med	v
5010	Al Iblah-SW1	Wuday-W	Gold	42.0747220	26.1007780	Sumaira'a	Undefined	v
4569	Rawdat Al Baayith	Rawdat Al Baayith	Gold-Silver	41.8599170	26.0906940	Sumaira'a	Med	v
1269	Al Amudah Al Janubiyah	Wagt	Gold	42.8135000	26.0858890	Al Dulaymiya	VL	v
5009	Al Baayith	Al Baayith	Gold	41.8176390	26.0800830	Sumaira'a	Med	v
3896	Jidhibat Al Iqab-N	Agob-N	Gold	42.1172780	26.0652220	Sumaira'a	Med	v
3272	Shaib Abu Hsahayim	Ar Rahail	Gold	42.0458060	26.0607780	Sumaira'a	VL	uncertain
3268	Adanat Al Fuqu	Jurrayir-SE	Gold	42.5786940	26.0459440	Sumaira'a	Med	v
1271	Jidhibat Al Iqab	Agob	Gold	42.1163060	26.0262780	Sumaira'a	Med	v
3263	Jabal Al Hadir	Hadhir	Gold	42.7081110	26.0215560	Al Dulaymiyah	VL	v
3264	Al Fawwarah	Al Fawwarah	Gold	42.6805280	26.0157780	Al Dulaymiyah	VL	v
3267	Wadi Al Jurayyir	Wadi Jurrayir-SE	Gold	42.6166670	26.0000000	Al Dulaymiyah	VL	v
1272	Shaib Abu Amayir	An Najadi, Amayir Al Madan	Gold	42.0876390	25.9996110	Al Dulaymiyah	Med	v
4952	Al Mohsoniyah	Al Muhsiniyyah	Antimony-Gold	42.7718890	25.9906390	Al Dulaymiyah	Med	v
4248	At Tarfawi	At Tarfawi-NE	Gold	42.1855280	25.9595000	Al Dulaymiyah	Med	v
1270	At Tarfawi	Afra	Gold	42.1855280	25.9595000	Al Dulaymiyah	Med	v
4343	Darat Al Jibu	Darat Al Jibu	Gold	42.5675560	25.8982220	Al Dulaymiyah	Undefined	v
1604	Wadi Al Jurayyir	Wadi Al Jurayyir	Gold	42.7671390	25.8529440	Al Dulaymiyah	Undefined	dd, v
0545	Asmar Al Ishar	Jabal Al Achar	Gold	41.2255000	25.8459440	Al Nuhaiteyah	Undefined	v
0550	Dulayat Silim-N	Al Musamah	Gold-Silver	41.4664720	25.8046390	Al Nuhaiteyah	Undefined	v
0546	Dulayat Silim	Jabal Al Musamah	Gold	41.4782220	25.7892500	Al Nuhaiteyah	Undefined	v

Table 25
The Sukhaybrah – As Safra Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
0549	Shaib Dulayat Silim	Jabal Al Musamah	Gold-Silver	41.4923330	25.7804720	Al Nuhaiteyah	Undefined	v
0383	Jibal Al Musamma	Jibal Al Musamma	Gold	41.5006390	25.7650280	Al Nuhaiteyah	Low	v
3941	Al Khaymah	Al Khaymah	Gold	42.5028890	25.6777780	Al Dulaymiyah	Undefined	V
0959	Dulu Al Maysariyah	Umm Jirfan	Gold	42.7787220	25.6093890	Al Dulaymiyah	Undefined	V
1287	Al Habla-NE	Al Habla-NE	Gold-Silver	42.3575830	25.5730280	Uglat Asugour	Undefined	v
4239	Al Habla-NW	Al Habla-NW	Gold-Silver	42.2540000	25.5660000	Uglat Asugour	Undefined	v
1286	Al Habla	Al Habla	Gold-Silver	42.2777780	25.5583330	Uglat Asugour	Undefined	v
3512	Al Habla-E	Al Habla-E	Gold-Silver	42.3234720	25.5408890	Uglat Asugour	Low	v
1267	Al Habla-SE	Al Habla-- SE-Central	Gold-Silver	42.2903060	25.5337780	Uglat Asugour	Med	v
3513	Mutribah	Al Madraba	Gold-Silver	42.3052220	25.5076390	Uglat Asugour	Undefined	v
3940	Hishshat Akkash-W	Akkash-W	Gold-Silver	42.0290560	25.4977220	Uglat Asugour	Undefined	v
3114	Hishshat Akkash	Sukhaybarat-NE	Gold-Silver	42.0874170	25.4946390	Uglat Asugour	Undefined	v
4242	Hishshat Akkash-SE	Jabal Akkash-SW	Gold-Silver	42.1061110	25.4772220	Uglat Asugour	Med	v
0406	Sukhaybrah-E	Sukhaybarat Ash Sharqiyah	Gold	42.0000000	25.4591670	Uglat Asugour	Very high	v
0405	Sukhaybrah	Sukhaybarat Al Gharbiyah	Gold	41.9541670	25.4541670	Uglat Asugour	Undefined	v
0222	Jabal Al Ihmum	Jabal Al Aymum	Gold	41.4681670	25.4475000	Uglat Asugour	Low	v, stockwork
4342	Hishshat Akkash-SW1	Sukhaybarat-SE	Gold	42.0042220	25.4438610	Uglat Asugour	Med	v
0407	Shaib Sukhaybrah Aljharbi	Shaib Sukhaybrah Aljharbi	Gold	41.8972220	25.4083330	Uglat Asugour	Undefined	v
4325	Al Bidawiah	Sukhaybarat-SE	Gold	42.0443890	25.4052220	Uglat Asugour	Undefined	v
0958	Jabal Al Qinaynah	Jarrar	Gold	42.7991390	25.3956670	Hedban	VL	v
4559	Jabal Al Humaymah-SE1	Jabal Jumayah Mideast	Gold	41.6492780	25.2993890	Hedban	Med	v
0408	Jabal Al Humaymah-E	Jabal Jumaymah-E	Gold	41.6766390	25.2965000	Hedban	Undefined	v
0957	Dulay Ad Darabil	Ad Dirabi	Gold	42.6793330	25.2810280	Hedban	VL	v
4561	Jabal Al Humaymah-SE	Jabal Jumayah Central	Gold	41.6690000	25.2794720	Hedban	Undefined	uncertain
0220	Sumayra Umm Al Mijarib	Sumayra Umm Al Mijarib	Gold	41.0849440	25.2522780	Hedban	Low	v
4245	Jibal Al Muqawqi	Jibal Al Muqawqi	Gold	42.6055560	25.1902220	Hedban	VL	v
0399	Shaib Abu Nubtah-NE1	Jabal Mawan-NE	Gold	41.6642500	25.1369170	Hedban	Undefined	v
0397	Shaib Abu Nubtah-NE	Jabal Mawan-SW	Gold	41.6568060	25.1273610	Hedban	Med	v
0398	Umm Zarib	Umm Zarib	Gold	41.6980280	25.1254720	Hedban	Undefined	v
4244	Dulayat Quqqa	Wadi Jarir-W	Gold	42.2443610	25.0943610	Hedban	VL	v
2660	Abraq Shawfan-S	Abraq Shawfan-S	Gold	42.5724720	25.0576940	Hedban	Undefined	v
0608	Bulghah-3	Bulghah	Gold	41.5661110	24.9766940	Hedban	VL	dd, v
4287	Shaib Uqayriban	Al Bihrah	Gold	41.8519720	24.8676670	Hedban	VL	dd, v
1067	Jabal Al Ghulb	Gulb-N	Gold	42.1053610	24.8562780	Talal	Med	dd, v
1071	Wadi Ukaymin-N	Al Kwaimeen-N	Gold	42.1292220	24.8442780	Talal	VL	dd, v
2099	Ash Shumta	Ashumta	Gold	42.2958610	24.8365280	Talal	Med	dd, v
1084	Wadi Al Hutaymiyah	Al 'Aitiyah-N	Gold	42.3653610	24.8329440	Talal	Med	dd, v
1070	Jabal Al Ghulb-SE	Gulb	Gold	42.1059170	24.8296110	Talal	VL	dd, v
1066	Jabal Al Kawm-E	Al Koom-E	Gold	42.1036390	24.8284440	Talal	Med	v
1072	Jabal Ukaymin	Al Kwaimeen-N	Gold	42.1334170	24.8240000	Talal	VL	dd, v
1083	Jabal Al Kawm-W	El Koom-W	Gold	42.0340000	24.8045280	Talal	Med	dd, v
1068	Jabal Ukaymin	Al Kwaimeen-SW	Gold	42.0966670	24.8025000	Talal	VL	dd, v
1069	Jabal Ukaymin	Al Kwaimeen-SE	Gold	42.1288330	24.7948060	Talal	VL	dd, v

Table 25
The Sukhaybrah – As Safra Gold Belt, Arabian Shield

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
1108	Ash Shumta-SE	Ash Shumta-SE	Gold	42.2721670	24.7946390	Talal	Med	v
4289	Dulayat Darabin-SW	Jabal Zarabin-SE prospect	Gold	41.8721670	24.7877500	Talal	VL	v
2100	Sinfan Umm Shieh	Umm Shieh	Gold	42.2305560	24.7805560	Talal	Med	dd, v
1110	Al Hutaymiyah	Al Hitaimiyah	Gold	42.2347780	24.7788330	Talal	VL	v
0587	Dulayat Darabin-S1	Jabal Zarabin-SE	Gold	41.8858610	24.7539170	Talal	VL	dd, v
4291	Jibal Al Bihrah-SW	Al Burhah	Gold	41.8810000	24.7514720	Talal	VL	v
4290	Jibal Al Bihrah	Al Burhah	Gold	41.8816110	24.7490830	Talal	VL	v
4288	Dulayat Darabin-S	Jabal Zarabin-SE prospect	Gold	41.8866110	24.7415280	Talal	Med	v
0588	Dil Abu Nubtah-NW2	Jabal Burhah-E	Gold	41.9180280	24.7251110	Talal	VL	dd, v
4292	Jabal Al Bihayrah	Al Buhairah	Gold	41.8983330	24.7116390	Talal	VL	undetermined
0595	Humaymah (also 0596-598)	Humaymah (Makhruqah)	Gold	41.7181810	24.7094110	Talal	High	dd, v
4297	Talal-E1	Talal	Gold	41.9722220	24.7030560	Talal	VL	v
4296	Talal-E	Talal	Gold	41.9763890	24.7027780	Talal	VL	v
4295	Talal	Talal	Gold	41.9713890	24.7027780	Talal	VL	v
4293	Jabal Tayma	Jabal Tayma	Gold	41.9695670	24.5929170	Talal	Med	dd, v
1279	Wadi Al Baharah	Al Boharah	Gold	42.2643890	24.5767500	Talal	VL	v
0577	Jidhib Al Hamir	Al Nayzah	Gold	41.7795830	24.5598060	Talal	VL	dd, v
0579	Dulay Al Ubayd-W	Al Obaid	Gold	41.8007780	24.5563060	Talal	VL	dd, v
0576	Wadi Unayzah-NE1	Al Nayzah-SE	Gold	41.7775560	24.5395280	Talal	VL	dd, v
0572	Shaib Fardakhiyah-NE8	Wadi Al Furdukhiyah	Gold	41.9559720	24.5373610	Talal	VL	dd, v
1275	Zafar	Zafar	Gold	42.4833330	24.5333330	Talal	VL	dd, v
4294	Shaib Al Fardakhiyah-N	Al Furdukhiyah	Gold	41.8619720	24.5325280	Talal	VL	dd, v
0571	Shaib Fardakhiyah-NE6	Wadi Al Furdukhiyah	Gold	41.9610000	24.5302220	Talal	VL	dd, v
0574	Wadi Furaydikh-N	Wadi Al Nayzah	Gold	41.7913330	24.5229440	Talal	VL	dd, v
0581	Wadi Furaydikh-NE	Al Obaid-SE	Gold	41.8007500	24.5203890	Talal	VL	stratiform
0570	Shaib Fardakhiyah-NE7	Wadi Al Furdukhiyah	Gold	41.9897220	24.5188890	Talal	VL	dd, v
0573	Wadi Furaydikh-SE	Wadi Al Nayzah	Gold	41.7894720	24.5130830	Talal	VL	dd, v
0391	Jabal Tawban-NE3	Jabal Thuban-N	Gold	41.8095830	24.4869720	Talal	VL	dd, v
0393	Jabal Tawban-NE2	Jabal Thuban-N	Gold	41.8215000	24.4660560	Talal	VL	dd, v
0392	Jabal Tawban-NE1	Jabal Thuban-N	Gold	41.8086940	24.4581670	Talal	VL	dd, v
0296	B'ir Tawan	B'ir Tawan	Gold	41.8491670	24.4336110	Talal	VL	dd, v
0297	Al Maham-N	Al Maham-N	Gold	41.9615000	24.4306940	Talal	Med	v
0295	Dil Abu Nubtah-NW	Jabal Umenupta	Gold	41.7073890	24.3339170	Talal	VL	dd, v
0298	Shaib Al Fardakhiyah	Wadi Al Furdukhiyah-SE	Gold	41.8537780	24.3113060	Tharb	VL	dd, v
4571	Jibal As Sufrah-N1	As Safra Gold prospect	Gold	41.8937780	24.2296110	Tharb	Med	dd, v
1494	Jibal As Sufrah-S2	As Safra	Gold	41.8958060	24.2178610	Tharb	Med	dd, v
1278	Jibal Ikliyat	Akliyah	Gold	42.6332500	24.1890280	Tharb	Med	dd, v
0908	Jabal Tukhfah Ash Shahba-E	Jabal Tukhfah-E	Gold	42.2467500	23.9893610	Tharb	VL	dd, v
0907	Shaib Mibhil Al Janubi	Jabal Al Usaybiyat-W	Gold	42.3003610	23.9602780	Tharb	Med	dd, v
0906	Jibal Al Isibiyat	Jabal Al Usaybiyat-W	Gold	42.2977500	23.9416670	Tharb	Undefined	dd, v
0905	Shaib Rughwah	Jabal Tukhfah-SE	Gold	42.2252500	23.9181670	Tharb	Med	dd, v

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium. (2) dd = disseminated; v = veins

The Raha Fault Zone gold occurrences are located near the most northern end of the gold district in what is locally referred to by the BRGM as the "Silsilah District", situated near the Silsilah plutonic complex. Two major gold prospects are situated along approximately 30 km of strike on the Raha fault, a major NE-trending structure associated with the development of the Murdama Basin to the south.

At the eastern end of the fault zone is the Jabal ar Raha gold occurrence (MODS 3266) and the Shaib Ash Shuayla occurrences (1383 and 5000) formerly known as Shaila, are located approximately 3 km apart at the western end. Very little work is reported on these occurrences other than surface sampling. The initial work by the BRGM in 1991-93 included detailed 1:2,500 scale mapping, geochemical sampling (655 sites), a radiometric survey, the excavation of 13 trenches totaling 2,590 m and eight shallow drill holes (422.70 m) in the north part of the prospect. Gold values as high as 34 ppm were found in samples collected from the Raha fault zone and 25 dump samples of vein quartz at the Raha ancient mine site produced gold assays as high as 60 g/t with an average of 11.4 g/t. Significant mineralization in country rock is indicated by one sample of slightly iron-stained diorite wallrock which contained 18.2 g Au/t, and other samples of wallrock contained gold values of 5.2 g/t and 1.3 g/t. The BRGM pointed to similarities between the Raha site and the Sukhaybarat Mine.

At Shaib Ash Shuayla 43 quartz dump samples contained as much as 280 g/t or 8.2 oz/ton! Bedrock chip samples assayed as high as 52 g Au/t, although most assayed as <2 g/t. During late 1993 and late 1994, the BRGM carried out a comprehensive program of trenching (14 totaling 1,380 m), bedrock sampling (228) and dump sampling (15), 1:2,500 scale geological mapping and grids-based geophysical surveying (magnetometer, VLF-EM at 704 stations) at the two main prospects, Shaib Ash Shuayla and Shaib Ash Shuayla South. In addition, a radiometric profile was prepared for each of the 14 trenches and 20 samples were studied petrographically (Jehani and Récoché, 1995). At Shaib Ash Shuayla South, the chip-channel bedrock sample carried low gold values with a maximum of only 3.9 g/t – the BRGM recommended discontinuing work, however trenches at Shaib Ash Shuayla exposed iron-stained, metasedimentary and felsic metavolcanic rocks with abundant disseminated pyrite which were cut by narrow (1-15 cm) gold-bearing quartz veins. Chip channel samples in two trenches assayed 0.8 g Au/t across 30 m and 0.7 g Au/t across 23 m, respectively. The BRGM recommended additional trenching to explore for large volume/low grade mineralization. During 1994-1995, the BRGM also completed reconnaissance level exploration at an antimony-gold occurrence at Jabal ar Rukayb (MODS 4251) formerly known as Ar Rokaib or Shaila located on a branch of the Raha fault. Geological mapping and sampling demonstrated the presence of gold values as high as 41.5 g/t in quartz veins with a prevalent antimony-silver-arsenic association and lower grade mineralization (<5.5 g/t) in hydrothermally altered listwaenite, possibly derived from an ultramafic parent rock (Récoché and Jehani, 1996). Magnetometer surveying detected an anomaly which was unexplained. The BRGM recommended several drill holes to test the prospect.

During the foregoing work program in 1995 reported by Récoché and Jehani (1996), The BRGM also carried out a small program of follow-up exploration at the Buqaya Ash Ashamaliyah Cr-Fe anomaly (3155), formerly known as the Buqaya Jasperoid Area, which was previously reported to have high-grade gold values. This time, the sampling returned maximum gold values of 0.81 g/t and the BRGM concluded that

the values were too low to justify additional exploration. The 1995 exploration program also included follow-up reconnaissance-scale work at Al Amudah Al Janubiyah (1269) formerly known as Wagt, Wadi Al Jurayyir-N (3269) formerly Jurrayir-N, Wadi Al Jurayyir (3267) formerly Wadi Jurrayir-SE, Al Fawwarah (3264) and Jabal al Hadir (3263) previously known as Hadhir. At Al Amudah Al Janubiyah, analytical results showed gold contents of 0.1 to 6.0 g/t with a tungsten (scheelite) association. Follow-up trenching was recommended. Gold values as high as 38 g/t in bedrock and dump samples at Wadi Al Jurayyir-N were considered to be disbursed and of insufficient interest for the BRGM to recommend follow-up work despite the fact that sample assaying >1 g/t accounted for 25% of the population. At the main Wadi Al Jurayyir site, the geology included Murdama layered rocks and an Idah Suite granodiorite, however no samples contained more than 0.66 g Au/t except for samples from ancient mine dumps. Despite the favourable geological setting, and the findings of values as high as 22.6 g/t by previous explorers, the BRGM recommended no further work. At Fawwarah, 11 rock samples from ancient mine dumps were analysed for gold and nine of these contained between 0.2 g/t and 11 g/t, averaging 0.6 g/t. Despite the reconnaissance nature of the exploration which should have been satisfied only to demonstrate the presence of gold, the BRGM recommended no further work. At Hadhir, 9 out of 16 samples gave gold values of between 0.6 g/t and 6.7 g/t, however as at Fawwarah, the BRGM concluded the results were insufficient to recommend continuing work (Récoché and Jehani, 1996).

Located about 30 km WSW of Shaib Ash Shuayla, the Dulay Ash Shuhayba area, previously identified as the Meshaheed area, was rediscovered during 1956 by Schaffner who was working for SAMS (Viland and others, 1987). Little exploration was carried out in the area until reconnaissance bedrock mapping and sampling with regional wadi geochemical sampling was completed by USGS between 1980 and 1983 (Smith and Samater, 1984). In order to trace shear zones below the workings, widely spaced audio-magnetotelluric and telluric-electric surveying was carried out by the USGS. This was followed by a minor amount of trenching and grid-based bedrock sampling near the ancient workings in an area of approximately one square kilometre to confirm the previously reported gold grades and to locate new mineralized zones. Geochemical Pb, Cu, B and Sn anomalies were detected and a large low-resistivity anomaly more than 2 km in width was discovered extending to depths in excess of several kilometers below the workings (Smith and Samater, 1984). This was interpreted to indicate the presence of similar, if not more intensely altered rocks in this area, however bedrock sampling failed to detect gold anomalies within the alteration zone – only two out of 283 rock-chip samples contained more than 1 ppm gold (8.0 ppm and 6.6 ppm) (Smith, 1985a). The low values returned appear to have discouraged any further exploration in the area until the mid 1990s (or later). WGM understands that Ma'aden has since worked in the area however none of the Ma'aden exploration data was available for this review.

Approximately 35 km farther to the WSW from Dulay ash Shuhayba, an even larger cluster of gold occurrences and ancient mine sites is found in the Iblat Ar Rihayl – Al Iblah area, formerly known by the names of Wadi Sha'bah (MODS 4234 and 4235) and Wuday (3273 and 5010). The two sites at Dulay ash Shuhayba are Ag-Au occurrences. The USGS originally mapped the area surrounding the Iblat Ar Rihayl occurrences at a scale of 1:100,000 as part of a regional reconnaissance mapping program between 1982 and 1984. The ancient workings were rediscovered by Riofinex and were sampled during the 1984-85 field

season at which time 11 gold-bearing sites were visited (Howes and, others, 1986). Bedrock samples were collected from 26 trenches representing 1,286 m of sampling. All rock types were sampled including representative samples from quartz veins, quartz plus Murdama metasedimentary host rock, altered Murdama rock, and altered and unaltered granodiorite. Sample lengths were not reported however the gold contents were of sufficient interest to be encouraging to Riofinex, and to justify a recommendation for further mapping and channel sampling. It is unknown whether this work was actually completed. In the Al Iblah area, gold-bearing quartz veins are hosted by Murdama sandstone and by Idah Suite biotite granodiorite – gold values as high as 51.4 g/t are reported. The area of ancient mines at Shaib Abu Hashayim (MODS 3272), formerly known as Ar Rahail and located only 5 km south of Al Iblah, was rediscovered by SAMS in 1941. The initial exploration work comprised programs of bedrock and dump sampling (Smith and others, 1984a). The USGS mapped the area during 1981 as part of a regional 1:100,000-scale reconnaissance geological mapping program. The Al Rahail and nearby occurrences, including Al Iblah, were re-examined and sampled at that time. Follow-up exploration in 1984-85 consisted of 1:1,000 scale geological mapping, and 1,486 m of trenching along 38 profiles as a sectional spacing of approximately 30 m. Ancient workings were mapped and chip sampled at 1:100 scale producing 293 samples, each 5 m in length. The initial sampling produced irregular and low gold assays up to 4.2 ppm. A telluric survey indicated a lobate anomaly at depth directly below the irregularly shaped intrusive. There is little question that the geology and geophysical anomalies associated with mineralization at Al Iblah and Shaib Abu Hashayim conform to the Sukhaybarat-Bulghah model.

The Rawdat al Baayith prospect (4569) is situated about 13 km WSW of the Wadi Iblat ar Rihayl prospects and about 22 km west of the Al Iblah area. It is an isolated occurrence, yet it is still within the cluster of gold prospects that is found in this area. Exploration by the USGS in the region comprised the collecting of 1,311 wadi sediment samples in the Wadi ash Shubah Quadrangle (Miller and Arnold, 1987). After being digested (solvent unknown), the samples were analyzed by emission spectrograph, and it is worth noting that elements such as As, Bi, Cd, Sb, Au and Ag were <u>not</u> detected in these samples despite the large number of gold occurrences in the area. During 1985, the USGS collected rock-chip samples from one square metre areas of bedrock exposure, and these samples were similarly analyzed by spectral methods. One sample of highly quartz-veined bedrock from Rawdat al Baayith contained 30 g Au/t and 3 g Ag/t. Other samples along strike on the vein carried gold contents as high as 8.6 ppm, with anomalous Ag, As, Bi, Mo, and W values. No of the mid-1990s, no follow-up work had been performed in this area. WGM understands that this and other prospects nearby are on a licence owned by Ma'aden, and that Ma'aden has done work in the area however the results were not available to WGM for review during this assignment and little specific is reported in the available literature regarding the geology of this specific area.

The ancient gold workings at Shaib abu Amayir (1272), formerly known as An Najadi, are located about 6 km SSE of Shaib abu Hashayim (Ar Rahail), and have been described as being among the most extensive ancient excavations in the whole of the Arabian Shield (Howes and others). SAMS sampled the ancient workings between 1955 and 1956 (Schaffner, 1956a) revealing an average gold content of 3 g/t in 17 dump samples. Eleven test pits dug into waste piles averaged 2.4 g Au/t. Trenching was initiated by the USGS during 1982 and 1983 (Cole, 1985a). Maximum gold contents of 52 g/t were found in quartz veins, vein

selvages and altered halos surrounding veins and within hematized diorite and metaclastic wallrock. Regional follow-up exploration by Riofinex during 1984-85 included Shaib abu Amayir and 10 other prospects in the cluster found in the area. A program of wadi-sediment sampling was carried out, resulting in 463 samples from an area of 1,132 km^2. This equates to a sample density of one site per 2.4 km^2. The An Najadi and adjacent gold prospect at Jidhibat al Iqab (1271), formerly Agob, were indicated by gold anomalies greater than the 25 ppb (95 percentile) contour. Riofinex's work also included 166 samples of ancient dump material, the excavation of 23 trenches totaling 3,163 m and the collection of 441 trench channel samples (Howes and others, 1986). Quartz veins were more strongly mineralized than the country rocks with gold contents as high as 70.7 g/t. It is uncertain whether any work has been carried out in the area since the early 1990s when WGM completed its historical review and recommended the site as a high potential exploration target.

About 70 km east of Shaib Abu Amayir (An Najadi), the Al Mohsoniyah antimony-gold occurrence (4952), formerly known as Al Muhsiniyyah, became a focus of activity by the BRGM during the late 1990s. Surface exploration included 1:2,500 scale geological mapping, 961 rock geochemical samples, geophysical (VLF-EM, magnetometer, resistivity and radiometric) surveying and the excavation of 28 trenches totaling 2,100 m. In trenches, the average thickness of the mineralized zones was 9.5 m grading 1.2 g Au/t (Récoché, Al-Jehani and Shanti, 1998). Follow-up exploration included 20 shallow drill holes totaling 1,256 m. Initial modelling of the zone by the BRGM produced an estimate of 340,500 t averaging 2.15 g Au/t, and the ultimate resource potential was estimated at as much as 1 Mt. The mineralization was largely found to be uninteresting because of its refractory and "dispersed = irregular" character. The BRGM recommended additional work along the Murdama-Idah Suite intrusive contact.

The ancient gold workings at Al Khaymah (3941) are located 54 km SE of the Shaib abu Amayir area and are thus well outside of that cluster including Al Iblah, Iblat ar Rihayl and Rawdat al Baayith. It is a single prospect with no other gold occurrence within a 15 km radius. The USGS initiated modern exploration of the ancient workings following 1:100,000-scale regional reconnaissance mapping and sampling in the early 1980s (Cole, 1985b). Samples collected in five separate areas of ancient mine dumps carried anomalous gold values. Follow-up sampling from various sites along the Ata Fault and other reconnaissance sites produced interesting base metal and indicator element anomalies were present in listwaenite (e.g. 2,000 ppm Pb, 300 ppm Sb and 200 ppm Sn; up to 1,200 ppm As). However, no mention is made of interesting gold values, and it appears to WGM that little work has been done at Al Khaymah since the initial work by the USGS.

The Al Habla area is near the northern end of the gold belt, but south of the clusters of prospects in the Iblat ar Rihayl and Shaib abu Hashayim areas. The Al Habla cluster of prospects comprises MODS indices 1267, 3512, 1286, 4239 and 1287 as well as the Mutribah (formerly Al Madraba) occurrence (3513) which is a gold-silver prospect. The area also encompasses an interesting Ag-Pb-Zn prospect at Jabal ash Shuhaban (4240). Ancient gold workings at Al Habla follow a northerly-striking vein system for approximately 3.7 km, reaching a maximum width of 900 m near the northern end. The area was initially sampled by the Saudi Arabian Mining Syndicate ("**SAMS**") in 1946. Approximately 30% of the samples

assayed more than 8.6 g Au/t (Schaffner, 1955). The gold system was estimated to be in excess of 3 km in length and drilling was recommended, however only trenching was actually carried out. Assay values from the trenches were deemed to be lower than what was considered interesting at the time, and work was discontinued. The USGS returned to the site in the early 1980s and initial bedrock sampling reported gold values as high as 44.6 ppm and mean gold and silver contents were 12.51 ppm and 2.89 ppm, respectively. Dump samples produced gold values to 150 ppm from the Al Habla East workings and phyllitic wall-rock produced assays to a maximum of 6 ppm (Begg, 1981). Continuing work comprised 1:20,000 scale geological mapping, wadi sediment sampling, bedrock chip sampling and modelling of the gold zones (Smith and others, 1984b). Follow-up exploration by Riofinex during 1984-85 covered the region but no site-specific investigations were carried out and the Al Habla area was again abandoned without being drilled.

The Hishshat Akkash gold occurrences (MODS 3114, 3940 and 4242) are located approximately 24 km WSW of Al Habla. The main occurrence (3114) is also known as Sukhaybarat Northeast. The USGS work in the area during the early 1980s consisted of prospect mapping and sampling as well as geophysical surveying. Reconnaissance grab samples of quartz veins contained gold values as high as 15 g/t, and gold contents of 0.4-9.4 g/t were found in altered diorite and "gossanous material". Silver and base-metal contents were also anomalous. Several years later, Riofinex followed up excavating nine trenches totalling 1,379 m, followed by 1:2,000-scale geological mapping, 232 chip-channel samples and geophysical surveying using magnetometer, IP, resistivity, seismic, radiometric (spectrometer) and gravity (Sanderson and Harvey, 1985). The trench samples generally carried gold values of less than 1.1 ppm. IP-resistivity surveys were able to distinguish between intrusions and plutonic rocks but failed to differentiate between zones with gold-bearing veins and country rock.

The Sukhaybrah ancient gold workings, formerly known as Sukhaybarat Gharbiyah (MODS 0405) and Sukhaybarat ash Sharqiyah (0406), are located about 50 km east of Nuqrah and about 4 km south of the Akkash prospects. They have also been referred to as the Sukhaybarat Red Hill and East Mine deposits, respectively (Clegg, 1986). The Sukhaybrah area was first examined during 1937 by SAMS which located and sampled ancient mine workings over an aggregate strike length of 1,048 m. Five samples taken over a strike of 460 m averaged 18.3 g Au/t. Schaffner (1955b) subsequently reported that the quartz veins found in excavations have a width 0.6-1.2 m. Schaffner noted more recent assay results that were much lower than previously reported - in-situ quartz veins averaged 1.7 g Au/t across 1.2 m, however he recommended diamond drilling to explore several vein systems. In 1956, trenching of the south workings and one 43 m diamond drill hole on the northern ancient workings resulted in an intersection of 2.4 g Au/t across 1.8 m in a zone of only 14% core recovery (Schaffner, 1956a). Sludge samples from the hole gave much higher values of 5.1 g Au/t over 5.5 m. No follow-up exploration was completed until the early 1970s when the Jabal Mawan quadrangle was mapped at a scale of 1:100,000 as part of a regional BRGM reconnaissance exploration program (Aguttes and Chaumont, 1974). Bedrock sampling by the BRGM produced variable results ranging from trace amounts to 75 g Au/t with the best mineralization near the Murdama group contact with plutonic rocks. The analysis of 17 pan concentrated alluvial samples over the pluton produced gold assays as high as 25 g/t. Following this, the area surrounding the ancient workings

was geologically mapped by Riofinex at a scale of 1:20,000 in order to better define the geology of the prospect. In 1982, Petromin (now known as Ma'aden) completed a 61 hole (3,346 m) drilling program at Red Hill comprising 1/3 diamond drilling and 2/3 percussion drilling as well as 13 holes (674 m) at East Mine, only 17% was cored (Clegg). In 1983, a further 99 holes were completed (12,329 m) of which 9,448 m were cored. Based on this work, the total estimated resources at Sukhaybrah are estimated at 8.4 Mt grading 2.5 g Au/t and the mine commenced production in 1991. After exhausting the original orebodies, the mine suspended operations in 2004 – actual production data for the mine over its lifetime was not available for this review. During the period following closure of the mine, the Sukhaybrah mill continued to process ore trucked from the Bulghah deposit, and between 2004 and 2008 approximately 171,000 ounces of gold was produced and the Sukhaybarat mill was up-graded with a CIL circuit. With increasing gold prices in the post-2010 period, and after completing additional exploration drilling, the mine re-opened in 2014 with a JORC compliant resource estimate, based on a 0.5 g Au/t cut-off grade, of 19.69 Mt of Indicated Resources averaging 1.17 g Au/t and 8.11 Mt of Inferred Resources averaging 1.01 g Au/t (Wardell Armstrong International, October, 2013). Of this, 16.73 Mt grading 1.08 g Au/t were classified as Probable Reserves based on a 0.5 g Au/t cut-off grade.

A large number of ancient mines were developed on Murdama-hosted quartz veins in the greater region surrounding the Sukhaybrah Mine. These include Shaib Sukhaybrah Aljharbi also known as Wadi Sahub NE (0407). Some of the most significant of these occurrences are found at Shaib Al Jifrah (MODS 3270, formerly known as Khidar, the Jerayer occurrences comprising Adanat Al Fuqu (1268, 4259), formerly known as Jerayer, Wadi Jurrayir-SE (3267), previously known as Wadi al Jurayyir, Shaib Ar Ruwaydat (3268) also known as Jurrayir-SE and the Wadi Al Jurayyir occurrence (1604), as well as the occurrences at Jidhibat Al Iqab (1271, 3896) formerly Agob, At Tarfawi (4248), Dulayat Silim-N (0550) formerly Jabal Musamah, the Abraq Shawfan occurrence (MODS 0961, 2660), and the Wadi Sulayman occurrences (MODS 0091, 0415, 3508). These occurrences have been covered by systematic 100,000 scale regional (quadrangle) geological mapping and dedicated exploration programs have been carried out on each, initially comprising grab sampling of the waste dumps at ancient mines. Most of the occurrences are located within broad areas that geochemically sampled using wadi sediment media. Sample patterns were not adjusted to accommodate known mineralized sites, nor were sample densities, commonly less than 1 sample per 10 km, increased in the vicinity of these sites. Where economically interesting mineralization was found, more extensive bedrock sampling was completed across or along the old workings. Where higher gold values were discovered, chip sampling or channel sampling was used to better quantify the mineralization. Geological sketches were made at these sites to identify sample locations, however few of these sketches are included in published reports.

The early work at the Humaymah deposit, located 50 km south of Sukhaybrah, included regional mapping and occasional trenches by the BRGM and USGS, however no historical prospecting has taken place. In 2004, Maaden was the first to commence with regional soil geochemical program on its Mishkah license. One of the identified anomalies was Humaymah, this was followed up with a more detailed mapping and posthole drilling campaign. Exploratory drilling began in 2006. By June, 2007, the zone had been tested with RC drilling and then by diamond core drilling. In total, 103 holes were completed, and the mineralized

zone was thought of as open in all directions. A total of 301 boreholes (69,486 m) have been drilled to date. Using a 0.5 g Au/t cut-off, the indicated and inferred mineral resources total 54.23 Mt at an average grade of 1.01g Au/t.

The ancient workings at Shaib Abu Nubtah-NE1 (0399), formerly Jabal Mawan, and Umm Zarib (0398) are located about 50 km southwest of Sukhaybrah. Shaib Abu Nubtah-NE1 was rediscovered by Dirom in 1946 and Umm Zarib by Schaffner in 1956 while working for SAMS. Ancient workings are common at both sites. The northeast group of workings can be traced in a northwest direction for a distance of about 600 m. The discovery of visible gold in the northeast workings led to sampling that resulted in bonanza grade gold assays as high as 257.8 g/t or **7.52 ounces per ton!!** A series of grab samples taken over a 518 m strike length averaged 13.37 g Au/t. Visible gold was also reported in the southwest workings and grab samples yielded gold assays up to 264 g/t (7.70 oz/ton). A 620 m strike length of the zone averaged 12.7 g Au/t. The ancient workings at Umm Zarib are aligned to the northeast and cover a strike of approximately one kilometre. An average gold content of 11.3 g/t was found in dump samples over a sampled distance of 183 m. The structures at Shaib Abu Nubtah-NE1 were reported by Schaffner as being tested with six diamond drill holes totalling 347.5 m, but the locations and geology found in this drilling are not reported. The best gold intersections were very narrow and occurred in Hole 21 (235 g/t over 33 cm) and Hole 22 (6.17 g/t over 17 cm). Based on his interpretation of the geology, Schaffner concluded that as the vein structures pinched at depth and that the Shaib Abu Nubtah-NE1 prospect had limited potential. In the late 1960s, the BRGM visited the location of two INPUT EM anomalies in the Umm Zarib area and concluded that the probable source was fault/shear zones which did not merit additional follow-up work (Corpel and Delfour, 1970). It is interesting to note that although they discovered quartz veining (containing pyrite and chrysocolla) and ancient workings along the banks of a wadi coinciding with one INPUT anomaly they do did not appear to have done any sampling. During 1973, the BRGM visited the ancient workings at Shaib Abu Nubtah-NE1 and Umm Zarib during regional 1:100,000-scale geological mapping of the Jabal Mawan quadrangle (Aguttes and Chaumont, 1974). The ancient workings were mapped at 1:20,000 scale and the quartz vein was sampled at Umm Zarib. Unfortunately, the subsequent report did not present any analytical results for gold or silver from this sampling.

Modern exploration commenced in the Bulghah area in the early 1990s. The Bulghah gold mine is located 66 km southwest of the Sukhaybrah Mine. Unlike other projects in which the SGS, DMMR, USGS, BRGM and other surveys played an exploration role, Bulghah has been a Ma'aden project from the beginning. Consequently, nothing is publicly reported of its exploration history. WGM assumes that the project evolved from regional exploration programs recommended by WGM in its 1989-1992 review, and following which Ma'aden acquired extensive exploration licences in the Kingdom. Following its drilling programs and based on field mapping and geological core logging, wireframe surfaces were constructed by Ma'aden geologists representing the faults bounding the intrusive as well as wireframes of the aplite dykes. The geological wireframes were used to support a Mineral Resource block model based on a cut-off gold grade of 0.4 g/t. The geological model was constrained at surface by topography and was constrained at depth to half the drill hole spacing below the base of the drill holes. Additional sub-domains relating to the oxidation state were also modeled to further constrain specific gravity models. Following a preliminary feasibility study

completed in 1997 by Ma'aden, a final feasibility study was completed in August, 2000 by independent consultants who proposed the construction of an open-pit mining operation processing 4.0 Mt/annum of ore through a heap leach processing facility and producing 84,000 oz of gold per annum. Construction at Bulghah commenced in March, 2001 and the facility was commissioned during October, 2002 at a capital cost of US$70m. In July, 2007, the Bulghah Mine reported Mineral Reserves of 16.8 Mt grading 0.8 g Au/t. Total Mineral Resources comprised 24.0 Mt grading 0.8 g Au/t. In December, 2012, Ma'aden estimated the remaining resources to total 15.23 Mt averaging 0.85 g Au/t (Table 9.9 in excerpt from Ma'aden report, 20140917 GLD_BGM_NOT Bulghah Geology and Resources.pdf).

The Ash Shumta gold prospect (MODS 2099) is located immediately north of the Ashumta South occurrences. Exploration was initiated by SAMS during 1937 when two suites of bedrock grab samples were analyzed for gold. The first suite of five samples averaged 22.57 g Au/t and the second suite of two samples averaged 3.6 g Au/t (Bounny and others, 1987c). In 1956, Schaffner resampled the workings and reported an average gold assay of 8.4 g/t from five samples. During 1964-65, the USGS collected 200 reconnaissance geochemical samples from the region for analysis (results uncertain). In 1971 and 1973, two MSc theses were completed on the area (Khallah, 1973; Marzouki, 1973); this work focused primarily on the geological setting and gold metallogenesis. The first systematic mapping and sampling may have been carried out by Riofinex during 1981, and follow-up, trenching, and additional mapping and sampling were completed in 1983. In 1985 and 1986, the BRGM carried out 1:2,500 scale geological mapping of the trenches combined with the collection of 43 trench and dump samples. Geophysical surveying included 6,100 m of EM and IP, with a further 0.33 km^2 of detailed IP surveying. IP surveying detected a strongly conductive zone, at least 500 m which extended to a depth of approximately 50 m and spatially corresponded to the eastern gold-bearing zone. A second, more westerly zone of contrasting resistivities does not correspond to mineralization but appears to reflect the contact between greisenized and fresh granodiorite. The easternmost area of ancient workings on Jabal ash Shumta was not drilled or trenched because it was difficult to access. Nineteen percussion holes totalling 656 m were completed to a maximum vertical depth of 58 m. This drilling was successful in intersecting gold mineralization to a maximum of 5.4 g Au/t over 3 m (Bounny and others). Broader gold-mineralized sections include 3.42 g/t over 6 m and 3.14 g/t over 21 m. The latter of these intersections indicated an extension of mineralization beyond the base of the hole. Additional IP and resistivity geophysics, and in-fill drilling were recommenced to investigate the area between the east and west zones.

The Ashumta South (Wadi umm Shifa) gold occurrences (MODS 1108, 1110, 1111 and 1112) are located immediately south of the Ash Shumta prospect described in the previous paragraph. This area also includes the Simfan umm Shieh occurrence (2100) which is situated about 4 km to the WSW. The main prospect at Ashumta South (1108) has been extensively explored. Gold exploration was initiated in 1937 with a number of examinations of ancient workings by SAMS. During the mid 1950's, Schaffner collected bedrock and dump samples from the Ashumta workings and may have visited the Wadi umm Shifa site (Schaffner, 1956a). Reconnaissance geological mapping and geochemical sampling work was carried out during 1964 and 1965 by the USGS as part of a 78,000 km^2 regional survey. During 1981, the area was remapped and sampled by Riofinex. Nine samples of vein quartz produced gold assays ranging from 3.6

to 24.0 ppm and silver assays from 1.4 to 16.0 ppm (Begg, 1981). In these samples, gold and silver contents averaged 1.8 and 9.3 ppm, respectively. One sample of limonitic wallrock contained 2.8 ppm Au and 1.4 ppm Ag. Sampling by the BRGM in 1983 failed to detect interesting gold or silver values (Bounny and others). Mapping also covered the Simfan umm Shieh area where 20 trenches were excavated across the mineralized veins. During 1986, three unsurveyed percussion holes totalling 189 m were drilled on the most highly mineralized sections of the vein at Simfan umm Shieh. It is not reported why this area was favoured for drilling, however samples from these holes contained less than 2 g Au/t.

The Jabal al Koom East and West gold prospects (MODS 1066 and 1083) are located approximately 5 km apart and 45 km ESE of the Bulghah Mine. The area of interest also includes six additional mineral prospects which are within a 5 km radius of the main prospect. These include Jabal al Kwaimeen North, South and Southwest (1072, 1069 and 1068) and Wadi al Kwaimeen North (MODS 1071), as well as Jabal Gulb North and South (MODS 1067 and 1070). Waste rock sampling at ancient mine workings by the DMMR in 1963 initiated exploration of the Jabal al Koom area. During the early 1970s, several MSc research programs were undertaken university students who carried out mapping, sampling, trace-element analysis and test geophysical profiles on the prospects (e.g. Arinan in 1972 and Hanif in 1973). Riofinex completed a more intensive mapping and systematic chip sampling program in 1980 when 10 trenches were excavated (Boyle and Howes, 1983). Follow-up trenching in 1983 resulted in six additional trenches and both more detailed mapping, surface sampling and chip sampling in trenches. The gold-bearing veins in the trenches were reportedly narrow and the sampling program was unable to demonstrate continuity in grade along the veins. These factors have led previous workers to down-play the importance of this prospect, and no further gold exploration was recommended. It is uncertain whether any work has been carried out since that time.

The ancient working at Al Tayma (4293) was discovered in 1984 in the eastern Afif Terrane in the eastern segment of the Arabian Shield. The area is about 16 km north of the Al Maham prospect which is discussed in the following paragraphs. The ancient workings at Al Tayma occur a wide section and a strike of 400 m. The initial exploration work in 1987 comprised geological mapping, sampling, geophysics (EM and dipole-dipole IP), minor trenching (243 linear metres) and the completion of 4 shallow percussion drill holes totaling 385 m. Fractures in granodiorite are rusty and contain pyrite, sphalerite, galena and ilmenite. Initial grab samples gave gold values of as much as 12.5 g/t, and follow-up sampling showed gold values as high as 38.5 g/t. Follow-up trenching and IP surveying was completed to developed targets for drilling. Grab sampling of bedrock in the trenches gave very impressive results with a high proportion of gold assays >10 g/t. Unfortunately, the BRGM at this time was relying heavily on percussion drilling. The best drill hole intersection was 8.0 g Au/t over 3 m which the BRGM thought to be disappointing. Given the fact that samples from percussion holes typically under-report grades and smear mineralization, the results are highly encouraging but the significance of this economically interesting intersection is uncertain. Following WGM`s favourable review of Jabal Tayma in 1989-91, the BRGM reappraised the prospect in the late 1990s. Three diamond drill holes totaling 216.15 m were cored and three reverse circulation holes totaling 224 m were completed that confirmed the -45^{o} west-dipping structures (Leistel et al, 2001a). Several new zones sub-parallel to the original zone were discovered. The best of the more recent cored holes

intersected 2.52 g Au/t over 3 m. The best RC intersection was 4.87 g Au/t over 3 m. Following completion of the most recent work, the BRGM recommended no further work be completed at Jabal Tayma due to the uneconomic character of the zone. It is unknown if any more recent work has been done.

The Al Maham prospect area (MODS 0297) is located about 20 km southeast of the Jabal Hamikh prospect. The ancient workings were first discovered in 1967 by Duhamel (1971) who sampled dump material that returned assays of between 0.05 and 14.0 g Au/t. During 1968, the BRGM completed limited trenching and SP work which gave variable results. During 1986, the BRGM mounted a more detailed follow-up program consisting of mapping at 1:1,000 scale, sampling, geophysical surveying (SP, EM, and gravity) and percussion drilling (10 holes totaling 697 m). Encouraging results were obtained from sampling in trenches 1 and 2 with gold values of 3.2 g/t over 17 m and 7.2 g/t over 12 m respectively. Geophysical surveying has presented a complex picture of a north-trending series of IP anomalies, one of which is coincident with a magnetic low. A series of transverse faults represented by magnetic highs intersected the formational anomalies. Results from the drilling were generally disappointing with the exception of holes P3, P4 and P5 which were drilled in the vicinity of trenches 1 and 2: P3 intersected 29.7 g Au/t over 9 m in a quartz vein. Hole P8 drilled in the southern part of the prospect returned a value of 9 g Au/t over 3 m. Despite being disappointed by the results, Shanti and Gelot (1987) recommended additional drilling to explore the gold intercepts obtained in the first drilling program. Very little work was carried out on the prospect until 2000 when the Saudi Geological Survey ("**SGS**") excavated 15 trenches totalling 781 m, and completed 11 diamond cored holes (1,450.35 m) and six reverse-circulation drill-holes (400 m) (Leistel et al, 2001b). The drilling encountered many technical problems and was cut short for budgetary reasons. In the northern part of the zone, the best gold intersection was 2.06 g/t over 7.6 m. An RC hole in the southern part of the zone returned 5.69 g/t across 11 m. The SGS concluded that the northern zone contained approximately 2 Mt at 0.85 g Au/t and that a smaller resource of 280,000 t averaging 3 g Au/t was present in the southern zone. No additional work at Al Maham has been completed since the SGS program.

The Jibal As Sufrah (formerly As Safra) Au-Ag prospect (MODS 0002) is part of a large north-trending hydrothermal alteration (chlorite, sericite, silica) zone that extends for a distance of approximately 2.5 km and is up to 1 km wide. Ancient miners worked portions of this area for copper and, until recently, exploration efforts were focused on this commodity (Twitchell, 1936; Conraux and Delfour, 1970). During 1986, BRGM carried out reconnaissance sampling for gold, resulting in the discovery of the As Safra gold prospect. Twitchell's grab samples assayed between trace and 12.4 g Au/t. In 1956 Schaffner and McGarry carried out trenching on the ancient workings and several years later Quinn (1963b) mapped the workings at 1:2,800 scale. Between 1967 and 1969, the BRGM carried out several exploration programs that included mapping, geochemistry, geophysics, and drilling. The SP, magnetic, Turam, and IP surveys conducted over the prospect delineated only weak anomalies even though the IP surveying was specifically designed to detect disseminated mineralization, unfortunately using a 240 m profile spacing. Seven holes, totalling 2,059.3 m were drilled in 1968 and 1969, and the best intercept obtained assayed 4.07% Cu over 5 m (hole SE-l). Delfour (1981) estimated that the prospect contained 18 Mt grading 1.0% Cu. In 1986, interest in the gold potential of the area was revived and BRGM carried out a reconnaissance chip sampling program for gold which highlighted the As Safra gold-carbonate zone. Detailed chip and channel sampling

confirmed the gold anomalies and helped define the distribution of the mineralization. Individual samples assayed as high as 242 g Au/t and 556 g Ag/t. Trench sampling gave gold values of 5 g/t in widths up to 6 m. Almost incredibly, the BRGM concluded that these results did not justify any further work on the prospect (Beziat and Billa, 1989). No significant exploration has been carried out on the prospects since this time due to the presence of the Trans-Arabian Pipeline extending through the prospect area. The most recent work at As Safra (0002) was by the BRGM and SGS which restarted work during 2000 consisting of establishing a grid over a 4.3 km^2 area followed by collecting 368 surface bedrock samples, ground geophysics comprising induced polarization, self-potential, electromagnetic and radiometric surveys, and the excavation of 13 trenches totalling 1,226 linear metres (Leistel et al, 2000). Geochemical analyses of dump and trench samples confirmed the presence of two types of mineralization:

1) Cu-dominant mineralization found in the dump samples from the South Workings and in earlier drill-holes in the North Workings and Slag area; and,
2) Gold-base metal mineralization found only in the Central area in a carbonate layer and in the ancient workings north of the pipeline.

The BRGM interpreted the two styles of mineralization to reflect different paragenetic events in the same mineralizing system, possibly representing an epithermal model. Radiometric and magnetic surveys mostly outlined the dike corridor in the central part of the prospect, and the main NW-SE structural trend to the south. The IP measurements revealed two major polarizing anomalies likely to correspond to disseminated-sulfide deposits in the North and South Workings areas. The north anomaly is much stronger than the south one, but these two anomalies may converge at depth under the central part of the prospect resulting in a continuous polarizing structure over the prospect at depths ranging from 100 to about 300 m, and deepest in the Central prospect area. The former drill-holes were not drilled deep enough to test the depth range of the north anomaly. Most recently, the BRGM estimated the As Safra resources as having potential for 2 Mt at an average grade of 2% Cu or 18 Mt averaging 1% Cu (BRGM-TR-2000-8). A recommendation was made for additional exploration, especially in the northern area however working in this area is restricted area within 500 m on either side of the ARAMCO pipeline.

Geology

The northern end of the Sukhaybrah-As Safra gold belt is underlain by Murdama group clastic and carbonate rocks of the Maraghan formation which, along the north margin of the area, are thrust over younger Murdama Group strata of the Hibshi Fm. And locally are overthrust on even younger rocks of the Al Jurdhawiyah Group creating a potential for Great Basin-type, carbonate-hosted gold mineralization not yet seen in the KSA.

In the northern part of the belt, the two prospects associated with the Raha Fault, Jabal ar Raha and Shaib Ash Shuayla, are underlain by steeply folded Murdama metaclastic rocks. The prospects are within 2 km of the Raha Fault zone, an easterly-striking Najd related structural complex along which Maraghan rocks are steeply overthrust on older formations (Zablocki and others, 1985). Country rock proximal to the fault,

as well as the rocks of the fault complex, are locally intruded by diorite, granite porphyry, monzogranite, and fine-grained felsic dikes. Alteration includes serpentinization, carbonatization, and localized 'jasperoid alteration'. In the northern part of the area, a low ridge of carbonate rock is described by the BRGM as being listwaenite, but its geological setting and origin are not discussed. The fault is thought to be a deeply penetrating structure along which volcanic, intrusive, and hydrothermal activity has occurred. Bodies of listwaenite are found in the fault zone suggesting that this rock is the product of hydrothermal alteration. Gold is commonly associated with quartz veins that are generally north-striking. Gold values as high as 34 ppm have been found in samples collected from the Raha fault zone and 25 dump samples of vein quartz at the Raha ancient mine site produced gold assays as high as 60 g/t with an average of 11.4 g/t. Significant mineralization in country rock is indicated by one sample of slightly iron-stained diorite wallrock which contained 18.2 g Au/t, and other samples of wallrock contained gold values of 5.2 g/t and 1.3 g/t. The BRGM pointed to similarities between the Raha site and the Sukhaybarat Mine, and the fact that an Idah Suite intrusion is present supports this model.

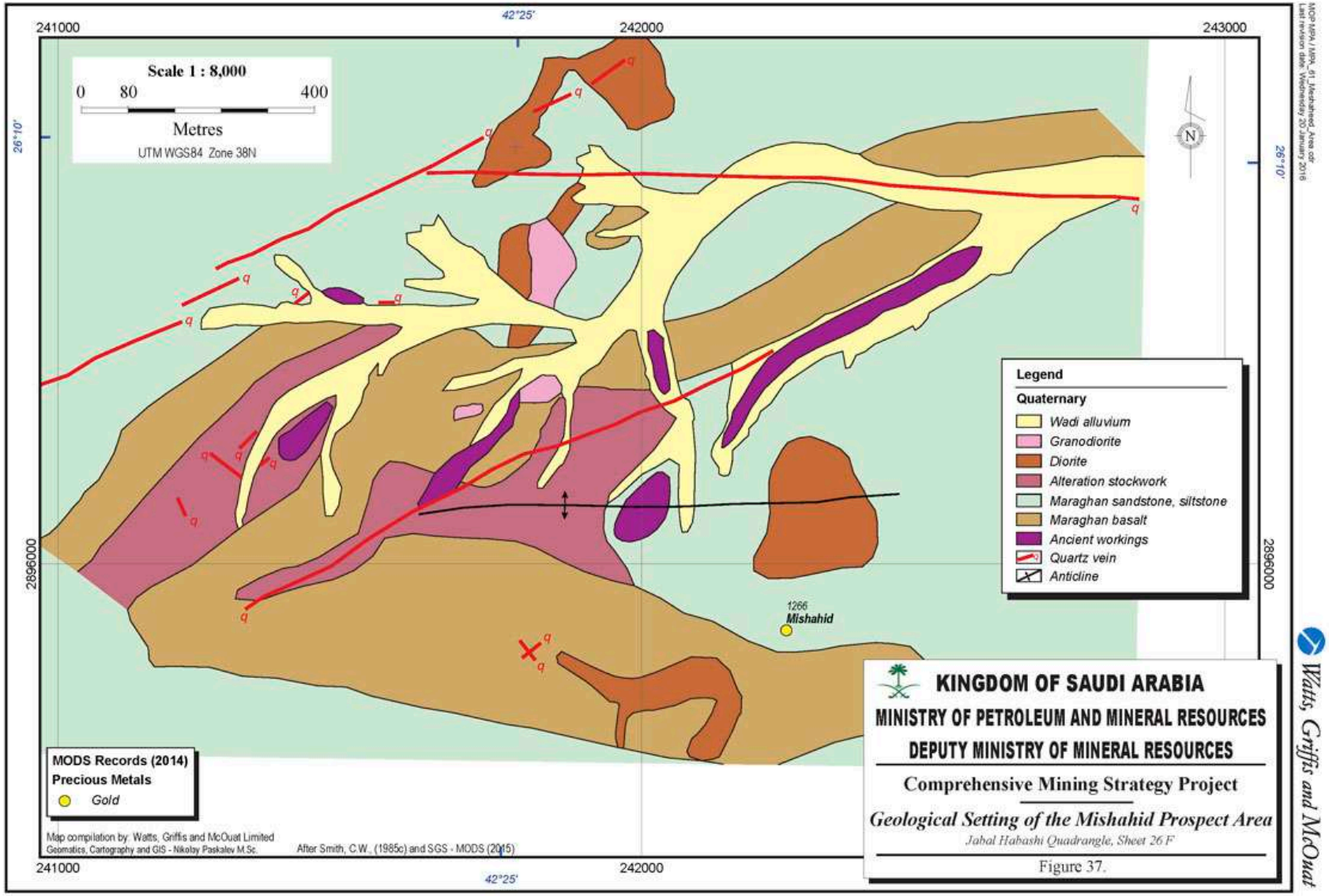
The gold content of the jasperoid alteration, such as is found at the Buqaya Ash Ashamaliyah Cr-Fe anomaly (3155), formerly known as the Buqaya Jasperoid Area, is not important. The fact that jasperoid alteration occurs may signify potential for Carlin-type gold mineralization as is found in Nevada, USA. Carbonatized rock (listwaenite) and jasperoid alteration are enriched in chromium and nickel, and are relatively depleted in molybdenum and copper. These lithologies point to a potential for Carlin-type epithermal gold mineralization, possibly associated with sedimentary strata and/or major structural zones.

The principal Shaib Ash Shuayla occurrence (1383) consists of gold mineralization in quartz veins, stockworks, and silicified zones, whereas the other occurrence (MODS 4238) is a gossan. Gold contents in 43 quartz dump samples were as high as 280 g/t or 8.2 oz/ton! Bedrock chip samples assayed as high as 52 g Au/t, although most assayed as <2 g/t (Smith and Samater, 1985). Low sulphide contents and arsenic concentrations of less than 700 ppm generally characterize the veins. Minor amounts of stibnite were reported in some dump samples. Apart from the strong alteration of the fault zone, hydrothermal alteration at the occurrences is neither widely nor strongly developed adjacent to veins.

A number of gold occurrences are situated in the Dulay Ash Shuhayba area, however the most important are the ancient gold mines at Dulay Ash Shuhayba (1266), formerly known as Meshaheed, as well as Dulay Ash Shuhayba-SE (5011) and Dulay Ash Shuhayba-E (5012). Gold-bearing quartz veins are hosted by granodiorite of the Idah suite and by adjacent sandstones and siltstones of the Murdama group (Figure 37). Bodies of quartz parallel north-easterly trending faults or shear zones which are haloed by hydrothermal alteration. These structures have undergone sinistral offset along Najd faults (Smith, 1985a). Gold occurs in quartz-molybdenite stockworks located in both intrusive and sedimentary rocks as well as along NE-striking quartz-gold-stibnite veins. The mineralization has been characterized as occurring within three very continuous shear zones which are a maximum of 2 m in width. The west shear zone, a 2 km long zone of discontinuous quartz veining and ancient workings, is reported to average 9.1 g Au/t and 10.7 g Ag/t. The central shear zone, a "hydrothermalized shear", is highly fracturing with average gold and silver contents of 3.8 g/t and 2.3 g/t, respectively. The eastern shear zone is poorly exposed due to alluvial cover, but

several samples indicate gold concentrations of 3.6 and 10.6 g/t. Significant gold and silver mineralization occurs in altered rocks adjacent to the veins with gold contents up to 421 g/t and silver values up to 14.5 g/t detected in samples comprising 95% wallrock (Viland and others, 1987). Other gold prospects in the surrounding area include Al Hubayriyah (1265), Dulay ash Shuhayba NE (4241), Mishahid NE (3275) and Dulay ash Shuhayba (4243) and Wadi al Jurayyir N (3269) however little is specifically known regarding the exploration of these sites. The widespread mineralization in this cluster of sites may be attributable to a large buried intrusion which has provided a heat-engine to drive hydrothermal activity.

The host rocks in the Iblat Ar Rihayl (Sha'bah) area comprise amphibolite basement rock and related quartz diorite which are unconformably overlain by Murdama Group sedimentary rocks (Figure 38). Over-thrusting of the metasediments onto older rocks occurs along a NE-striking reverse fault. The Au-Ag occurrences are in quartz veins that are hosted within shaley, limonitic and locally carbonaceous metaclastic rocks, intruded by coarse-grained bodies of granodiorite (Howes and others, 1986). Regional schistosities strike ENE whereas quartz veins have a variable configuration, ranging from very shallow dipping to sub-vertical. The veins are generally less than 15 cm in thickness. Ancient workings exploited veins of much greater width. Gold assays as high as 9.6 g/t are reported, and minor stibnite is found in the Iblat Ar Rihayl S prospect. The copper occurrence at Iblat Ar Rihayl, contains up to 2% Cu in a malachite-bearing zone of calcareous and carbonaceous, schistose rocks in a "stratabound" shear. This occurrence was mined for copper rather than gold. Sampling by Riofinex at the northeast occurrences returned gold assays of 26.7 and 35.4 g/t, respectively, whereas the average gold concentrations in composite vein and metasediment samples averages 5.3 and 7.6 ppm Au, respectively. According to Howes and others (1986), one high-grade sample from the northeast occurrence contained 2.2% Au ! Similar high-grade values were reported at Al Iblah, and there is little or no doubt that the mineralization conforms to the Sukhaybarat-Bulghah model. Northerly-striking quartz vein zones are associated with a similarly north-trending body of Idah Suite diorite. Gold-bearing veins occur at distances up to 400 m from the intrusive contact, and drainage patterns suggest that the veins may be located within fracture or shear zones sub-parallel to this contact. Significant gold and silver values up to 51.4 ppm and 9.5 ppm, respectively, are found within the veins (Smith and others, 1984a). Approximately 5 km to the south, the Shaib Abu Hashayim (Ar Rahail) prospect is underlain by siltstone and claystone of the Murdama Group which is intruded by an irregularly exposed body of Idah Suite porphyritic biotite-hornblende granodiorite (White and others, 1987). The NW-trending, largely Murdama-hosted gold-bearing quartz veins contain minor amounts of molybdenite. The veins were worked by ancient miners and were rediscovered by the USGS during reconnaissance mapping in the early 1980s. Some high-grade gold assays were reported.


241000
42°25'
242000
243000
26°10'
2896000
Scale 1 : 8,000
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Metres
UTM WGS84 Zone 38N
N
Legend
Quaternary
Wadi alluvium
Granodiorite
Diorite
Alteration stockwork
Maraghan sandstone, siltstone
Maraghan basalt
Ancient workings
Quartz vein
Anticline
1266
Mishahid
MODS Records (2014)
Precious Metals
Gold
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
After Smith, C.W., (1985c) and SGS - MODS (2015)
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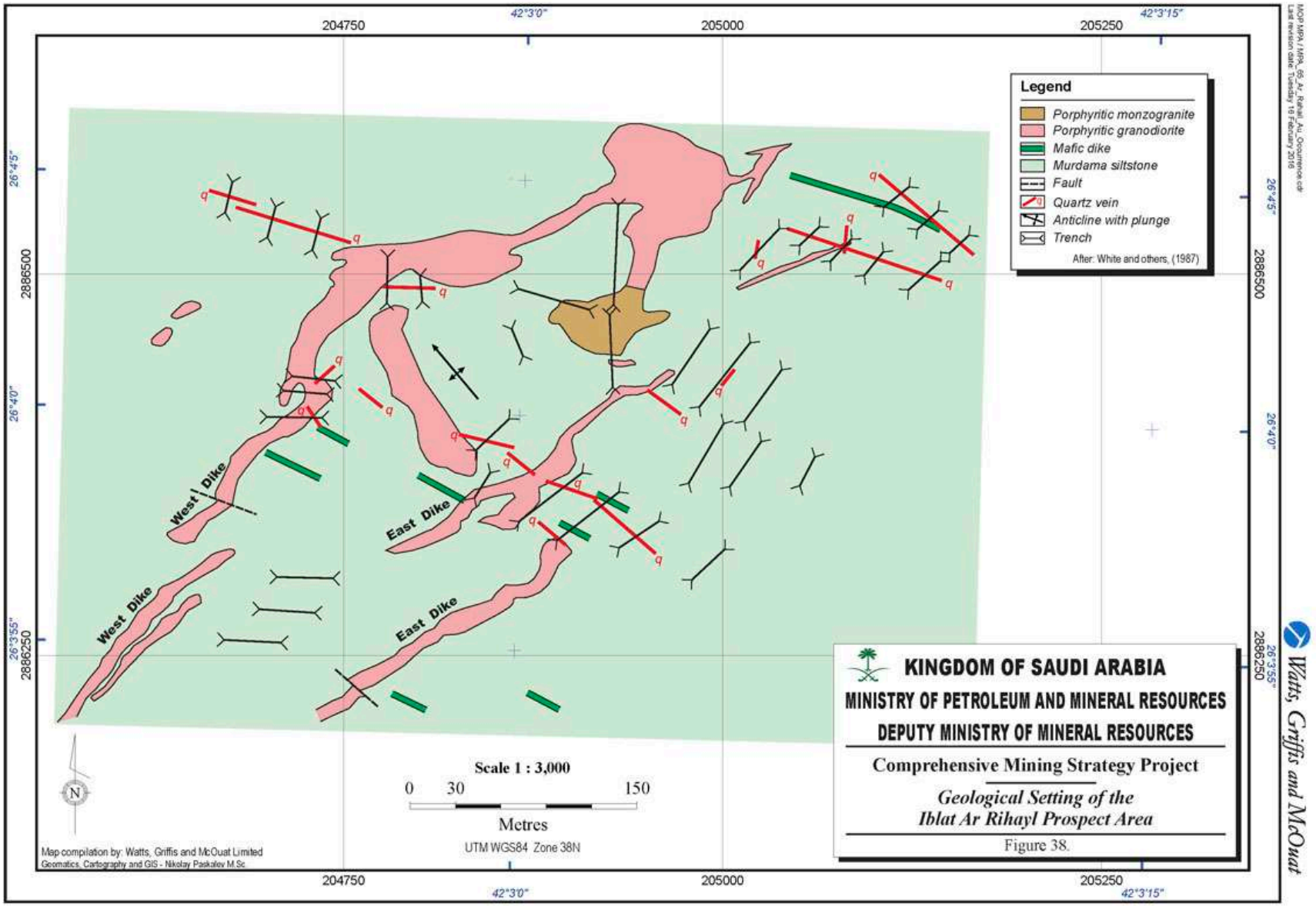
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Mishahid Prospect Area
Jabal Habashi Quadrangle, Sheet 26 F
Figure 37.
Watts, Griffis and McOuat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205000
205250
42°3'0"
42°3'15"
26°4'5"
26°4'0"
26°3'55"
2886500
2886250
Legend
Porphyritic monzogranite
Porphyritic granodiorite
Mafic dike
Murdama siltstone
Fault
Quartz vein
Anticline with plunge
Trench
After: White and others, (1987)
West Dike
East Dike
West Dike
East Dike
Scale 1 : 3,000
0 30 150
Metres
UTM WGS84 Zone 38N
N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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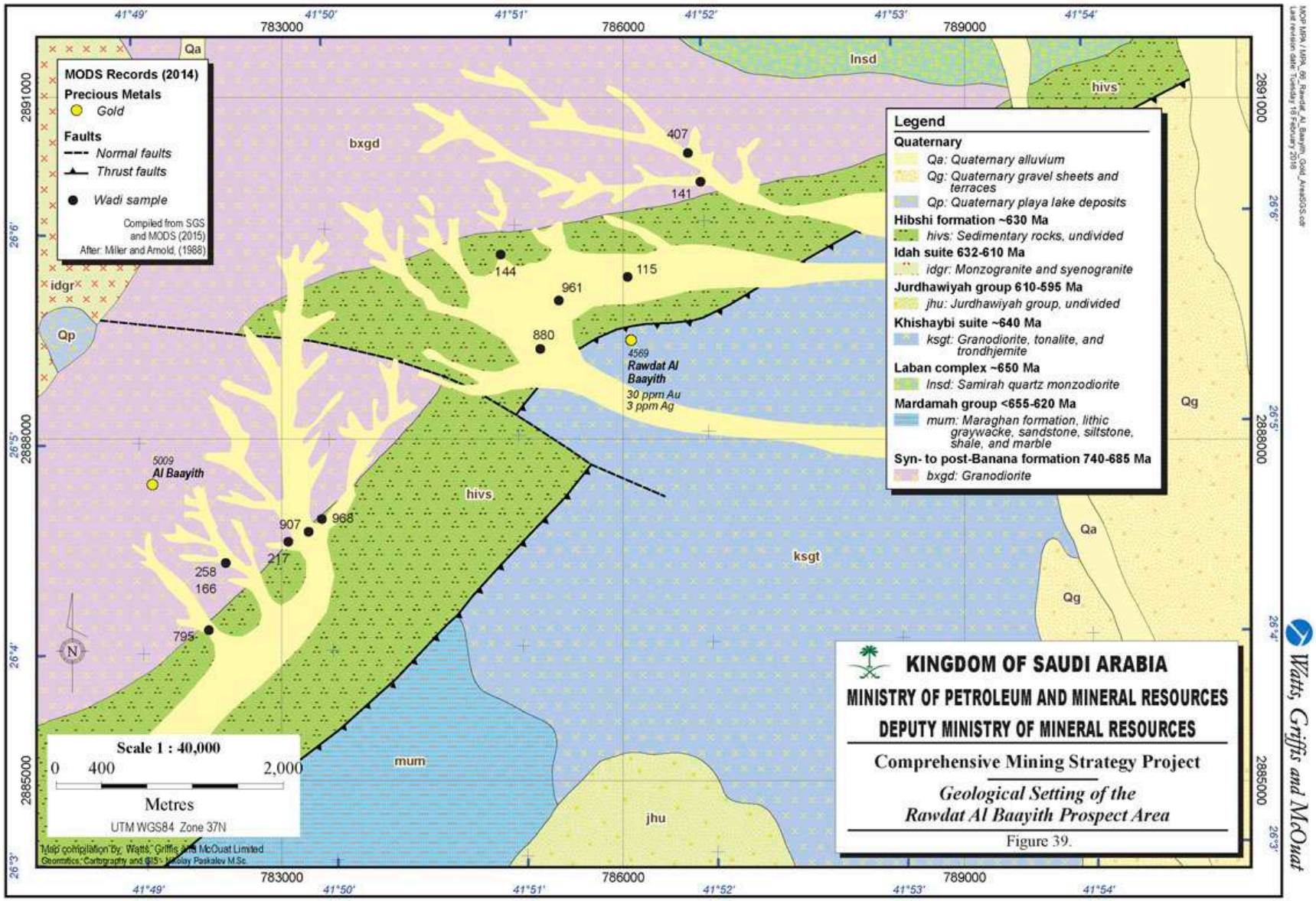
Geological Setting of the
Iblat Ar Rihayl Prospect Area
Figure 38.
Watts, Griffis and McOuat

The Rawdat al Baayith prospect is an intensely quartz-veined area associated with a granodiorite pluton (Figure 39). Gold assays as high as 30 g/t have been reported (Miller and Arnold, 1988). The area in which the prospect is located is distinguished by a NE-striking thrust fault along which younger Murdama clastic rocks (Zaydi Fm.) are pushed on top of older Murdama Group strata (Hibshi Fm.). The fault is part of the Raha fault complex which extends easterly across the adjoining Samirah and Silsilah quadrangles (Miller and Arnold, 1988). Prior to dislocation, all layered rocks were intruded by Idah suite granodiorite and the assemblage was offset along a NW-trending Najd fault. Gold mineralization in the area is associated with quartz veins that are spatially associated with Idah Suite plutonic rocks. The occurrence appears to be small and seems to have attracted little if any follow-up exploration. WGM attempted to visit the occurrence during 2007-08 and was unable to find it based on the MODS co-ordinates available at that time.

Gold mineralization at Shaib abu Amayir (An Najadi) occurs within Fe-stained quartz veins that are hosted by a sequence of openly folded, Murdama Group rocks comprising calcareous siltstone, shale, argillite, greywacke and limestone (Viland and others, 1987). The NNW-striking vein system extends for more than 4 km and is up to 700 m wide in some areas. Gold assays as high as 70.7 g/t are reported from grab samples of mineralized quartz veins. Samples of vein and altered Murdama group rocks contained up to 44.7 g Au/t. The hematized vein selvages seldom contained greater than 3 g Au/t. Altered wallrock assayed between 0.5 and 2.5 g Au/t over appreciable widths (e.g., 1.7 g/t over 5.2 m and 0.6 g Au/t over 95 m). Other less-altered or less veined rocks carried lower values; base-metal values were reported to be negligible. Veins previously worked by ancient miners vary from 60 cm to 1.0 m in width and exhibit a westerly dip of 35º to 45º, and the zones typically exhibit hematization and silicification in the adjacent wall rocks. Two bodies of Idah Suite dioritic pluton occur within the areas most extensively veined, and these are in turn intruded by late feldspar-biotite porphyry dikes (Howes and others). The layered rocks in contact with these intrusives are metasomatized to hornfels. The area is thought to be underlain by a larger body of intrusive rock than what is visible on surface. The major geological elements of the Shaib abu Amayir (An Najadi) and Al Iblah (Wuday) prospect area are shown in Figure 40.


MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Thrust faults
Wadi sample
Compiled from SGS and MODS (2015)
After: Miller and Arnold, (1988)
Legend
Quaternary
Qa: Quaternary alluvium
Qg: Quaternary gravel sheets and terraces
Qp: Quaternary playa lake deposits
Hibshi formation ~630 Ma
hivs: Sedimentary rocks, undivided
Idah suite 632-610 Ma
idgr: Monzogranite and syenogranite
Jurdhawiyah group 610-595 Ma
jhu: Jurdhawiyah group, undivided
Khishaybi suite ~640 Ma
ksgt: Granodiorite, tonalite, and trondhjemite
Laban complex ~650 Ma
lnsd: Samirah quartz monzodiorite
Mardamah group <655-620 Ma
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
Syn- to post-Banana formation 740-685 Ma
bxgd: Granodiorite
4569
Rawdat Al Baayith
30 ppm Au
3 ppm Ag
5009
Al Baayith
407
141
144
115
961
880
907
968
217
258
166
795
Scale 1 : 40,000
0 400 2,000
Metres
UTM WGS84 Zone 37N
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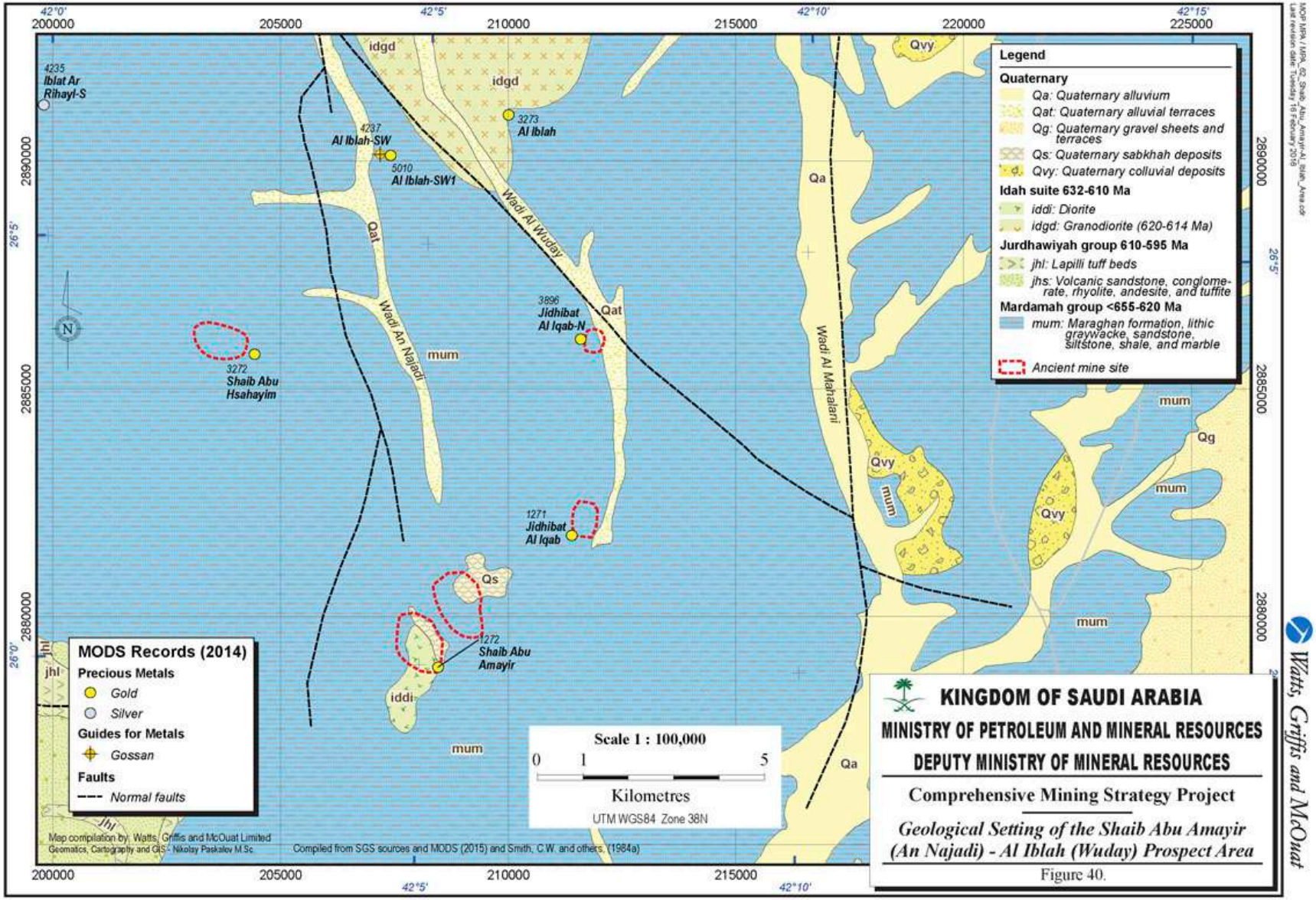
Geological Setting of the Rawdat Al Baayith Prospect Area
Figure 39.
Watts, Griffis and McOuat


42°0'
42°5'
42°10'
42°15'
200000
205000
210000
215000
220000
225000
2890000
2885000
2880000
26°5'
26°0'
4235
Iblat Ar Rihayl-S
4237
Al Iblah-SW
5010
Al Iblah-SW1
3273
Al Iblah
3272
Shaib Abu Hsahayim
3896
Jidhibat Al Iqab-N
1271
Jidhibat Al Iqab
1272
Shaib Abu Amayir
Wadi Al Wuday
Wadi An Najadi
Wadi Al Marralarni
idgd
Qat
mum
Qa
Qvy
Qs
jhl
iddi
Qg
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qvy: Quaternary colluvial deposits
Idah suite 632-610 Ma
iddi: Diorite
idgd: Granodiorite (620-614 Ma)
Jurdhawiyah group 610-595 Ma
jhl: Lapilli tuff beds
jhs: Volcanic sandstone, conglomerate, rhyolite, andesite, and tuffite
Mardamah group <655-620 Ma
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
Ancient mine site
MODS Records (2014)
Precious Metals
Gold
Silver
Guides for Metals
Gossan
Faults
Normal faults
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 38N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalov M.Sc.
Compiled from SGS sources and MODS (2015) and Smith, C.W. and others, (1984a)
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Shaib Abu Amayir (An Najadi) - Al Iblah (Wuday) Prospect Area
Figure 40.
Watts, Griffis and McOuat

The Al Mohsoniyah antimony-gold occurrence (4952) is a series of stibnite and gold-bearing quartz veins and lenses and lesser sericite-bearing hydrothermal alteration zones that are spatially associated with the contact zone between Murdama Group metasedimentary rocks and an Idah Suite quartz-diorite pluton. In trenches, gold mineralization averaged 1.2 g/t across 9.5 m (Recoche, Al-Jehani and Shanti). Lenticular bodies of quartz in hydrothermally altered rock are up to 6 m thick and 70 m long oriented along WNW-striking reverse faults and shear zones. Dump samples near ancient mine workings averaged 1.97 g Au/t, and a clear association was seen between those samples containing >5% stibnite which averaged 5.55 g Au/t and those containing <5% stibnite which averaged 0.22 g Au/t. Disseminated sulphides and gold are found in altered plutonic rocks and country rock although the grades reported were much lower (<0.2 g Au/t). The accepted exploration model is based on the Sukhaybrat Mine. The mineralization has a distinct Au-Sb-As-Ag geochemical signature, and the BRGM describe the mineralization as being “refractory”. Some of the stibnite is essentially massive. The follow-up drilling program produced the following selected intersections:

Hole	From (m)	To (m)	Width (m)	Gold (g/t)
C001	39.55	39.75	0.20	1.09
C002	112.0	113.05	1.05	5.36
C003	16.00	22.20	6.20	5.78
C004	18.10	20.20	2.10	1.79
C005	18.30	21.45	1.86	3.15
C015	51.00	52.80	1.80	6.13
C018	20.65	21.95	1.30	5.30
C020	58.35	63.55	5.20	1.13

The BRGM drilling was very shallow with the deepest intersections at less than 50 m vertical depth. The BRGM resource estimate of 340,500 tonnes averaging 2.15 g Au was classified as “proven” although it considered the mineralization to be irregular in character with uncertain, probably low, geological continuity (Récoché, Al-Jehani and Shanti). Although not precisely the same, the Bi’r Tawilah deposit was also thought of as too poorly mineralized to be economically interesting.

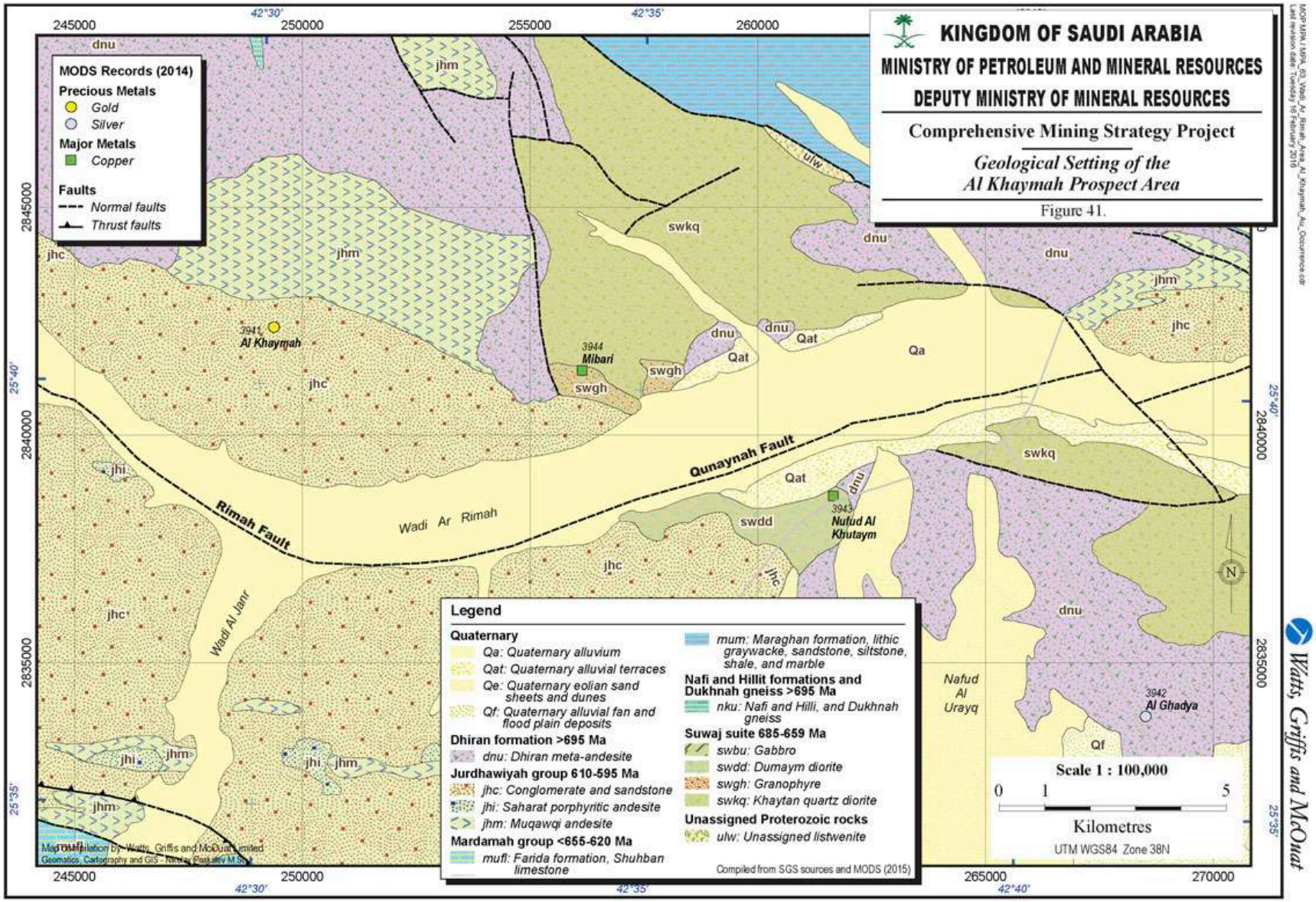
The Al Khaymah area is underlain by Jurdhawiyah Group volcaniclastics and pebble conglomerates near the northern margin of the Idayri Basin (Figure 41). These rocks are somewhat younger than the Murdama Group metaclastic rocks that host most of the mineralization in this gold belt. Immediately north of the mineralized area, the south-dipping clastic rocks are underlain by Jurdhawiyah andesite. The area is spatially associated with a well-defined circular magnetic anomaly that may reflect an unexposed pluton underlying the prospect (Smith and others,1985). The Ata fault system is a major, deeply rooted structure which crosses the northern and eastern margins of the Al Khaymah area. It is considered to have a prolonged history of movement (Cole, 1985b). Rocks adjacent to these structures are often silicified and quartz veined, and boudins within the fault zone are strongly carbonatized to 'listwaenite' (Smith and others, 1985). The gold-bearing quartz veins are NW-striking and are locally iron and copper stained, varying in thickness from a few centimeters to as much as 4 m (average 1 m). The veins are locally traced continuously for 100 m along strike. Visible gold is commonly associated with pyrite and chalcopyrite with

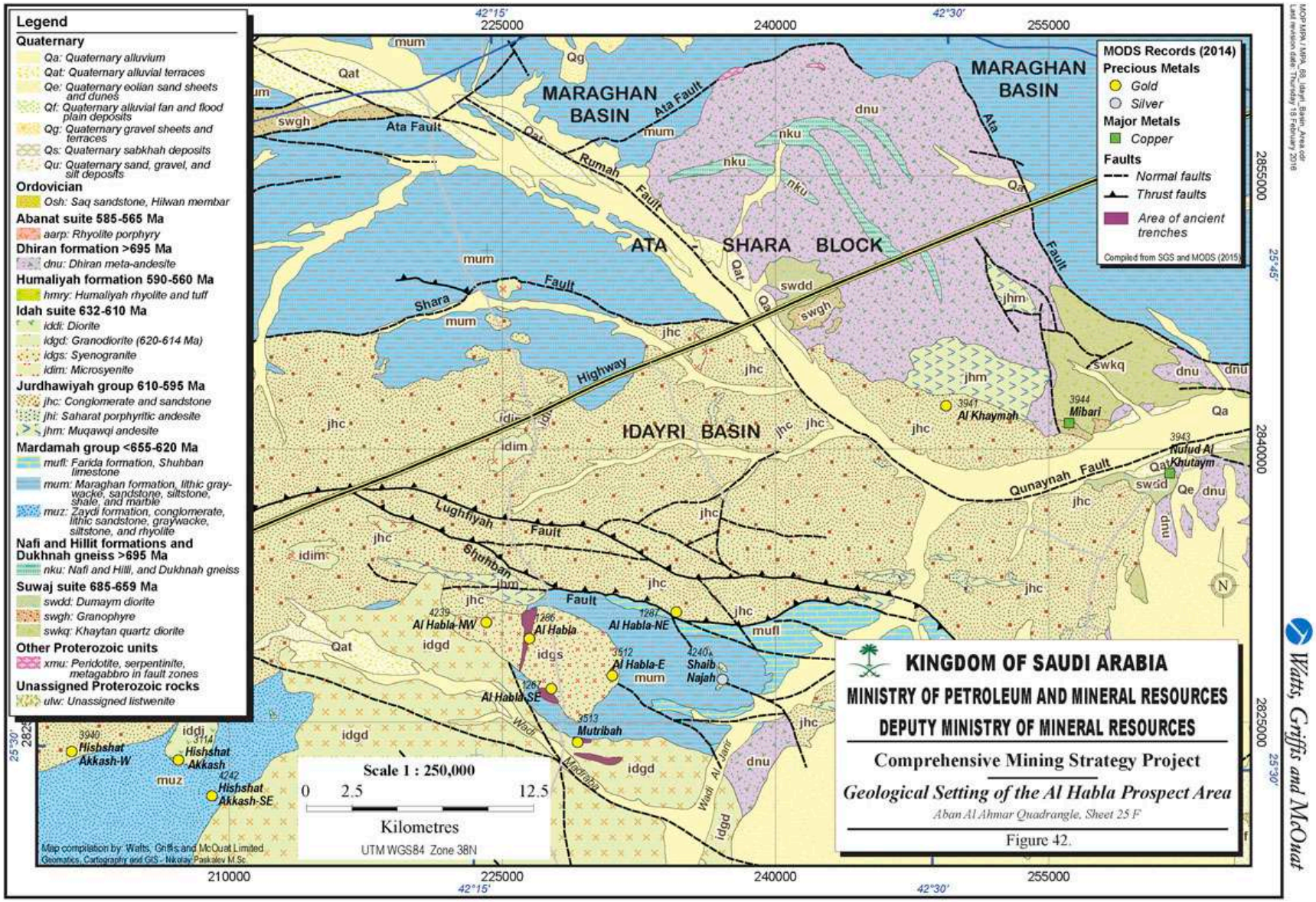
minor ankerite, calcite and manganese minerals, and assays as high as 161 g Au/t are accompanied by low but anomalous silver and copper. There is no appreciable alteration of wallrock adjacent to veins. High nugget-effects are evident in some samples as illustrated by one which assayed 119.2 g/t and subsequently returned two trace assays.

The Al Habla prospects are situated in an area with abundant westerly-striking faults and Idah suite granite and granodiorite plutons as shown in Figure 42. These intrusions are of the same character as those which host gold mineralization at the Sukhaybarat Mine. The Al Habla occurrences are typical of the mineralization in this area of the shield, consisting of gold-bearing quartz veins which are hosted within Idah granite porphyry (MODS 1286), or are located in cataclastic zones along the Idah granodiorite-Murdama sandstone contact (3512 and 1267). Gold also occurs in breccia along faults in sedimentary strata (1287). The Al Habla SE workings trace a vein for 1.2 km and similar workings at Al Madraba trace a vein system over a distance of 3 km.

Gold mineralization at Jabal Akkash, like that at Al Habla, occurs in weakly metamorphosed greywacke and argillite of the Murdama group in an area extensively intruded by Idah Suite granodiorite. Gold-bearing quartz veins are located within the margins of the granodiorite and within the surrounding hornfels contact aureole like at the Sukhaybarat Mine. Vein-type Au-Ag-Pb mineralization carries maximum values of 15 ppm Au, 228 ppm Ag, and 1.3% Pb (Sanderson and Harvey, 1985).

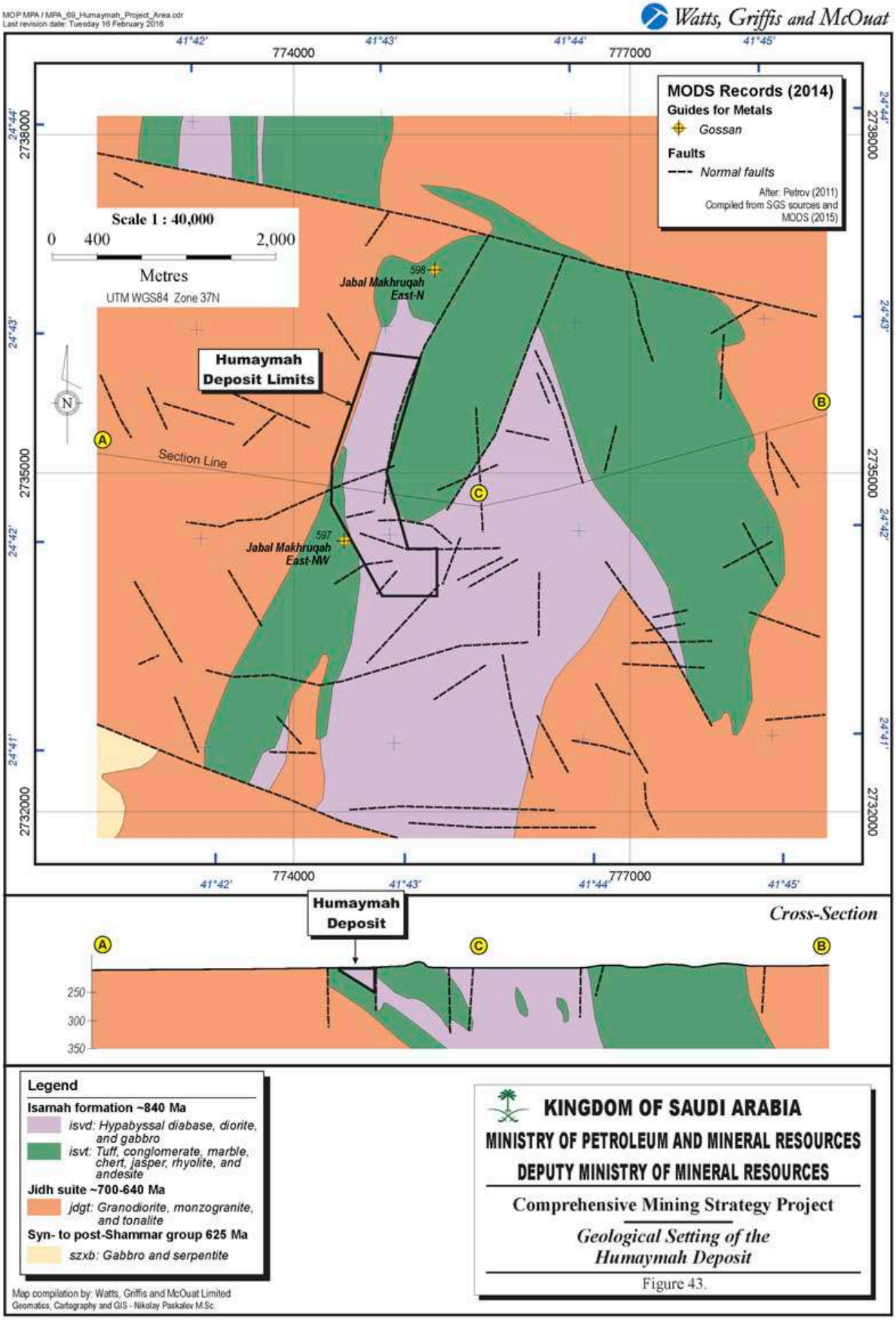
The Sukhaybarat gold deposit is situated in the Afif Terrane in an area underlain by weakly metamorphosed, thinly bedded sandstone, limestone and polymictic conglomerate of the Murdama Group. These layered rocks are intruded by Idah Suite plutonic rocks comprising granodiorite and lesser diorite, granodiorite porphyry, tonalite and granite. Gold mineralization is found with quartz veins at ancient mine areas. At Red Hill, native gold is finely disseminated in shallow-dipping quartz stockworks within a sill of red feldspar porphyry. At East Mine, gold mineralization is associated with pyrite and arsenopyrite in altered Murdama clastic rock at the margin of an Idah suite granodioritic intrusive. The northern and southern workings, 500 m apart, were initially reported to have strike lengths of 135 m, and 620 m, respectively. Schaffner (1955d) further reported that the veins strike from N. 70° E. to N. 40° w., with southerly dips of 30° to 50°, and contained gold concentrations up to 1.85 oz/ton (63.4 g/t). Clegg (1986) reported that assays of dump samples produced average gold contents between 7.9 and 20.2 g/t. A number of gold occurrences are found in the area surrounding Sukhaybarat and many of these are spatially associated with Idah Suite dioritic plutonic rocks. Disseminated-type mineralization is common within alteration halos of variable thickness which surround the veins, but the precise temporal and structural relationship between alteration and veins is uncertain.


KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the
Al Khaymah Prospect Area
Figure 41.
MODS Records (2014)
Precious Metals
Gold
Silver
Major Metals
Copper
Faults
Normal faults
Thrust faults
3941 Al Khaymah
3944 Mibari
3943 Nufud Al Khutaym
3942 Al Ghadya
Qunaynah Fault
Rimah Fault
Wadi Ar Rimah
Wadi Al Jarr
Nafud Al Urayq
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Dhiran formation >695 Ma
dnu: Dhiran meta-andesite
Jurdhawiyah group 610-595 Ma
jhc: Conglomerate and sandstone
jhi: Saharat porphyritic andesite
jhm: Muqawqi andesite
Mardamah group <655-620 Ma
mufl: Farida formation, Shuhban limestone
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
Nafi and Hillit formations and Dukhnah gneiss >695 Ma
nku: Nafi and Hilli, and Dukhnah gneiss
Suwaj suite 685-659 Ma
swbu: Gabbro
swdd: Dumaym diorite
swgh: Granophyre
swkq: Khaytan quartz diorite
Unassigned Proterozoic rocks
ulw: Unassigned listwenite
Compiled from SGS sources and MODS (2015)
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 38N
Watts, Griffis and McOuat


Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Ordovician
Osh: Saq sandstone, Hilwan membar
Abanat suite 585-565 Ma
aarp: Rhyolite porphyry
Dhiran formation >695 Ma
dnu: Dhiran meta-andesite
Humaliyah formation 590-560 Ma
hmry: Humaliyah rhyolite and tuff
Idah suite 632-610 Ma
iddi: Diorite
idgd: Granodiorite (620-614 Ma)
idgs: Syenogranite
idim: Microsyenite
Jurdhawiyah group 610-595 Ma
jhc: Conglomerate and sandstone
jhi: Saharat porphyritic andesite
jhm: Muqawqi andesite
Mardamah group <655-620 Ma
mufl: Farida formation, Shuhban limestone
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
Nafi and Hillit formations and Dukhnah gneiss >695 Ma
nku: Nafi and Hilli, and Dukhnah gneiss
Suwaj suite 685-659 Ma
swdd: Dumaym diorite
swgh: Granophyre
swkq: Khaytan quartz diorite
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ulw: Unassigned listwenite
MODS Records (2014)
Precious Metals
Gold
Silver
Major Metals
Copper
Faults
Normal faults
Thrust faults
Area of ancient trenches
Compiled from SGS and MODS (2015)
MARAGHAN BASIN
ATA - SHARA BLOCK
IDAYRI BASIN
Ata Fault
Rumah Fault
Shara Fault
Highway
Lughfiyah Fault
Shuhban Fault
Qunaynah Fault
Al Habla
Al Habla-NW
Al Habla-NE
Al Habla-E
Al Habla-SE
Shaib Najah
Mutribah
Al Khaymah
Mibari
Nulud Al Khutaym
Hishshat Akkash-W
Hishshat Akkash
Hishshat Akkash-SE
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 38N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Al Habla Prospect Area
Aban Al Ahmar Quadrangle, Sheet 25 F
Figure 42.
Watts, Griffis and McOuat
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc
42°15'
42°30'
225000
240000
255000
210000
2855000
2840000
2825000
25°45'
25°30'

The Humaymah Deposit is hosted within a broad structural zone of anatomising fractures, striking approximately north-south along the contact zone between the main tonalite-diorite-granodiorite-gabbro pluton which is the prevalent host rock and country rocks comprising a layered volcanosedimentary sequence of dacite, rhyolite, tuff, andesite, basalt, dolomitic-marble, graphite and slate (Figure 43). The intrusion, which belongs to the Idah Suite and which is extended along the structural zone, is thought to have been emplaced into a pre-existing fault. According to Ma'aden, the country rocks are carbonate-altered and silicified along the contact zone and in areas of mineralization. The mineralization in quartz-carbonate veins and stockworks dips steeply to the east and tends to be concentrated in close spatial association with a volcano-sedimentary unit at the footwall of the intrusive body. Three zones of mineralisation were recognized, referred to as the South, Central and North bodies. The thickness of mineralisation ranges from a few meters in the central section to an excess of 100 m in the south. The margins of the mineralized zone tend to be gradational as might be expected in a porphyry-type deposit. In the Sukhaybarat-As Safra belt, this type of pervasive or disseminated mineralization is typical of that component of the deposits which is hosted in the Idah pluton whereas the component in the exo-contact zone tends to be quartz-hosted vein-type. Unfortunately, Ma'aden has not publicly reported its exploration work nor its exploration results, so much of the geology of Humaymah is unknown. Ma'aden is currently reporting a JORC-compliant Indicated Mineral Resource, based on a 0.5 g Au/t cut-off grade, of 17.0 Mt grading 0.94 g Au/t plus an Inferred Resource of 18.8 Mt grading 0.80 g Au/t (1.03 Moz gold). Ma'aden refers to Humaymah as a deposit very similar to Bi'r Tawilah. WGM visited the Humaymah deposit during late 2008 and noted the presence of a well-exposed east-west trending limestone ridge to the west of the exploration site that is buff-coloured and seems to be dolomitized. Project personnel had not considered the possibility that the limestone could be mineralized, although blocks of limestone have been seen in contact with the diorite, and rarely enclosed within diorite, and that diorite is gold-bearing. A potential for Jerritt Canyon-type, disseminated gold mineralization was identified to Ma'aden but it unknown whether Ma'aden followed up on WGM's comments and recommendations.

The Shaib Abu Nubtah-NE1 (Jabal Mawan) and Umm Zarib prospects are marked by zones of ancient workings in migmatitic granodiorite near the south-western edge of a late peralkaline granite plug. Located 4 km apart, the two appear to be related to the same NW-trending fault zone. Two separate groups of ancient workings at Shaib Abu Nubtah-NE1 are distributed along a northeast trend and consist of a series of pits and trenches excavated on a quartz vein. Mine dump specimens contain hematite and limonite as well as rare sulphides and malachite. The south-western workings comprise a series of en-echelon trenches aligned in a north-south direction forming an aggregate length of about 1,200 m. These workings cut a reddened shear zone containing minor quartz. Visible gold is present in the northeast workings and bonanza grade gold values as high as 257.8 g/t or **7.52 ounces per ton were achieved!!** A series of grab samples taken over a 518 m strike length averaged 13.37 g Au/t. Visible gold was also reported in the southwest workings and grab samples yielded gold assays up to 264 g/t (7.70 oz/ton). A 620 m strike length of the zone averaged 12.7 g Au/t. At Umm Zarib (Figure 44), the zone also strikes northeast and an average gold content of 11.3 g/t was found in dump samples over a sampled distance of 183 m. Drilling showed that the veins were narrow but locally bonanza grade with one intersection of


MOP MPA / MPA_69_Humaymah_Project_Area.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
41°42'
41°43'
41°44'
41°45'
774000
777000
2738000
2735000
2732000
24°44'
24°43'
24°42'
24°41'
MODS Records (2014)
Guides for Metals
Gossan
Faults
Normal faults
After: Petrov (2011)
Compiled from SGS sources and MODS (2015)
Scale 1 : 40,000
0 400 2,000
Metres
UTM WGS84 Zone 37N
598
Jabal Makhruqah East-N
597
Jabal Makhruqah East-NW
Humaymah Deposit Limits
Section Line
A
B
C
N
Humaymah Deposit
Cross-Section
250
300
350
Legend
Isamah formation ~840 Ma
isvd: Hypabyssal diabase, diorite, and gabbro
isvt: Tuff, conglomerate, marble, chert, jasper, rhyolite, and andesite
Jidh suite ~700-640 Ma
jdgt: Granodiorite, monzogranite, and tonalite
Syn- to post-Shammar group 625 Ma
szxb: Gabbro and serpentite
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalov M.Sc.
KINGDOM OF SAUDI ARABIA
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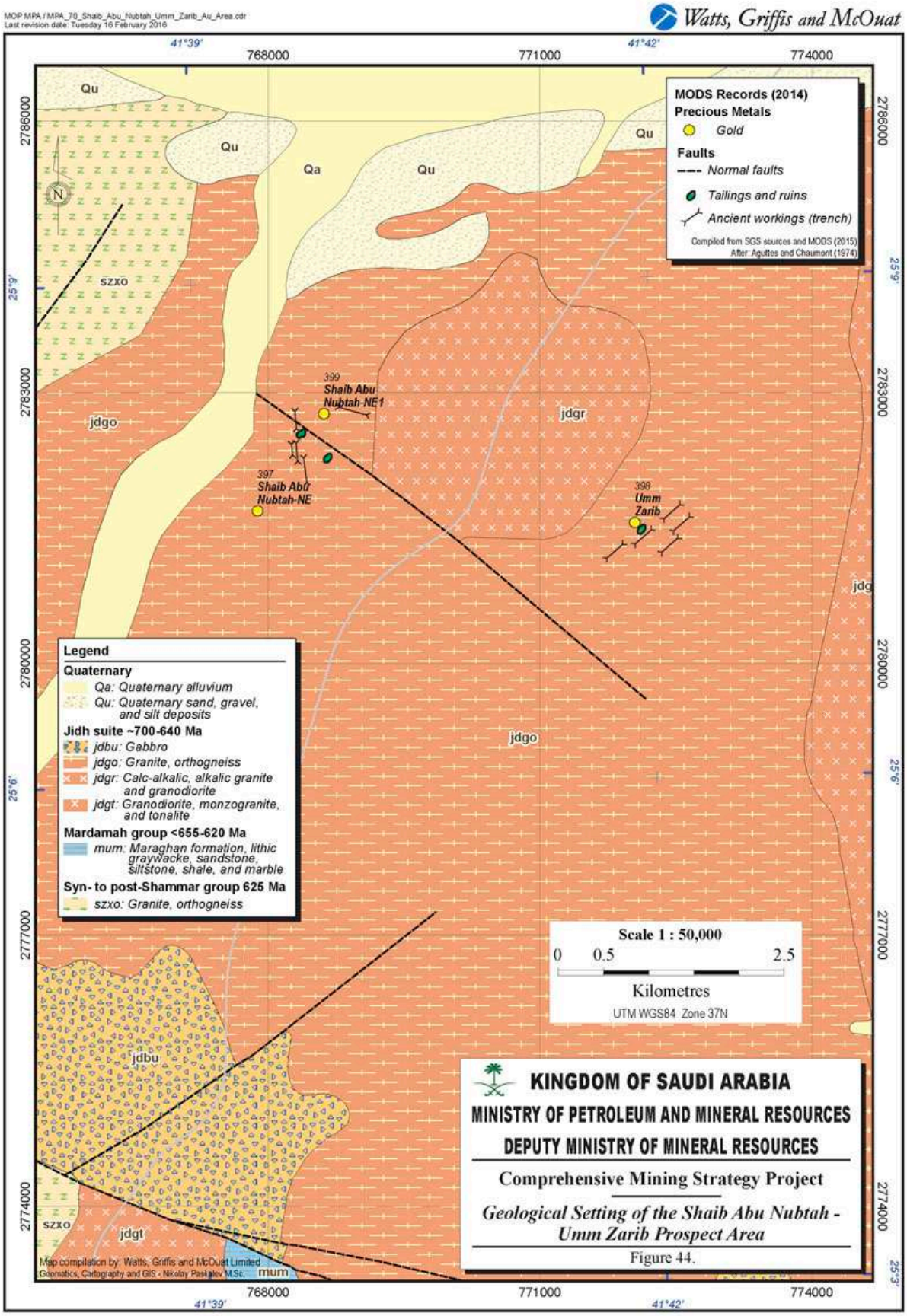
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Humaymah Deposit
Figure 43.


MOP MPA / MPA_70_Shaib_Abu_Nubtah_Umm_Zarib_Au_Area.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
41°39'
41°42'
768000
771000
774000
2786000
2783000
2780000
2777000
2774000
25°9'
25°6'
25°3'
N
Qu
Qa
szxo
jdgo
jdgr
jdgt
jdbu
mum
399
Shaib Abu Nubtah-NE1
397
Shaib Abu Nubtah-NE
398
Umm Zarib
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults
Tailings and ruins
Ancient workings (trench)
Compiled from SGS sources and MODS (2015)
After: Agutter and Chaumont (1974)
Legend
Quaternary
Qa: Quaternary alluvium
Qu: Quaternary sand, gravel, and silt deposits
Jidh suite ~700-640 Ma
jdbu: Gabbro
jdgo: Granite, orthogneiss
jdgr: Calc-alkalic, alkalic granite and granodiorite
jdgt: Granodiorite, monzogranite, and tonalite
Mardamah group <655-620 Ma
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
Syn- to post-Shammar group 625 Ma
szxo: Granite, orthogneiss
Scale 1 : 50,000
0 0.5 2.5
Kilometres
UTM WGS84 Zone 37N
KINGDOM OF SAUDI ARABIA
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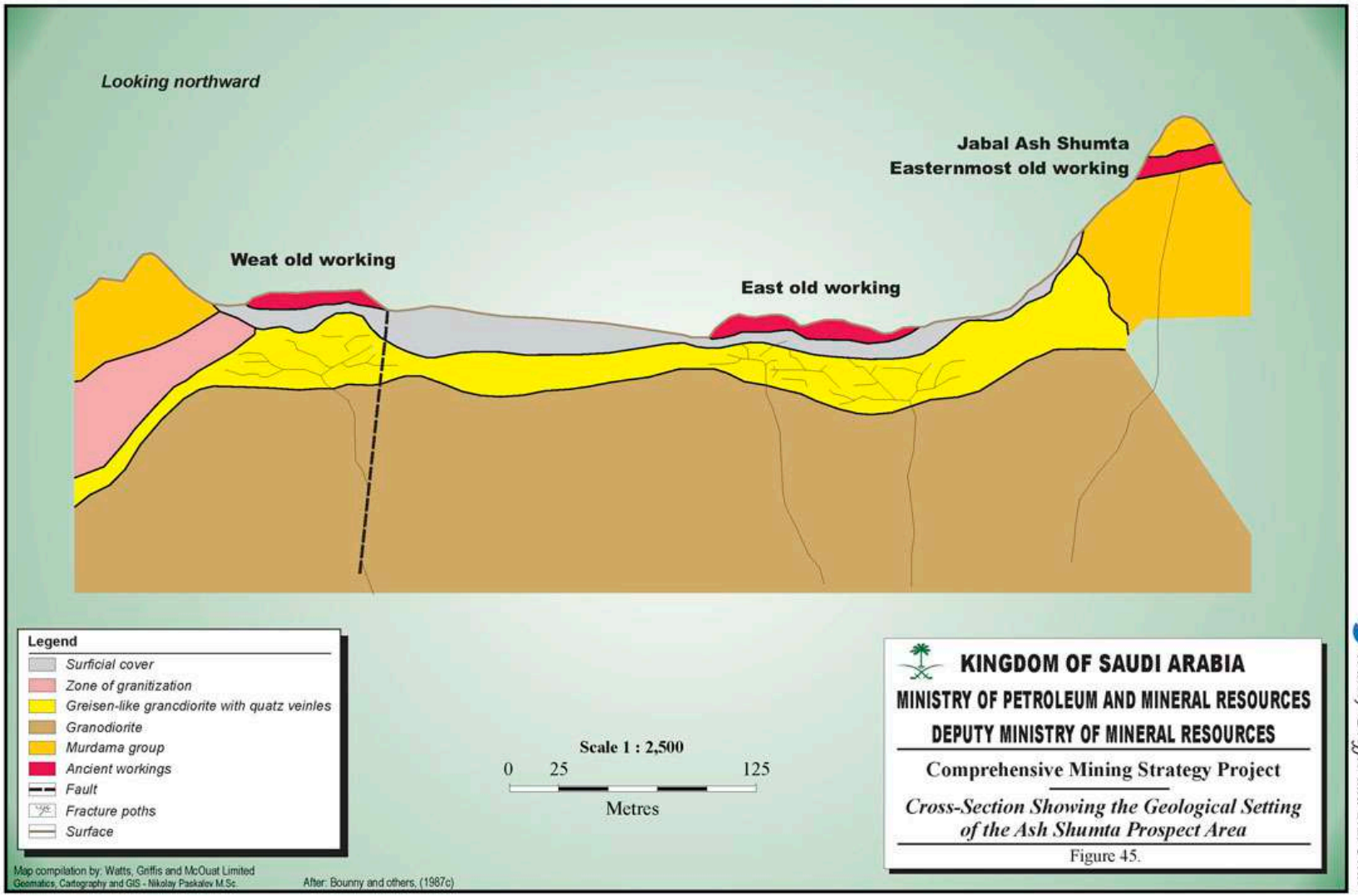
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Shaib Abu Nubtah - Umm Zarib Prospect Area
Figure 44.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

235 g/t over 33 cm. These value suggest the presence of nuggety, irregularly distributed gold which requires that the other drill hole results be assessed in this context.

The Bulghah Gold mine is situated in an area underlain by weakly metamorphosed sedimentary and volcanic rocks of the Murdama Group and Idah Suite plutonic rocks which intrude the layered sequence. Gold mineralisation in the region occurs in gold-bearing quartz veinlets mainly associated with the margins of the intrusions and the surrounding Murdama meta-sediments. At Bulghah, the majority of the mineralisation is hosted within the faulted eastern and western flanks of the north-south trending diorite / tonalite intrusion. The mineralized zone dips easterly at approximately 60°, and minor gold mineralisation extends outwards into the surrounding metasedimentary and metavolcanic units. Like at the As Suq Mine, weathering at Bulghah has led to two distinguishable types of mineralisation: oxide and sulphide. Oxide mineralisation is principally associated with kaolinized feldspar and iron oxide (limonite), extending from surface to a depth of approximately 30 m. The mineralisation is confined to fractures, pervasive replacement and dissemination in the surrounding host rock. Alteration within the intrusive comprises both propylitic and phyllic alteration. Sulphide-bearing mineralisation occurs below 30 m depth, is associated with pyrite, pyrrhotite and arsenopyrite, and occurs within fractures and as disseminations within the surrounding wall rocks. Ma'aden used digital modelling to develop a 3D model of the geology for resource estimation purposes in accordance with the JORC. The initial mineral resources prior to mining were approximately 43 Mt grading 0.8 g Au/t.

In the Ash Shumta prospect area, the country rock is composed of Murdama Group epiclastic sedimentary rocks and Idah Suite granodiorite. The main prospect at Ash Shumta (2099) consists of a quartz vein stockwork which reportedly lacks a singular structural control (Bounny and others, 1987c). The dominant host to quartz veins is a calc-alkaline granodiorite although some veining occurs within a hornfels contact aureole. Individual veins are 20 to 50 cm in thickness and are shallowly dipping. They are surrounded by greisen-like alteration halos and beyond this by zones of sericitization. The highest concentrations of gold are within the altered vein selvages, principally associated with pyrite. Two major structural zones have been identified, however the eastern zone is thought to be associated with the Murdama-Idah contact and is not mineralized. As it is also difficult to access, it was not drilled. Percussion drilling on the western zone intersected gold mineralization to a maximum of 5.4 g Au/t over 3 m (Bounny and others). One percussion hole intersected 3.14 g Au/t over 21 m, and the end of the hole was in mineralization.

Unlike at Ash Shumta, the country rocks at Ash Shumta South are Hulayfah Group andesitic metavolcanics however they also are intruded by a pluton belonging to the Idah suite. Figure 45 depicts a cross-section showing the geological setting of the Ash Shumta Prospects. Mineralization occurs in veins localized in structures (shears) on the contact between the metavolcanic rocks and biotite granodiorite. Gold is hosted in brecciated andesite and andesitic tuff and extends for approximately 300 m along a SE trend (Bounny and others, 1987c). A 2-m-wide zone of parallel quartz veins containing hematite and pyrite with lesser amounts of malachite, chalcopyrite and brown carbonate dips shallowly southwest and exhibits evidence of sub-vertical shearing. The gold-bearing veins report gold values as


Looking northward
Jabal Ash Shumta
Easternmost old working
Weat old working
East old working
Legend
Surficial cover
Zone of granitization
Greisen-like grancdiorite with quatz veinles
Granodiorite
Murdama group
Ancient workings
Fault
Fracture poths
Surface
Scale 1 : 2,500
0 25 125
Metres
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MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Cross-Section Showing the Geological Setting of the Ash Shumta Prospect Area
Figure 45.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalov M.Sc.
After: Bounny and others, (1987c)
Watts, Griffis and McOuat

high as 24 g/t, and anomalous gold mineralization extends across the vein-structure for at least 25 m into country rock (Begg, 1981). The Simfan umm Shieh occurrence is a gold-bearing northerly-striking quartz vein system on which only low gold values were intersected in the three percussion holes drilled.

In the Jabal al Kawm area, the andesitic to basaltic metavolcanic country rocks are intruded by Idah Suite diorite and younger bodies of biotite granite (Figure 46). Quartz veins are hosted by both andesitic rocks and by intrusive rocks in the area. These layered rocks have been openly folded along northerly-striking axes and gold-bearing veins tend to be northerly striking, ranging from 285° to 020°, and dip steeply east to southeast. In some areas, such as at Jabal al Kawm East, the veins tend to be more NW-striking. North to northeast-trending faults are major structural control for the veins (Hanif, 1973). The quartz vein system exhibits hydrothermal alteration comprising ferruginization (sulphidation) and sericitization with possible dolomitic carbonatization. Some studies indicate the possibility of greisenization of the granitic rocks in zones up to 2 m thick surrounding the veins at Jabal al Kawm East (Boyle and Howes, 1983). These veins averaged 7.2 g Au/t. At Jabal al Kawm West, veins are reported to carry gold values as high as 295 g/t, and tungsten contents up to 0.8% were reported from greisen-associated veins in the Jabal al Kawm East area. Anomalous base-metal contents in the Jabal al Kawm West veins were noted by Hanif.

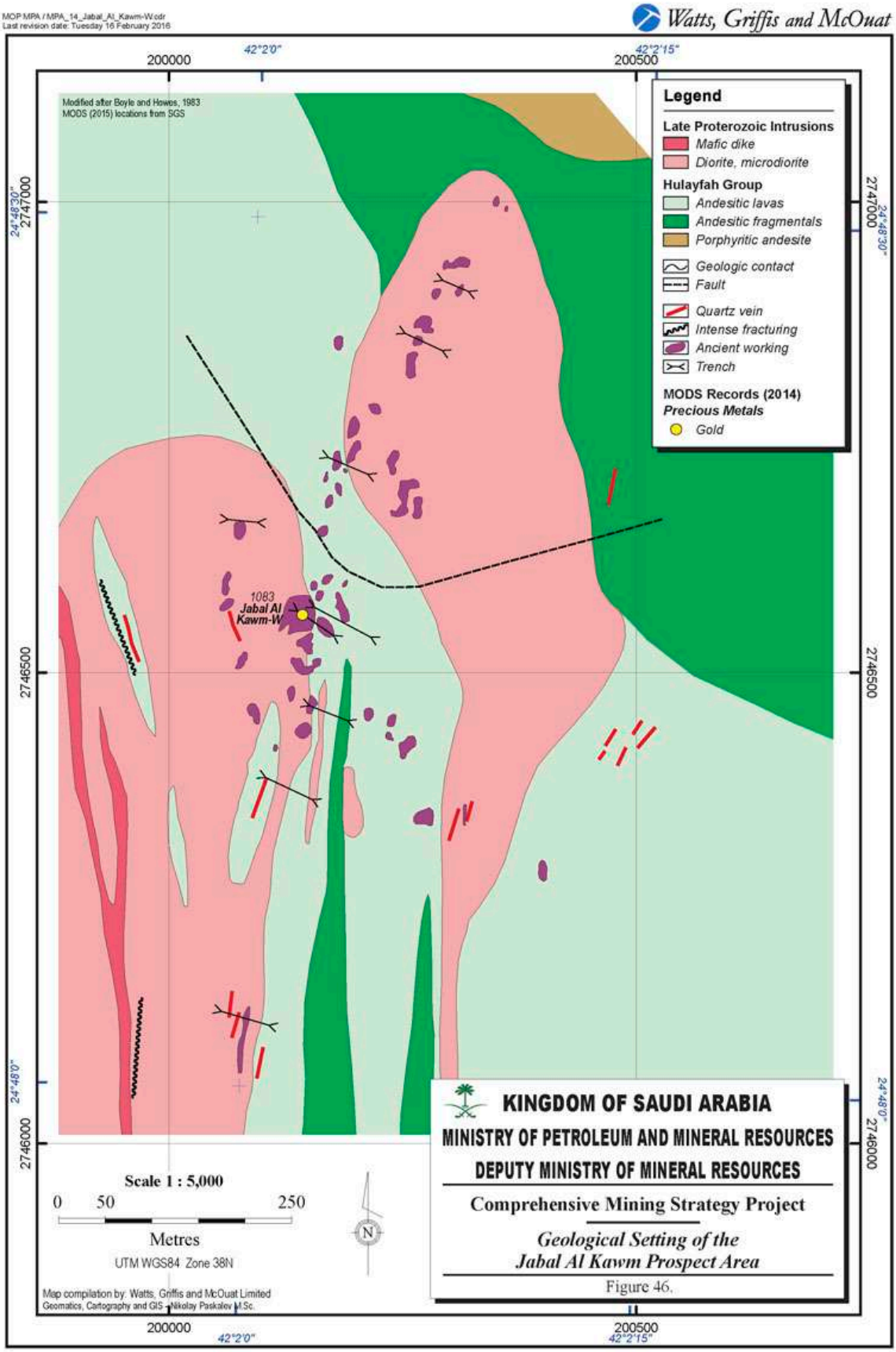
The ancient workings at Al Tayma occur over a 50-70 m wide section and a strike of 400 m (Figure 47). Fractures in granodiorite are rusty and contain pyrite, sphalerite, galena and ilmenite. Initial grab samples of this rock gave gold values of as much as 12.5 g/t, and follow-up sampling showed gold values as high as 38.5 g/t. Alteration was reported to form isolated bands less than 10 cm thick, and no major or well mineralized structures (or veins) were found.

At Al Maham, shown in Figures 48 and 49 and situated about 16 km south of Al Tayma, polymetallic gold mineralization together with pyrrhotite, pentlandite, chalcopyrite, sphalerite, molybdenite and arsenopyrite occurs in quartz veins and in quartz-feldspar schist and graphitic shale (Au + pyrrhotite, arsenopyrite, sphalerite, marcasite, magnetite, molybdenite and pentlandite). The host rocks are represented by the schist near its contact with the graphitic unit which may also be a schist. Gold occurs in a mainly felsic, silica and potassium-altered sequence of Hulayfah volcanics cut by folded quartz veins up to 20 m thick. Two styles of mineralization have been recognized:

- disseminated pyrite and pyrrhotite ± pentlandite, chalcopyrite, sphalerite, molybdenite ± arsenopyrite in quartz; and,
- disseminated pyrite and pyrrhotite ± chalcopyrite ± arsenopyrite ± sphalerite ± marcasite ± graphite ± magnetite ± molybdenite ± pentlandite in quartz-feldspar schist and graphitic shale.

The SGS refined this classification to:

1) stratiform sulfides, mainly pyrite and pyrrhotite poor in base metals and gold, hosted by the volcano-sedimentary succession, locally containing a strong geochemical Ni signature (0.28% Ni over 13.95 m in hole C005), which forms strong surface gossans; and,
2) gold mineralization linked to quartz veins and disseminated sulfides, mainly arsenopyrite, on which the old mine workings are located, covering an area measuring 500 m x 2,000 m.


MOP:MPA / MPA_14_Jabal_Al_Kawm-W.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
42°2'0"
200000
42°2'15"
200500
Modified after Boyle and Howes, 1983
MODS (2015) locations from SGS
Legend
Late Proterozoic Intrusions
Mafic dike
Diorite, microdiorite
Hulayfah Group
Andesitic lavas
Andesitic fragmentals
Porphyritic andesite
Geologic contact
Fault
Quartz vein
Intense fracturing
Ancient working
Trench
MODS Records (2014)
Precious Metals
Gold
24°48'30"
2747000
1083
Jabal Al Kawm-W
2746500
24°48'0"
2746000
Scale 1 : 5,000
0 50 250
Metres
UTM WGS84 Zone 38N
N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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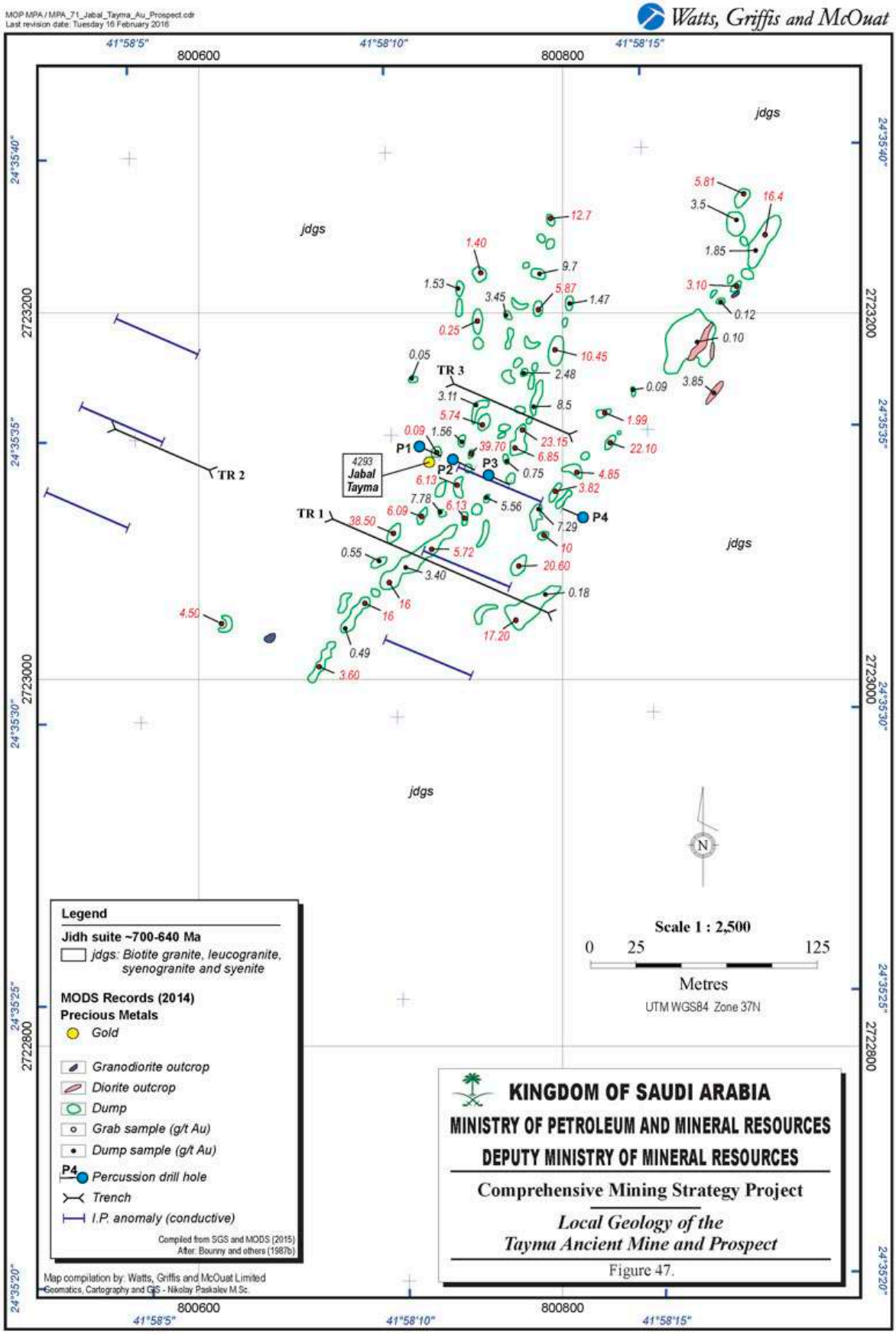
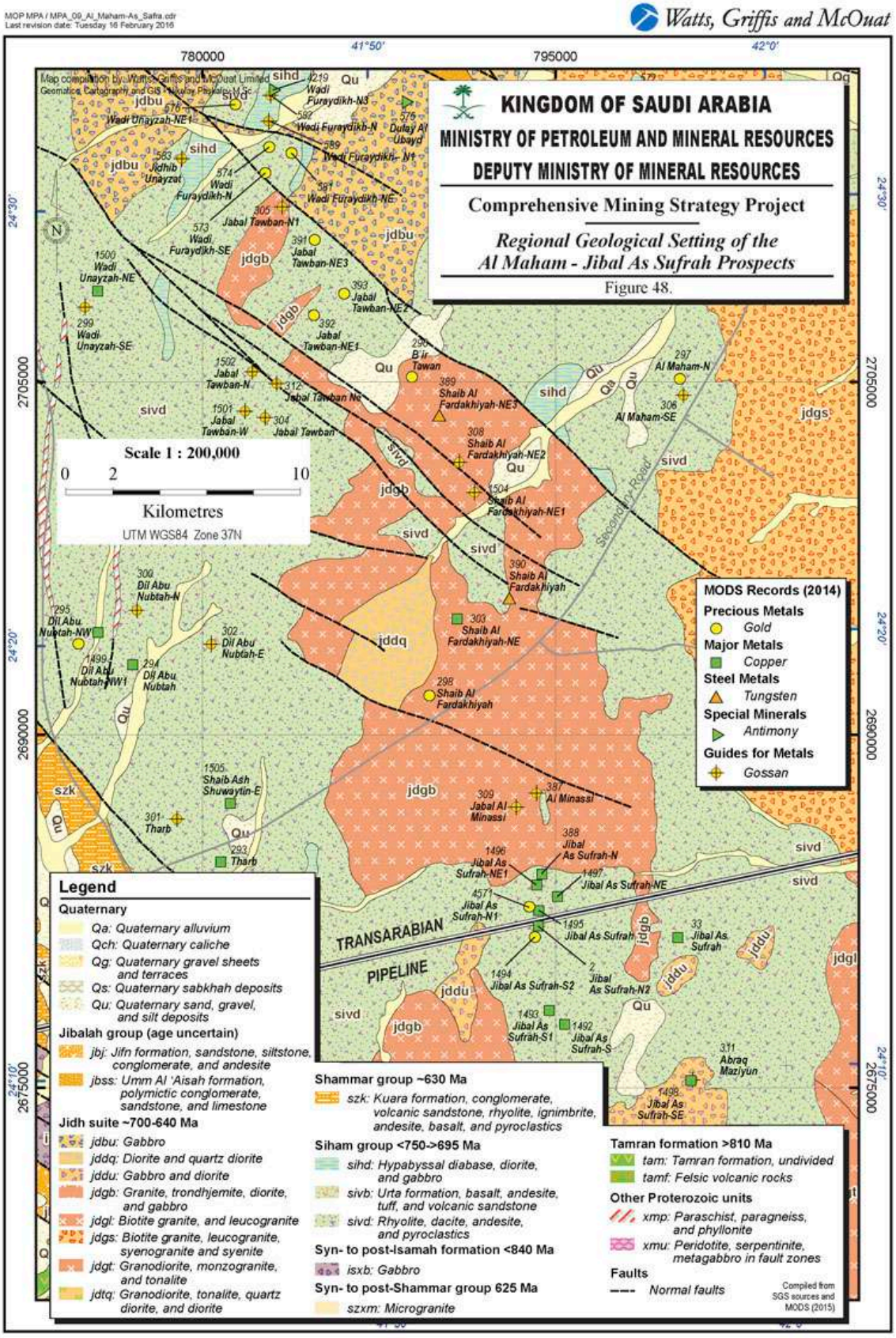
Comprehensive Mining Strategy Project
Geological Setting of the
Jabal Al Kawm Prospect Area
Figure 46.


MOP MPA / MPA_71_Jabal_Tayma_Au_Prospect.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
41°58'5"
41°58'10"
41°58'15"
800600
800800
24°35'40"
24°35'35"
24°35'30"
24°35'25"
24°35'20"
2723200
2723000
2722800
jdgs
TR 1
TR 2
TR 3
P1
P2
P3
P4
4293
Jabal
Tayma
N
Scale 1 : 2,500
0 25 125
Metres
UTM WGS84 Zone 37N
Legend
Jidh suite ~700-640 Ma
jdgs: Biotite granite, leucogranite, syenogranite and syenite
MODS Records (2014)
Precious Metals
Gold
Granodiorite outcrop
Diorite outcrop
Dump
Grab sample (g/t Au)
Dump sample (g/t Au)
Percussion drill hole
Trench
I.P. anomaly (conductive)
Compiled from SGS and MODS (2015)
After: Bounny and others (1987b)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Local Geology of the
Tayma Ancient Mine and Prospect
Figure 47.


MOP MPA / MPA_09_Al_Maham-As_Safra.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
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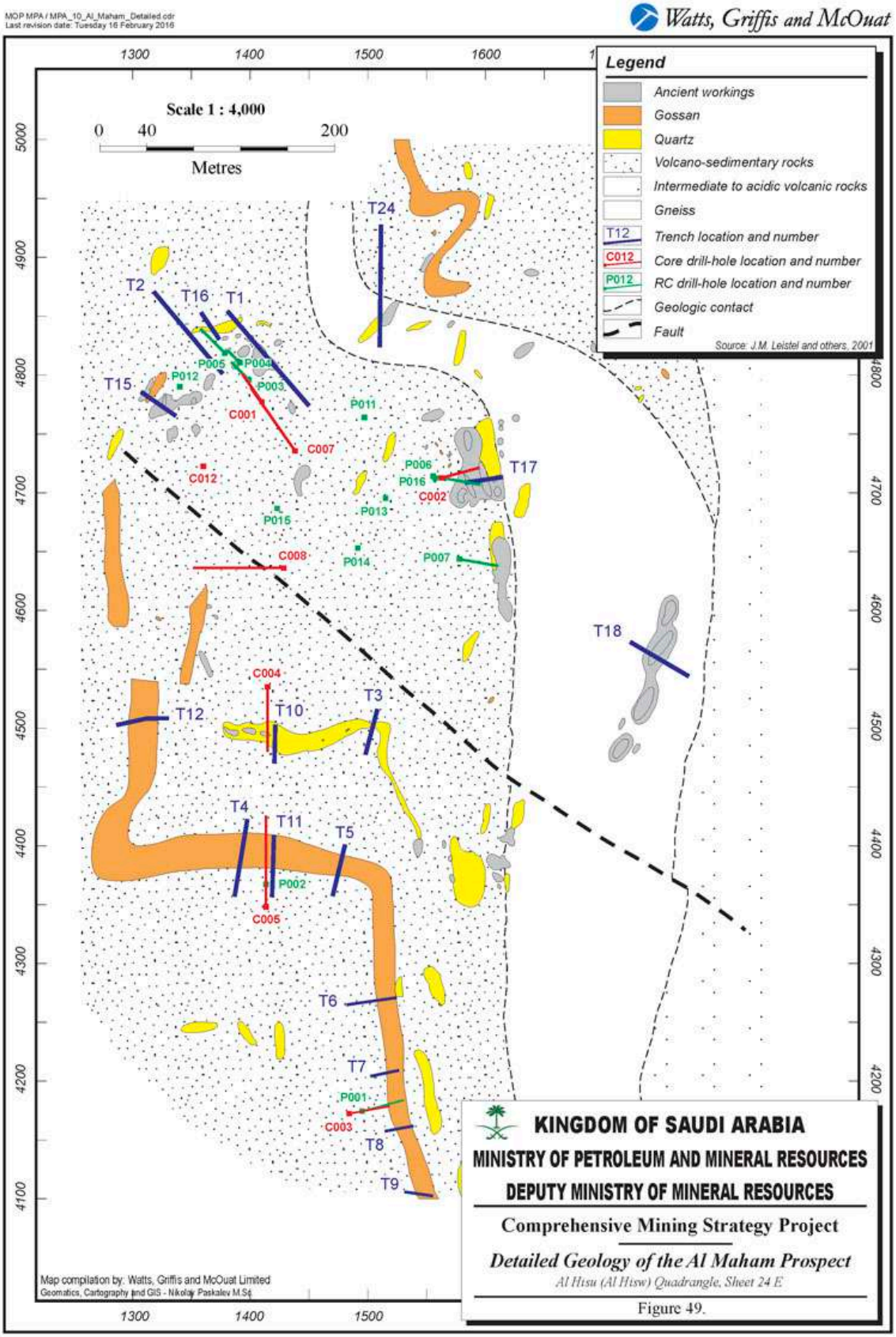
Comprehensive Mining Strategy Project
Regional Geological Setting of the
Al Maham - Jibal As Sufrah Prospects
Figure 48.
Scale 1 : 200,000
0 2 10
Kilometres
UTM WGS84 Zone 37N
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
Steel Metals
Tungsten
Special Minerals
Antimony
Guides for Metals
Gossan
Legend
Quaternary
Qa: Quaternary alluvium
Qch: Quaternary caliche
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Jibalah group (age uncertain)
jbj: Jifn formation, sandstone, siltstone, conglomerate, and andesite
jbss: Umm Al 'Aisah formation, polymictic conglomerate, sandstone, and limestone
Jidh suite ~700-640 Ma
jdbu: Gabbro
jddq: Diorite and quartz diorite
jddu: Gabbro and diorite
jdgb: Granite, trondhjemite, diorite, and gabbro
jdgl: Biotite granite, and leucogranite
jdgs: Biotite granite, leucogranite, syenogranite and syenite
jdgt: Granodiorite, monzogranite, and tonalite
jdtq: Granodiorite, tonalite, quartz diorite, and diorite
Shammar group ~630 Ma
szk: Kuara formation, conglomerate, volcanic sandstone, rhyolite, ignimbrite, andesite, basalt, and pyroclastics
Siham group <750->695 Ma
sihd: Hypabyssal diabase, diorite, and gabbro
sivb: Urta formation, basalt, andesite, tuff, and volcanic sandstone
sivd: Rhyolite, dacite, andesite, and pyroclastics
Syn- to post-Isamah formation <840 Ma
isxb: Gabbro
Syn- to post-Shammar group 625 Ma
szxm: Microgranite
Tamran formation >810 Ma
tam: Tamran formation, undivided
tamf: Felsic volcanic rocks
Other Proterozoic units
xmp: Paraschist, paragneiss, and phyllonite
xmu: Peridotite, serpentinite, metagabbro in fault zones
Faults
Normal faults
Compiled from SGS sources and MODS (2015)
TRANSARABIAN PIPELINE
Secondary Road
780000
795000
41°50'
42°0'
24°30'
24°20'
24°10'
2705000
2690000
2675000


MOP MPA / MPA_10_Al_Maham_Detailed.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
Legend
Ancient workings
Gossan
Quartz
Volcano-sedimentary rocks
Intermediate to acidic volcanic rocks
Gneiss
T12 Trench location and number
C012 Core drill-hole location and number
P012 RC drill-hole location and number
Geologic contact
Fault
Source: J.M. Leistel and others, 2001
Scale 1 : 4,000
0 40 200
Metres
T24
T2
T16
T1
T15
P005
P004
P012
P003
C001
C007
P011
C012
P006
P016
C002
T17
P013
P015
C008
P014
P007
T18
C004
T3
T12
T10
T4
T11
T5
P002
C005
T6
T7
P001
C003
T8
T9
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Comprehensive Mining Strategy Project
Detailed Geology of the Al Maham Prospect
Al Hisu (Al Hisw) Quadrangle, Sheet 24 E
Figure 49.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc
1300
1400
1500
1600
5000
4900
4800
4700
4600
4500
4400
4300
4200
4100

The highest gold grades are contained within meter-wide quartz-bearing structures. The surrounding host rock commonly contains disseminated sulfides in gold-bearing zones up to 40 m wide which contain low average gold values of about 0.5 g/t. SGS suggested that a continuous mineralized envelope can be drawn around the northern part of the prospect which takes in approximately 2 Mt of quartz veins and low-grade disseminated mineralization at an average grade of approximately 0.85 g Au/t. The southern part of the prospect is marked by a N-S trending structure, with discontinuous gold-bearing quartz veins averaging 1.9 to 5.6 g Au/t. Boudinaging of the veins along the structure is thought by the SGS to preclude any estimation of the gold potential.

At Jibal As Sufrah (formerly As Safra), which marks the only significant prospect near the southern end of the belt, gold mineralization was found to be associated with sheared and brecciated carbonate rocks cut by an east-trending series of rhyolite dikes (Figure 50). Altered host rocks consist of a series of mafic to felsic tuffs and dolomitic marble which are variably mineralized with disseminated and stringer-type pyrite, chalcopyrite, and/or galena, sphalerite, pyrrhotite and bismuthinite. A possible Canadian analogue to the As Safra prospect is the Bousquet deposit (Abitibi area Quebec) which hosts resources of 10.3 Mt grading 5.8 g Au/t contained within ore zones that are approximately 500 to 700 m long (Savoie, 1986). These ore bodies are located within or adjacent to a muscovite-quartz-pyrite schist (10 to 100 m wide) traceable along strike for 8 km. They consist of concordant, gold-bearing lenses of banded, veined, disseminated, and massive pyrite (Stone and others, 1988), with minor telluride, chalcopyrite, sphalerite, and galena. The mineralization is part of a large north-trending hydrothermal alteration (chlorite, sericite, silica) zone that extends for a distance of approximately 2.5 km and is up to 1 km wide. Geophysical surveys identified only weak anomalies even though the IP surveying was specifically designed to detect disseminated mineralization, however the profile spacing was very large (240 m). The best intersection in seven drill holes was 4.07% Cu over 5 m (hole SE-l) – gold contents were not determined. The BRGM estimated that the prospect contained 18 Mt grading 1.0% Cu (Delfour, 1981). Subsequent interest in the gold potential of the area highlighted the As Safra gold-carbonate zone which produced individual samples assaying as high as 242 g Au/t and 556 g Ag/t. Trench sampling gave gold values of 5 g/t in widths up to 6 m. Almost incredibly, the BRGM concluded that these results did not justify any further work on the prospect (Beziat and Billa, 1989). The BRGM resumed work with the SGS during 2000, and confirmed the presence of two types of mineralization:

1) Cu-dominant mineralization with a Cu-Co (Zn-Cd-Mo-Bi) geochemical signature best found in the dump samples from the South Workings and in earlier drill-holes in the North Workings and Slag area; and,
2) Gold-base metal mineralization found only in the Central area in a carbonate layer and in the ancient workings north of the pipeline, mostly in gossanous rocks, with a Au-(Zn-Pb-Ag-Cd ± Mo) geochemical signature.

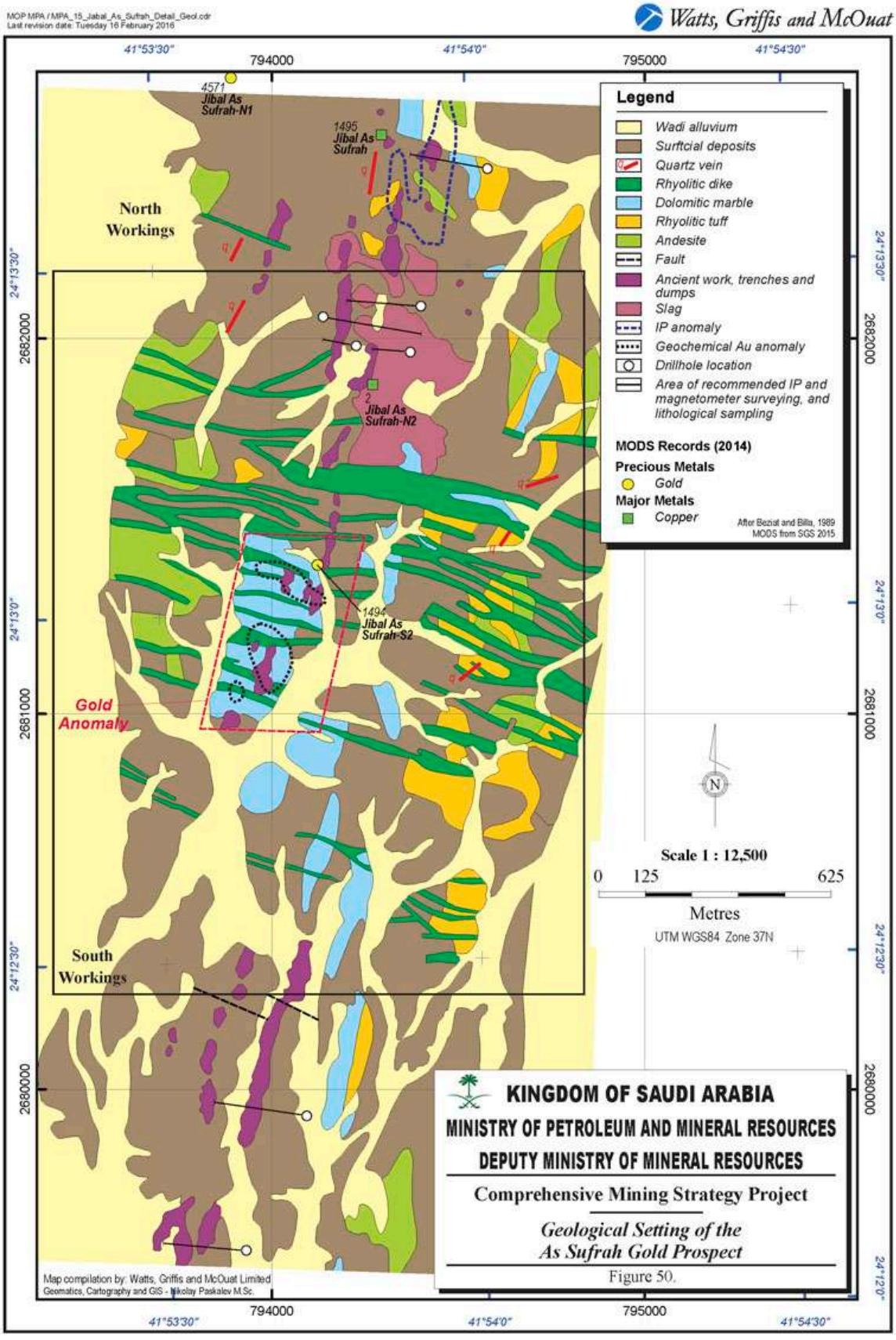
The BRGM interpreted the two styles of mineralization to reflect different paragenetic events in the same mineralizing system, possibly representing an epithermal model. Radiometric and magnetic surveys mostly outlined the dike corridor in the central part of the prospect, and the main NW-SE structural trend to the south. The IP measurements revealed two major polarizing anomalies likely to correspond to disseminated-

sulfide deposits in the North and South Workings areas. The north anomaly is much stronger than the south one, but these two anomalies may converge at depth under the central part of the prospect resulting in a continuous polarizing structure over the prospect at depths ranging from 100 to about 300 m, and deepest in the Central prospect area. The former drill-holes were not drilled deep enough to test the depth range of the north anomaly or to enlarge or test the BRGM resource estimate.

Recommendations

Very little modern exploration has been done in the Raha - Shaib Ash Shuayla area despite being underlain by favourable rocks intruded by Idah Suite plutons and cut my major fault zones. Ma'aden's work in the area is largely un-reported. Rocks in proximity to these structures are carbonatized with local 'jasperoid alteration'. This setting is sufficiently similar to that of the Sukhaybarat and Bulghah mines, as well as deposits in the Great Basin of the western USA that additional exploration is demanded. Reconnaissance exploration work and further detailed sampling has confirmed the anomalous gold contents previously established at Dulay Ash Shuhayba (Meshaheed) by Smith and Samater (1984). However, despite some limited drilling at Raha, the level of exploration is still at the reconnaissance stage, with limited mapping and no systematic geophysical surveys to trace known veins and structures. Grid sampling of gold occurrences is generally considered inappropriate unless mineralization is evenly distributed within a large rock volume, which is not the case at Dulay Ash Shuhayba. The bedrock samples were not fire-assayed, and so a very real potential exists for gold contents to be under-reported. Geophysical surveying indicated a possibility of mineralization within a large volume of rock below the workings but further work is required to trace the structure along strike. The geologic setting is considered to be highly favorable for porphyry-type mineralization however further exploration work including induced polarization (IP) geophysics is needed to more thoroughly investigate what appears to be a large mineralizing system and to develop targets for diamond core drilling.

The exploration carried out in the Iblat Ar Rihayl area confirmed the presence of anomalous gold mineralization with locally associated copper and antimony. Locally the mineralization reaches bonanza grade indicating the likelihood that the gold is coarse and irregularly distributed. The sampling has not been sufficiently detailed to accurately outline the extent of the mineralized zones and the assaying technique used was not sufficiently robust as to capture all of the gold potentially in the samples. Consequently, there is insufficient data upon which to determine targets for further exploration, but the results to date certainly justify additional work. Until the early 1990s, exploration had not proceeded beyond the point of reconnaissance geologic mapping and sampling at Shaib abu Hashayim. That sampling involved 5-metre sample lengths which are extremely inappropriate for gold exploration, and the low gold values returned (4 g/t) are indicative of narrower, higher grading zones being extended over unmineralized rock. The resulting downward averaging effect is not consistent with industry best practices. Shorter, maximum one metre samples are required to characterize the mineralized zones. Many targets are present, and systematic exploration is needed including the use of IP surveying to investigate the intrusive contact zone at depth and for diamond drill hole planning.


MOP:MPA / MPA_15_Jabal_As_Sufrah_Detail_Geol.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
41°53'30"
41°54'0"
41°54'30"
794000
795000
2682000
2681000
2680000
24°13'30"
24°12'30"
4571
Jibal As Sufrah-N1
1495
Jibal As Sufrah
North Workings
2
Jibal As Sufrah-N2
1494
Jibal As Sufrah-S2
Gold Anomaly
South Workings
Legend
Wadi alluvium
Surficial deposits
Quartz vein
Rhyolitic dike
Dolomitic marble
Rhyolitic tuff
Andesite
Fault
Ancient work, trenches and dumps
Slag
IP anomaly
Geochemical Au anomaly
Drillhole location
Area of recommended IP and magnetometer surveying, and lithological sampling
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
After Beziat and Billa, 1989
MODS from SGS 2015
N
Scale 1 : 12,500
0 125 625
Metres
UTM WGS84 Zone 37N
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the As Sufrah Gold Prospect
Figure 50.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

Exploration in the area of the Rawdat al Baayith gold occurrence has seemingly not progressed beyond the most basic reconnaissance stage. The area has potential for gold mineralization in high-grade quartz veins, but little detailed geologic information is present to identify specific controls over mineralization. Given that the regional wadi sediment sampling program of the USGS failed to detect even a single measurable gold content in 1,311 samples, WGM places no confidence in the reliability of these results. Taken as a whole, the abundance of gold occurrences is considered a very positive indicator for the mine-making potential of the area - further work is warranted to determine the geological setting of the prospect and the extent of the gold-bearing veins.

There has been repeated sampling of the Shaib abu Amayir (An Najadi) ancient workings and bedrock exposures in the adjacent area, however there is a lack of data on lithologies and structures which might control gold mineralization. As of the early 1990s, no systematic attempts were made to define specific targets, and to advance the prospect toward the diamond drilling stage. The geochemical survey carried out over the greater Shaib abu Amayir area is one of the best small-scale surveys carried out in the eastern Arabian Shield in respect to sample density. It should be used as a model for other gold geochemical surveys. Notwithstanding this, however, the gold anomalies have never been directly related to bedrock and may be due to transported debris from the ancient mines. This question should be resolved. Howes and others (1986) recommended follow-up detailed mapping and sampling of the occurrence, IP and gravimetric surveying, and 1,000 m of core or percussion drilling. Percussion drilling is inappropriate and diamond drilling is greatly preferred over reverse circulation drilling for this type of geology and mineralization. Based on the data available for this review, which may not be complete, the next step should be to better define individual mineralized zones and to develop targets at depth on each using IP geophysical surveying. A drilling budget for approximately 5,000 m of cored drilling is warranted.

The Al Mohsoniyah antimony-gold occurrence shows good evidence for a bulk tonnage gold deposit associated with an Idah Suite pluton. The presence of such strong antimony mineralization with gold should have been considered a very positive sign, yet the importance of the mineralization was large down-graded as being too refractory and disbursed to have any economic viability. The threshold which the BRGM sets for inception-stage projects is much too high, and it discourages future exploration on prospects where the true nature of the mineralization cannot be known with any certainty. The BRGM drilling to about 40 m vertical depth is inadequate to determine the geometry of the mineralized zone, and is also inadequate to assess whether the character of the hydrothermal alteration and mineralization changes with increasing depth. A substantial amount of drilling is needed on this interesting prospect. Before drilling, an IP survey should be used to identify sulphide-rock zones at depth which should be preferentially targeted. Consideration should be given to the use of the Bi'r Tawilah deposit as an exploration model.

Exploration on the Al Khaymah occurrence has not progressed beyond the reconnaissance stage of dump and bedrock sampling. The anomalous trace-element values are considered to be encouraging and possibly indicative of an epigenetic (orogenic) mineralizing system, however the results of the work completed to date have been poorly reported and suggest that this prospect has been forgotten, excepting any work that Ma'aden has completed which is unavailable for this review. Given the interesting structural

setting and Al Khaymah's proximity to the deeply rooted Ata Fault, additional systematic work is justified to quantify the amount of mineralization and put the occurrence within a well-defined geologic framework.

The work at Al Habla and Al Madraba prior to 1990 resulted in the discovery of a highly prospective gold system. The area is thought to have been explored by Ma'aden, however WGM has no records of such work. Nevertheless, it is surprising in the extreme that there are no reports available to indicate that the prospects have been drilled. The trench sampling, locally using continuous 50-m samples at Al Habla and up to 5 m in length at Jabal Akkash, was grossly inadequate and yet even these samples produced interesting gold assays. The combination of gold-bearing veins and breccias, Idah Suite intrusion and chemically reactive sedimentary rocks supports a variety of metallogenic models that are largely untested. Potential for lead-zinc-silver is also recognized in the carbonate rocks.

Although the exploration work at Jabal Akkash was comprehensive, the analysis of 5 m composite samples was completely inappropriate for gold-bearing zones. Reports on the gold bearing zones did not contain geological information (structure or alteration) for individual samples. The relationship between mineralization and structure, characterized by low resistivity, warrants further work using modern geophysical instrumentation. Additional exploration in the form of systematic mapping and sampling as well as geophysical surveying using appropriate techniques (e.g. IP) to identify targets for drilling is warranted on this prospect.

The exploration of the Sukhaybarat deposit capitalized on the presence of extensive ancient mine workings. The initial exploration work was episodic reflecting the fact that only marginal gold values were detected in respect to the prevailing gold prices. The more recent work relied on a high proportion of percussion drilling which was not appropriate for gold exploration, and the greater reliance on diamond drilling in later-stage drilling programs reflected this reality. The data available for this review contained no detailed geological maps, and WGM has previously noted their absence in the DMMR information base, a loss which is serious because of the geological importance of the Sukhaybarat deposit as the first modern gold discovery in the Kingdom. Given Sukhaybarat's role as a model for future exploration in the eastern Arabian Shield (and elsewhere), the DMMR should have a complete geological record of this important deposit. Ma'aden has a history of filing only such reports as it deems to be necessary, and the majority of its activities over the past two decades are unreported and/or unavailable for review by either the DMMR, academics, independent reviewers such as WGM or future explorers. In WGM's view, this amounts to:

- an impediment to the growth of geoscience knowledge concerning the Arabian-Nubian Shield;
- a handicap to future explorers, perhaps decades from now, who may waste money repeating work already done; and,
- a significant and substantial loss of the mineral exploration heritage of the Kingdom.

These failings are largely due to the special status granted to Ma'aden and its precursor companies by the DMMR, a historical aberration which has yet to be corrected. Despite the shortcomings of the 'system', sufficient research has been done by such authorities as the USGS and others that the metallogenic model is relatively well defined for Sukhaybarat-type gold deposits. What is missing is the detailed historical data

trail that led to the discovery and Ma'aden's regional exploration work since that time, leading to the discovery of the Bulghah Mine. One can only assume that Ma'aden has capitalized on its work as well as the work and advice of others, to refine its geological models and exploration programs. WGM has previously recommended to Ma'aden that it incorporate magnetometer and IP geophysical surveying into its exploration programs as a means of identifying buried intrusions below Murdama cover and of identifying subsurface bodies rich in disseminated sulphides (pyrite) commonly associated with gold mineralization. WGM also recommended greater use of satellite imagery or hyperspectral data as a means of detecting alteration halos surrounding Sukhaybarat-type deposits – Bulghah was used as a 'living' model. These exploration techniques should be widely used in the Arabian-Nubian Shield in the search for gold deposits. In the case of those programs targeting gold associated with Idah Suite plutons, the favourable target areas should be surveyed in great detail, and supported by 100 m grid-based post-hole geochemical sampling.

Given that very few ancient mines have been found in the area surrounding Sukhaybarat since the original regional mapping programs, it much be concluded that reconnaissance geological mapping has been an effective tool in the discovery of major mine sites. Studies have shown that low-density wadi-sediment geochemical sampling, as practised in this area, is not an effective method for the delineation of gold mineralization in the Arabian Shield. Densities of two samples per square kilometre, or more, are necessary to detect anomalies (Salpeteur and Sabir, 1989). Consequently, WGM is of the view that many of the initial geochemical surveys carried out in the area before 1990 may have used methods rendering the surveys ineffective and the results inconclusive at best, and potentially very misleading in terms of under-estimating potential. These inadequate methods include the sampling of surface scree, the use of eolian-contaminated size fractions, and the exclusion of magnetic fractions from alluvial samples prepared for analysis. None of the regional surveys carried out during the period in question met the collected specifications set out by Salpeteur and Sabir, and the specified 100 m by 100 m sample density for prospect-scale sampling was never accomplished. Much of the area in question is located on exploration licences that were acquired by Ma'aden following its assessment of WGM's exploration review reports delivered to the DMMR in 1992. For most of these occurrences, there is insufficient exploration data in the public records to precisely evaluate the occurrence and assess what additional work is justified. There are a considerable number of MODS-listed gold occurrences which have been the subject of little or no follow-up work according the public record. Many of these occurrences are of uncertain significance. Given the rarity of an economically viable deposit, most of these will undoubtedly prove to have no potential for a mine. However, the lack of detailed geological and exploration information means that a "pedigree" cannot be developed for these prospects. This effectively means that there is no foundation in the modern exploration record on which to base recommendations for additional work, and the possibility exists of repeating work that has already been done, a huge waste of time and money. WGM knows of several regional post-hole geochemical exploration programs executed in this area by Ma'aden in the post-2000 period, some of which included trenching and programs of reverse circulation and/or diamond drilling, however WGM has no knowledge of specific results from this exploration. It is therefore impossible to make meaningful recommendations as any WGM recommendations would include for each area of workings systematic deep-soil (or post-hole) geochemical surveying, magnetometer and IP geophysical surveying, trenching of anomalies and diamond drilling. Occurrences such as the Au-Ag-Cu occurrences along the

Habariyah structural complex (Pellaton, 1984) in the Kabshan Quadrangle (24/43A), and a broad zone of cataclasis associated with the Halaban-Zarghat fault (Cole, 1986) probably warrant more specialized exploration programs. Diorite associated gold occurrences east and west of the Meshaheed prospect in the Samirah (26/42C) and Silsilah (26/42D) quadrangles should be viewed and explored in a broader context than has been presented in the current available literature.

Like at Sukhaybarat, there is very little information concerning the exploration of the Humaymah area leading to the discovery of the deposits by the same name. Fortunately, the exploration of the Shaib Abu Nubtah-NE1 and Umm Zarib prospects began earlier and by the late 1980s, the exploration outlined at least three separate gold-bearing shear zones containing quartz veins, all of which have different orientations. Structure is obviously very important with regard to the location and form of the known veins. The BRGM's 1:20,000-scale reconnaissance mapping of the area did not adequately resolve the geology of the prospects by building a geological model. Detailed knowledge of the structure of the area is essential in guiding exploration for quartz veins when high-grade mineralization is present. Canadian experience with complex gold-quartz systems shows that only though detailed structural modelling can targets be developed for drilling. Care must also be used in assessing the results of drilling in nuggety systems because the probability of intersecting no gold is always greater than intersecting high-grade values. In many production stopes at the famous Dome Mine, only one hole out of six intersected economically interesting gold values (Rogers, 1981). Clearly, the failure of many holes at Umm Zarib to intersect interesting mineralization must be assessed in this context, and in the knowledge that simply rejecting the potential of the zone is a premature and inadequate approach to exploring a high-grade system like that found at Shaib Abu Nubtah-Umm Zarib. Detailed structural mapping of surface exposures and drill core, and higher densities of drilling are needed to adequately explore the two areas.

At Ashumta, the exploration work has generally been well implemented; however as with many prospects in the KSA, the conclusions of previous workers have been expressed with far greater certainty than can be supported by the available data. The data have short-comings both in terms of quality and quantity. The lack of detailed diamond drilling and drill core sampling and the reliance on percussion drilling is virtually guaranteed to under-report the grade of the mineralization. Gold intersections, such as the 3 m average of 5.4 g Au/t and the 21 m average of 3.14 g/t reported by Bounny et al, should have acted as a catalyst for aggressive follow-up drilling programs, yet they did not. Low-density reconnaissance geochemical sampling, such as that carried out in the mid 1960's (1 sample per 390 km2), is not definitive of prospective terrain, principally because of the low probability of detecting subcropping mineralization. The parameters of the IP survey are not reported. The present gold intersections represent either portions of a single large, relatively flat-lying deposit, or a multitude of steeply-dipping vein shoots, alternatives that cannot be properly assessed due to the lack of drilling below 58 m. The BRGM recognized that exploration of the prospect area is incomplete. WGM has previously underscored the fact that percussion drilling is not considered to be an adequate method for exploring and sampling a gold target. Diamond drilling is needed to provide drill core samples from which structures can be measured to provide data on which to base meaningful geological interpretations. The results on the project are sufficiently encouraging to warrant a continuation of exploration at Ash Shumta. Most of the prospects in the Ash Shumta area have

only had limited grab sampling of rock from irregular and limited surface exposures of mineralized veins. Previous reports failed to detail the relationships between veins and country rock and regional structure. There has been no documented attempt to determine the potential for disseminated mineralization in the host rock beyond the strict limits of vein exposures. As stated previously in this report, percussion drilling is not an appropriate exploration method for gold mineralization. The data derived from such drilling should not be used to assess exploration or economic potential. The only acceptable alternative is diamond drilling. The low gold concentrations in samples taken by BRGM are unexplained at this time and may be attributable to sampling techniques or analytical error since the BRGM was known to rely on a technique for its gold analyses (MIBK) that is accurate only for readily soluble gold. In view of the corroborated results from the earlier SAMS work and the average precious-metal content in this vein system, additional systematic exploration is warranted on the Ashumta South occurrences.

At Jabal al Koom, and in the surrounding area, the previous workers have carried out a significant amount of trenching on many of the prospects, however, grab and chip sampling are inherently unreliable methods to assess irregularly mineralized gold occurrences because substantial nugget effects demand the recovery of large samples and the use of laboratory techniques and analytical methods appropriate for these types of gold occurrences. WGM previously recommended additional exploration to more systematically test the occurrences and to investigate the potential for greisen-type gold mineralization in this area. This exploration should include methods appropriate for coarse nuggety gold. The subsurface could be modelled using IP surveying as has been recommended elsewhere in this report for the definition of targets for drill-testing using diamond drills.

At Al Tayma, the geological sections indicate a likelihood for the gold-bearing structures to pass from the granodiorite (seen on surface) to diorite at a relatively shallow depth of approximately 70 m. This change in rock type might have a positive effect on mineralization since the physical and geochemical properties of rocks directly impact their ability to host mineralization. WGM views the Al Tayma prospect as an excellent indicator of a mineralized structure that may not be well exposed on surface in this area, possibly due to the lack of major quartz veins. Greater reliance on geophysical surveying, IP in particular is needed to develop targets for drilling. The lack of mineralized outcrop is probably one reason why this area is relatively unexplored. Mineralization in the Al Tayma prospect may not be similar to the typical vein-type prospects found elsewhere in this area, and it may be more alike Bi'r Tawilah or the mineralization at Humaymah where gold is hosted within a broad zone of anatomising fractures. Nevertheless, the presence of Idah Suite tonalite-diorite-granodiorite plutons in the area is seen as a positive factor in respect to gold potential. Additional systematic diamond drilling is warranted given the previous drilling results.

The Al Maham area was on a Ma'aden licence during the 1990s, but has since been relinquished – Ma'aden's work is unknown, but it probably did not include any significant amount of diamond drilling. The recent work by the SGS has made up for some of the shortcomings in the historical exploration at Jabal Tayma. The SGS is mainly concerned about the affect of ductile shearing and boudinaging on the tonnage and grade potential of the gold-bearing shear system. WGM believes this concern is legitimate and can only be answered with systematic drilling on a spacing sufficiently open as to potentially step outside of the

area of concern. Structural affects such as those reported are usually the result of the physical characteristics of the host rocks. It is possible that by testing the host structure at depth or along strike, physically or geochemically different country rocks may be encountered that may allow for very different types of mineralization. WGM believes that the Al Maham zone remains sparsely drilled over a strike of 1,500 m, and that additional core drilling is warranted along strike on a step-out spacing of at least 100 m. It is likely that the Al Maham and Umm Zarib prospects are related to the same vein (structural) system. Although some high-grade values have been returned (e.g. 234.8 g Au/t over 3.1 cm), the tonnage potential of the zones seems to be very limited due to the spotty and coarse nature of the gold and the association of the veins with Najd faulting. The occurrences, however, are given additional importance due to proximity to the Bulghah Mine situated approximately 16 km to the southwest. WGM also believes that additional follow-up drilling is clearly warranted at a much closer spacing to define resources. Most importantly, WGM is uncertain that the drilling carried out to date has produced representative results, or that the samples were properly analysed given the presence of coarse gold as indicated by local high-grade assays. In the North part of the prospect, the mineralization can be considered as continuous, following the shape of the fold, over a 275 m x 230 m area. The true thickness of this mineralization is varying from 6 to 20 m along this area. The continuously mineralized envelope described by the SGS ignores some of the drilling which would tend to reduce the average gold grade somewhat to between 0.30 g/t and 1.94 g/t for the total true thickness taken in. Nevertheless, the SGS-BRGM resource estimate of about 2 Mt ore at 0.85 g Au/t seems to be reasonable. An additional resource could come from the second structure in the north part of the prospect, cut by drill-hole MAHC05 and trench MAH-T10. If we assume that the two mineralized intersections of drill-hole MAH-C05 represent the same folded structure the mineralization has an average thickness of 7.5 m. For a lateral E-W extension of 50 m on either side of drill-hole and trench, and a down-dip extension of 150 m, the resource potential of this structure could approach 300,000 tonnes at an average grade of 3 g Au/t. Along the north-south trending structure, it is very likely that the mineralization is discontinuous. Therefore, it is meaningless to try to draw a mineralized envelope without more drilling and trenching data. Nevertheless, it should be kept in mind that the best-mineralized intersections were found along this structure.

In the wider Al Maham prospect region, the area of interest includes 17 additional gold or copper prospects in an area of approximately 1,500 km^2 immediately north of the As Safra gold zones. The additional gold prospects include Jabal Tayma (4293), Wadi al Furdukiyah (0298, 0570, 0572), Talal (4295), Jabal al Bihrah (0588), Jabal az Zarabin (0587), Al Ashab (0580), An Nayzah (0576), Jabal Thuban (0392, 0393) and Jabal umm Nubtah (0295). The copper prospects include Wadi al Furdukiyah (0303), Jabal umm Nubtah (0294), Wadi al Nayzah (1500), An Nayzah (0578) and Jabal al Minasi (0584). Very little information is available concerning any of these sites. The presence of nickel mineralization with a komatiitic geochemical signature in the volcano-sedimentary rocks of the Nuqrah Formation is recognized by the SGS as an interesting feature given the presence of the Jabal Mardah nickel deposit in the same formation about 80 km to the northwest. The SGS clearly believes some additional exploration is needed to investigate the potential for stratabound nickel in the Tayma area.

The geochemical chip sampling and dump sampling confirmed that the As Safra alteration zone hosts gold mineralization associated with disseminated sulfides. This work is adequate to define the favorability of the As Safra area; however, the relatively low outcrop density precluded systematic sampling of the entire zone. Although the techniques used for exploration by the BRGM during the 1980s were 'industry-standard', the implementation of the surveys was poorly conceived. Using a sectional spacing of 240 m for IP surveying is much too wide to accurately define the geophysical signature of the area and to detect concentrations of disseminated sulfides (targets) that may be associated with gold mineralization. In addition, only two of the eight IP anomalies detected were drill tested. There is no doubt that further exploration is required to test the gold and base-metal potential of this highly prospective area which produced some of the highest gold-silver assays found anywhere in the Kingdom. Unfortunately, this first-priority north area is located in the restricted area of 500 m on either side of the ARAMCO pipeline, where no exploration or mining operation is permitted. Given that the most attractive target cannot be followed up, it was decided by the SGS and BRGM to halt further exploration during the 2000 program after the first phase of trenching, and the initially scheduled drilling program was cancelled. Under these circumstances, no further work is envisioned, however the presence of the Trans-Arabian Pipeline crossing the prospect area should not be an impediment to doing exploration on a high-value target like As Safra. While a degree of caution is needed in approaching the pipeline, there is absolutely no threat to the pipeline posed by routine diamond drilling, and any opinion to the contrary is simply wrong. The exploration of the underlying rocks will have no effect whatsoever on the pipeline. Should an economically viable deposit be found, it is quite possible that a mine could be constructed without any need to move or modify the pipeline. Even in the event that the mine could not be developed without moving the pipeline, the cost of relocation would be minor, possible trivial, in comparison with the value of the mineral production to the Kingdom.

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3.1.3.15 Miscellaneous Notes on Gold Occurrences

There are many gold occurrences in the Arabian Shield for which there is nothing more than a footnote in the exploration records, or a line entry in the MODS. It is not possible to assess the potential of these sites, nor is it possible to determine if they are isolated occurrences or part of a more extensive mineralized system or even a mineral belt. A good example is the Bir Umq chromium prospect (MODS 0015) which was explored by the BRGM for copper. Drill hole BU-2 intersected a 4-metre interval reported to average 20 g Au/t in chlorite-altered andesite. The area has not been highlighted for its gold potential, but the gold-bearing interval in the drill hole is compelling because chloritized andesite is unlikely to be gold-bearing without some other geological feature which has not been mentioned. There is no evidence of follow-up exploration dedicated to gold exploration. This and many other similar occurrences warrant follow-up exploration, and it is possible that some or many have been subject to follow-up by licence holders to determine their true potential. Unfortunately, there is no policy or regulation in force in the Kingdom to compel explorers to submit detailed reports on work performed such that this information might eventually be available to the Public and to new explorers. Consequently, it is impossible to properly assess the current status of hundreds of individual gold occurrences in the Kingdom although many are thought to be small and isolated in respect to the main gold belts discussed in this report.

A better example of a “stranded” gold occurrence is the Shaib al Qalt prospect (MODS 0024), formerly known as Aqiq Ghamid. It is located 30 km east of the Wadi Bidah gold belt. It is situated on a narrow, north-south striking structural lineament that can be traced 170 km from Harrat al Buqum southwards through the Aqiq area to the edge of the escarpment near Wadi Shora and beyond, passing under Phanerozoic strata near the town of Tharban. There is no other gold occurrence on this structure, so it cannot be accurately represented as a gold belt, yet its location is intriguing. The prospect was sampled in 1971 by the USGS and was mentioned in the noted on the 1:100,000 scale mapping of the Jabal Ibrahim Quadrangle (Cater and Johnson, 1986). The ancient mine at this site contains a well-preserved village. The host rocks include greenstone and diorite to tonalite plutonic rocks. Gold occurs in narrow quartz-sulphide veinlets hosted by pyritic, intensely sericitized sheared diorite and tonalite. The veins assay 1-5 g Au/t and altered rocks, extending as much as 5-7 m outwards from the veins, generally assay less than 1 g Au/t. Previous USGS workers have carried out systematic sampling of the mine workings, which produced gold assays as high as 28 g/t in dump samples (13 g/t in bedrock), and recommended diamond drilling (Worl, 1979). The SGS carried out detailed surface exploration in the early 1990s (Al-Fotawi and others, 1994). The most recent work, carried out by the USGS, was based on the Bulghah mine model and designed to assess the potential for a large lower-grading, bulk-mineable deposit. Samples were collected from trenches that were excavated across the mineralized zone and fire assayed. The best sections assayed 0.70 g Au/t across 13 m and 0.48 g Au/t across 10.4 m. While the exploration was disappointing to the USGS, several new zones assaying as high as 2.9 g Au/t were discovered that were remote from the ancient workings. The USGS concluded that the potential for a large deposit had been tested and that only the out-lying areas required further exploration. While WGM agrees that the surface results are disappointing in respect to grade, the USGS exploration did demonstrate the presence of widespread low-level gold mineralization, however the USGS not use any methods that address the

potential for mineralization at depth in terms of volume or grade. The exploration model demands that IP surveying be used in this sulphide-rich vein system to assess the potential for pyrite-rich zones at depth. These would represent excellent targets for diamond drilling and might occur at structural intersections or along the contact between greenstone and plutonic rocks. Additional exploration is clearly needed at the Shaib al Qalt prospect. Lessons learned here might also be applied to the remainder of this 170 km long structural zone which is conspicuous for its lack of any other gold prospect.

In addition to known gold occurrences, there are many gossans in shield areas which have been sampled for base metals but which have not received the same attention for gold, or, the analytical techniques used were adequate for base metals but not capable of giving precise gold determinations. Gold can be associated with base metals deposits, especially VMS-type deposits, and there are many good examples in the Kingdom including Al Amar, Nuqrah South and Al Hajar. Nevertheless, not all gossans have such potential, especially those which are pyrite-related such as those in the Wadi Wassat-Wadi Qatan area of the southern shield (Recoche and Zakariya, 1994). The assessment of gossans for gold potential requires an understanding of the nature of the underlying mineralization, and should be focused on those mineral belts with clear evidence of VMS-type base metal mineralization.

In exploring for gold deposits, global exploration experience has shown that new deposit types often go undiscovered for a long time because they are inaccessible, or they are not on a recognized “trend” and therefore do not subscribe to an established model. For this reason, care must always be taken in screening occurrences using well accepted models. Those doing the screening must be well qualified and ensure they are adequately informed in respect to any deficiencies in the both the model and the knowledge base they are using.

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3.1.4 SUMMARY OF PROSPECTIVE OROGENIC GOLD DEPOSITS

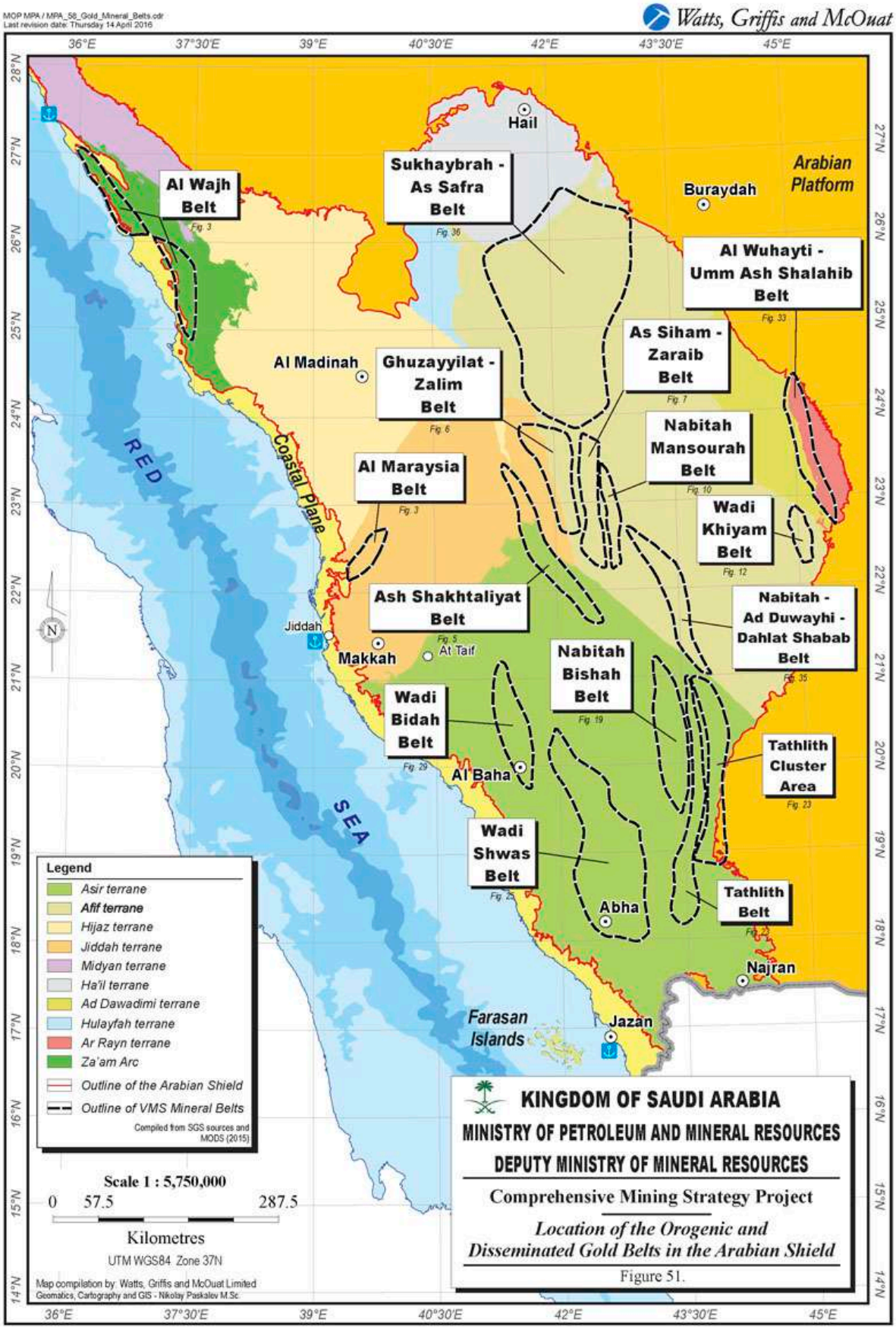
The gold belts identified in the foregoing sections are shown in Figure 51 and summarized in Table 26 together with WGM's estimate as to how many new undiscovered gold deposits might exist in each belt. The estimate is primarily influenced by the following parameters:

- number and distribution of existing mines, deposits and feasibility-level projects;
- an abundance of gold occurrences irrespective of individual status;
- association with a strong structural (deformation) zone, in particular the Nabitah Fault Zone;
- geological favourability based on known geological factors and compatibility with recognized deposit models;
- historical exploration results and the current status of gold prospects; and,
- the overall length of the gold belt.

A large number of existing mines and advanced projects (deposits) is an obvious signal that the geological framework of an area is capable of producing an economically significant deposit. The cluster of deposits in the Mansourah area is a good case in point, and the surrounding area has very high potential for additional deposits.

As with the occurrence of mines and advanced prospects in an area, an abundance of gold occurrences is important irrespective of whether those occurrences are individually attractive. Many deposits are outlined by zones in which many geochemical anomalies reflect an ore-field halo and this elevated geochemical profile is a clear indication that gold-bearing hydrothermal activity has occurred. Gold occurrences are rare, and so any clustering of occurrences may reflect leakage from a buried deposit. Taken as a whole, these occurrences may offer important clues to enable an exploration geologist to vector his programs towards a likely site for more economically important mineralization.

The association of known deposits with a strong regional structural trend is vital to having a positive outlook on the potential of the belt as a whole. Structural associations point to a cohesive influence on the localization of prospects such that explorers can be assured that the mineralization is not a random feature of the geological landscape. There are many gold occurrences in the Kingdom that are not associated with structural belts, and these occurrences cannot be placed in a conventional model because of the lack, or apparent lack, of a good structural control. The Nabitah Fault Zone is an excellent example of a regional structure that is known to host gold deposits, therefore prospects along the Nabitah must be thought of more favourably than those deposits that are not along this structure. To some extent, being close is relevant, but evidence form many other parts of the world indicates that potential rapidly diminishes away from such deformation zones.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Last revision date: Thursday 14 April 2016
Watts, Griffis and McOuat
36°E
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39°E
40°30'E
42°E
43°30'E
45°E
28°N
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16°N
15°N
14°N
Hail
Buraydah
Arabian Platform
Al Wajh Belt
Fig. 3
Sukhaybrah - As Safra Belt
Fig. 36
Al Wuhayti - Umm Ash Shalahib Belt
Fig. 33
As Siham - Zaraib Belt
Fig. 7
Al Madinah
Ghuzayyilat - Zalim Belt
Fig. 6
Nabitah Mansourah Belt
Fig. 10
Al Maraysia Belt
Fig. 3
Wadi Khiyam Belt
Fig. 12
RED
SEA
Coastal Plane
Ash Shakhtaliyat Belt
Fig. 5
Nabitah - Ad Duwayhi - Dahlat Shabab Belt
Fig. 35
Jiddah
Makkah
At Taif
Nabitah Bishah Belt
Fig. 19
Wadi Bidah Belt
Fig. 29
Tathlith Cluster Area
Fig. 23
Al Baha
Wadi Shwas Belt
Fig. 25
Tathlith Belt
Fig. 21
Abha
Najran
Farasan Islands
Jazan
Legend
Asir terrane
Afif terrane
Hijaz terrane
Jiddah terrane
Midyan terrane
Ha'il terrane
Ad Dawadimi terrane
Hulayfah terrane
Ar Rayn terrane
Za'am Arc
Outline of the Arabian Shield
Outline of VMS Mineral Belts
Compiled from SGS sources and MODS (2015)
Scale 1 : 5,750,000
0 57.5 287.5
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Location of the Orogenic and Disseminated Gold Belts in the Arabian Shield
Figure 51.

Table 26
Summary of Rational for Deposit Potential Assessments

Name of Gold Belt	Major Occurrences	Length (km)	Rationale for Potential Assessment	Potential New Deposits		
				10%	50%	90%
Al Wajd	N. Segment 44 S. Segment 19	200	Strong and complex structure – pre-Najd and probably an extension of the Nabitah; large vein systems, generally low level of exploration to date (backwater), major prospects are: Jibal Umm Quryyat and B'ir Al Qubbah. There are probably many other interesting sites however there is very little published on the belt that provides any details.	4	3	2
Al Marasia	16	63	Narrow but strong structure – polymetallic associations, some large ancient mines – potentially mainly vested in Al Marasia – other targets include the wide zone of ductile shearing at Abu Shahab, and chloritized, silicified and sericitized rocks at Jabal abu Musht. Given that the Al Marasia belt is relatively short in length, there is a possibility that no economically exploitable deposit will be found.	3	2	1
Ash Shakhtaliyat Belt	46	225	Ma'aden has several pre-development stage projects at this time on the Ar Rjum Project (Wasemah, Umm Naam), complex geology with range of targets including classic orogenic (structural) systems and Idah Suite disseminated gold. Major new targets include Ash Shakhtiliyat, Huwaymidan and Bari.	4	3	2
Ghuzayyilat-Zalim	60	170	Both Ghuzayyilat and Zalim ancient mining areas are major centres; cluster of ancient workings in the Burqan Hubayrin area suggests potential there as well; Shuqayra Jiza prospect associated with Ad Dafinah structure is also interest although it appears to be a Najd structure	3	2	1
As Siham-Az Zeraib	60	200	Strong structure –there is a lot happening in the As Siham area in addition to the As Suq Mine (Shaib Al Maliyah Al Janubi and Shiab Al Maliyah Ash Shamali prospects) for there not to be at a minimum a small mine somewhere; 12 areas of gold workings at Al Himar show good potential – also samples of wall rock were gold-bearing averaging 1.7 g Au/t. Shaib Lamisah remains a good target. In the Aban al Hafair prospect cluster is also a good target as is Zaraib at Tal.	6	4	3
Nabitah Gold Belt – Mansourah Segment	16	175	Excellent Nabitah structure in an area that has experienced a great deal of hydrothermal activity witnessed by the large number of deposits already discovered, including Mansourah, Masarah, Bi'r Tawilah and Ghadarah. Few specific clues to identify new sites due to alluvial cover. Most of the belt is unexplored.	4	3	2
Nabitah Gold Belt – Ad Duwayah-Dahlat Shabab Segment	18	165	The Nabitah Zone already hosts the Ad Duwayhi deposit. The Samhah prospect is an excellent exploration target – some bonanza grades. Not certain about Farthah. High alluvial gold values in the Jabal Hadah (formerly Hathah) and Warshah areas suggest the presence of something here. Umm Watierah and Dahlat Shababb are good targets.	5	4	3
Nabitah Gold Belt – Bishah Segment	25	175	Strong structure with high levels of alteration and many veins. Some polymetallic (epithermal) potential associated with felsic volcanic rocks. Very low level of exploration to date. Jibal Kutman illustrates the important of follow up even on a relatively minor historical prospect – good structural "address" is vital. Many prospects do not seem to be interesting - this may be an artifact of the way the work was done or the results reported? Al Lutaga looks like a winner but it's the only one with a good knowledge base as a result of more than basic exploration. At the northern end of the zone, the gold-bearing quartz veins in a 35 m wide N-trending Nabitah pyrite-sericite regional-scale shear zone at Jabal As Suwayda-SE is highly interesting even if the initial results were not encouraging. Either here or nearby, there is strong hydrothermal activity – good Au-As association. Current exploration is not conclusive. Similar geology occurs at Abraq Al Hamal where ESE-striking NNW-dipping sericite-carbonate-pyrite alteration zone encloses brecciated quartz-carbonate veins. The host rock is sheared diorite, and gold occurs in association with pyrite, chalcopyrite and minor galena in the quartz veins and to a lesser extent in the altered rocks. Ancient workings are found over a strike length of 530 m.	5	3	2
Tathlith	Main Belt 24 Cluster 32	200 +	Along the main structure, the Al Gariat Avala prospect is interesting. The lower contact zone of the Haj'r deposit is a possible of uncertain size – also look for feeder zones and imbricate shears; the Jibal Tayyib Al Isim area is interesting for its bonanza grades in an area of poor exposure (therefore not well explored). The gold hosted in granitic gneiss at Wadi Sha'la and Alawi Ghurran al Hashim could be of interest. The old Hajr Mine offers an interesting model of gold related to tectonically emplaced ultramafics (ophiolite).	3	2	1
Wadi Shwas	17	80	Gold values at Jabal Al Abla (the Ablah breccia Pipe) are intriguing and should be followed up by modern exploration. Breccia pipes are of interest for epithermal gold more so than orogenic gold, yet the entire geological package looks very interesting for obvious reasons. The Wadi Surum, Wadi Shirs South and Al Farah occurrences are hosted by granodiorite in a N-striking fault/shear zone near the western margin of the An Nimas batholith – good setting for gold. The Jabal Hamrah deposit attests to the potential which may be closely associated with base metal mineralization. Nevertheless the structural trend is very clear. In the Wadi Al Awja area a 50-metre wide shear zone containing secondary Cu in Fe-altered wall rocks in a carbonatized, sheared ultramafic lens. Cu-oxide shears and quartz-siderite zones are present in chlorite-sericite-siderite schists with pyrite, chalcopyrite and native gold are reported in narrow (1-12 cm) veins at Alawja-S, and pyrite-chalcopyrite mineralized shears at Wadi Al Awja. Hamrah Mine offers a good model of gold associated with copper.	4	3	2
Wadi Bidah	32	135	As a small initial deposit that was dismissed by the BRGM, Ma'milah is interesting as is Al Qihab and Shaib al Tayr. The width of mineralization at Jabal Gahab and Bani Sarr has economic potential. Also potential for late stage veining across or within VMS deposits such as occurs at Al Amar.	6	4	2
Al Wuhayti-Umm ash Shalahib	31	165	Umm ash Shalahib area is of interest primarily for gold but has been explored more for base metals. Jabal Bitran prospect requires more work - values up to 10.8 g Au failed to encourage the BRGM to do more work. Marjan and At Taybi are also very good targets. Very strong structure in this area along a major suture.	6	4	2
Wadi Khiyam	22	55	Very little known - prospects clustered in the Wadi Khiyam area have sulfide-bearing quartz veins within amphibolites gneiss and diorite – in the presence of a strong structural control, as is present here, economically interesting grades are quite possible in this geological setting. As defined by WGM, the belt is rather short in comparison with other belts. Given that the Wadi Khiyam belt is relatively short in length, there is a possibility that no economically exploitable deposit will be found.	2	1	1
Sukhaybrah – As Safra Gold Belt	125	275	Large area with a huge number of prospects and ancient workings: major clusters in the vicinity of Shaib Abu Hsahayim (Ar Rahail), Dulay Ash Shuhayba (Meshaheed), Shaib Abu Amayir (An Najadi), Wadi Al Jurayyir, Al Habla, Shaib Abu Nubtah-NE1 (Jabal Mawan-Umm Zarib), Ash Shumta, Jabal al Koom, At Tayma, Al Maham and Jibal As Sufrah (As Safra) demand systematic and sustained exploration. Most of these are associated with Idah Suite intrusions and the disseminated gold model as demonstrated at the Bulghah and Sukhaybarat Mines and the Humaymah deposit.	12	9	6

The geological favourability of any prospect, whether gold or base metal, is greatly enhanced if geologists can demonstrate that the prospect conforms to conventional metallogenic models, and is enhanced further if other known deposits in the region have the same geological setting and similar affiliations such as alteration and geochemical (indicator element) signatures.

It is clear that the exploration history of a prospect or group of prospects is important in respect to assessing potential. Economic realities change over time as commodity prices change, and what was once thought of as uninteresting can suddenly be a preferred exploration target. Negative results in the past must always be reconsidered in terms of the techniques and equipment used, the validity of the exploration model, the level of understanding of the geology at the time and the personal biases of those reporting the results. As we have pointed out in the foregoing sections, many high-quality prospects in the Kingdom were previously dismissed as being of little or no interest based on a perceived lack of continuity. The Al Amar mine was initially said to be uninteresting because the zinc mineralization lacked continuity without any regard to the great thickness of the sulphide sections and the overall impact of gold mineralization on mine economics. WGM has approached this review by assessing whether the available information is sufficient to justify walking away from a prospect, and if it is not, additional exploration is warranted in most instances where the exploration model is valid and poorly tested. WGM has favoured prospects and areas where the results to date have included some higher grading assays while being mindful that the analytical techniques used in the past seldom conformed to industry best practices standards. In the absence of standard fire assaying techniques, we understand that the analytical data may be lower than the actual gold contents. In the presence of coarse (visible) gold, we also are mindful of the fact that the reported gold assays may be influenced, positively or negatively, by coarse and irregularly distributed gold grains.

Lastly, the overall length of a gold belt is important because the longer the structure, the greater the chance of the various geological elements interacting in such a way as to produce a gold deposit. Two of the great orogenic gold belts of the Abitibi Greenstone Belt in Canada, the 300+ km long Destor-Porcupine Complex and the 360+ km long Larder Lake-Cadillac Break have produced gold in excess of 70 million ounces and 86 million ounces, respectively. The major gold deposits are not evenly distributed along the length of the belt, and tend to be clustered in major centres such as Timmins, Matheson, Harker-Holloway, Kirkland Lake, Rouyn-Noranda, Malartic-Cadillac and Val d'Or. On average, the belts have produced one million-ounces of gold production for every 4.2 kilometres of structure, a remarkable statistic. By comparison, the Kalgoorlie Gold Belt, including the St. Ives mining area, has a strike in excess of 120 km and has produced more than 85 million ounces of gold or about 1 million ounces for every 1.4 km of strike. All of the foregoing gold belts are Archean in age, and seem like unreachable levels of production in the context of the KSA. In the early Proterozoic Ashanti Greenstone Belt of Ghana, the 140 km segment of the Ashanti Fault Zone extending from the Konongo Mine to the Prestea Mine hosts more than 55 Moz of gold in four deposits alone: Konongo (1.4 Moz), Obuasi (41 Moz), Bogusu (7 Moz) and Prestea (6 Moz), or an average of 1 Moz for every 2.5 km of structure. The Paleozoic Tian Shan Belt in western China, Mongolia and Tajikistan, which is traceable for approximately 2,500 km, may produce in excess of 200 Moz of gold. Not all gold belts carry the same gold budgets. The 200 km long Juneau Gold Belt, a Tertiary structure in Alaska, has produced in excess of 7 Moz of gold and new discoveries are being made because of its relatively short

exploration history. Size is important, but systematic exploration is the key to unravelling the geology and discovering mines.

WGM's rationale and predictions for the number of new (undiscovered) gold deposits in each gold belt is summarized in the following table. The predicted number of gold deposits at 10%, 50% and 90% levels of confidence was used as in-put parameters for EMINERS software analysis. Two relatively short belts, Al Marasia and Wadi Khiyam, may have a chance of producing no economically viable gold discoveries and this possibility was also entered into the EMINERS as an in-put parameter.

3.1.5 EMINERS Modelling of Undiscovered Gold Belts and Probabilistic Out-Comes

EMINERS software, developed by the US Geological Survey, was used as a tool in estimating the gold resource potential of the various gold belts in the KSA. The software requires the user to name the mineral belt to be evaluated and to choose an appropriate metallogenic model for the expected type of mineralization. In this case, WGM chose the model entitled "Low-sulfide Au-quartz veins", however after reviewing the representative deposits that are the building blocks of the model, WGM concluded that many of the individual deposits did not have the characteristics of the gold deposits in the KSA. WGM also examined the model for "Au-Ag-Te veins associated with Alkalic Rocks". In this case, many of the deposits were appropriate in respect to geology, however many were not and the combination of genetic types and ages, mesothermal and epithermal deposits in setting ranging from orogenic to volcanic-plutonic and Archean to Tertiary, forced WGM to eliminate this model as well. Faced with no practical alternative, WGM constructed its own model based on orogenic vein-type and disseminated deposits in the Arabian Nubian Shield and in nearby terranes. The members of WGM's model are given in Table 27.

One issue that is integral to all of the EMINERS models is that the stated resources include many different jurisdictions and practices resulting in a lack of uniformity in the resource/reserve estimation methods across all deposits. Given that grade and tonnage tend to trade off against each other, the net effect of uniformity issues is probably less of a problem than one might think, especially within the context of the EMINERS outcomes.

Table 27:
Deposits Comprising WGM's EMINERS Model for Orogenic Gold in the KSA

Deposit / Mine	Country	Tonnes	Gold (g/t)	Silver (g/t)
Sukari	Egypt	174,200,000	1.470	n.a.
Ara	Egypt	5,000,000	1.500	n.a.
Hamash	Egypt	2,022,000	3.000	n.a.
Abou Tarda	Egypt	348,250	3.250	n.a.
Gupo	Eritrea	2,760,350	1.727	n.a.
Kodadu	Eritrea	990,000	1.240	1.61
Koka	Eritrea	4,600,000	5.100	n.a.
Adyabo	Ethiopia	9,315,000	2.260	2.20
Lega Dembi	Ethiopia	17,837,840	3.700	n.a.
Sakaro	Ethiopia	1,717,450	10.420	n.a.
Tulu Kapi	Ethiopia	20,200,000	2.650	n.a.
Al Duwayhi	Saudi Arabia	30,600,000	2.44	n.a.
Al Mansourah	Saudi Arabia	35,700,000	2.66	n.a.
As Suq	Saudi Arabia	8,500,000	1.32	n.a.
Bulghah	Saudi Arabia	76,000,000	0.82	n.a.
Ghazal	Saudi Arabia	700,000	1.32	n.a.
Humaymah	Saudi Arabia	35,800,000	0.866	n.a.
Jabal Qutman	Saudi Arabia	28,400,000	0.800	n.a.
Jibal Al Hajar	Saudi Arabia	1,170,000	2.800	n.a.
Jibal Al Hajar-NW1	Saudi Arabia	1,170,000	2.800	n.a.
Masarah	Saudi Arabia	22,300,000	2.19	n.a.
Sabkhat Buhayran	Saudi Arabia	7,800,000	2.630	n.a.
Shaib Al Qalt	Saudi Arabia	872,000	6.500	n.a.
Sukhabayarat	Saudi Arabia	27,600,000	1.1	n.a.
Umm Ash Shalahib	Saudi Arabia	900,000	10.600	55.500
Umm Nam	Saudi Arabia	33,700,000	1.25	n.a.
Waseemah	Saudi Arabia	28,100,000	1.42	n.a.
Hassai	Sudan	34,450,000	2.620	n.a.

At the time when WGM disclosed that it would use a model customized to the Saudi context, one question that was raised was whether such a model could capture all possible geological outcomes. Concern was expressed that WGM had removed some giant deposits found in other parts of the world and that this might result in EMINERS under-estimating gold potential. While it was true that some giant deposits were removed, WGM pointed out the fact that in some cases, giant deposits had been created artificially by amalgamating deposits that were close to each other into a single super-deposit. WGM pointed out that its model does include several deposits that are greater than 50 Mt and a large percentage of deposits (46%) greater than 20 Mt, and so the potential for under-reporting is thought to be minimal. WGM also pointed out the fact that many of the large deposits eliminated were from Archean greenstone belts and might not be entirely comparable to the late Proterozoic belts in the Arabian-Nubian Shield.

WGM discussed the make-up of its model with geologists at the USGS in Denver, Colorado to overcome some initial challenges involved in integrating its customized model into the EMINERS software. Once these teething problems were overcome, the software ran well and produced results that were within the range of outcomes expected by WGM. In respect to the global total gold resources expected from new, undiscovered gold deposits, the outcomes can be summarized as follows Table 28.

Table 28:
EMINERS Model for Orogenic Gold in the KSA

Confidence Level	Number of New Deposits	Total (Global) Resources		
		(M Tonnes)	(g Au/t)	(Ounces)
10%	67	2,632	1.38	117,028,548
50%	47	941	1.80	54,398,984
90%	30	260	2.07	17,268,142

Table 29 provides some of the physical characteristics of each belt, the EMINERS in-put parameters and the probabilistic outcomes from the software for each individual gold belt. For economic viability modelling, WGM selected the 50% confidence outcomes as its base case. Using these results on a belt by belt basis, and rounded to the nearest number of complete deposits, WGM re-assessed the geology and attributed the predicted resources to open-pitable and underground mineable deposits. In the real world, WGM recognizes that many of the underground deposits will contain resources that may be partially mineable through open-pit or open-cut techniques. WGM did not subdivide the resources further in this respect because the attribution of costs and production schedules within a hybrid mining scenario introduces assumption-based complexities in the economic viability models that require in-puts that are far beyond any level of precision inherent in this study. The outcomes would also imply a level of accuracy that cannot be achieved within the context of this study.

The 50% base case scenario results in an overall average grade of mineralization that is similar to what current mines are achieving in the region. The deposits shown in the EMINERS model have an average size of 41.4 Mt grading 1.69 g Au/t. The Saudi examples in the model are slightly smaller and lower grading with an average size of 31.3 Mt and an average grade of 1.48 g Au/t. Effectively, the model suggests that larger Saudi deposits have yet to be discovered as there is no reason to believe that the deposits in the Kingdom should not be on average the same size.

As stated, WGM attribution of gold resources to open-pit and underground operations was based on an assessment of the geology of the belt and the character of the existing prospects that are well known and sufficiently well defined such that it is possibly to envision the geometry of the potential deposit and the type of approach needed for mining. For an individual belt, the total contained gold was allocated between OP and UG deposits on a prorate basis however underground operations were awarded 10% more gold that open pit operations. Accordingly, if three open pit mines and only one underground mine would be developed in a belt, then for that belt the open pit mines would be allocated 75% of the global gold budget minus 10% and the underground mine would be allocated 25% of the global gold budget +10%. The physical size of the resource in each belt, as measured in tonnes, was allocated using a weighting factor to reflect the difference in underground mines which tend to follow relatively narrow vein-structure zones and surface mines which tend to mine outwards to the limits of the gold-bearing rocks. While both mine types are constrained by grade considerations, underground mines must be more selective due to higher mining costs. To reflect this fact, the tonnage allocated to open-pit mines was 4X weighted compared to

that allocated to underground operations. As such, if a gold belt contained a single open-pit mine and a single underground mine, then 80% of the tonnage was allocated to the open-pit mine. In any given combination of mine types, the open-pit mines were always given 4X the tonnage of any single underground operation. If four underground operations and only one open-pit operation was envisioned in a belt, then the two types would share the resources equally, however in terms of gold resources the average underground mine would be only 25% of the size of the open-pit mine. This approach generated 36 open-pit (surface) mines and 13 underground mines. The average characteristics for each are summarized in Table 30.

Table 29
Summary of Gold Belts: Gold Occurrences and Mines in the Arabian Shield, EMINERS In-Puts and Projections

Name of Gold Belt	Major Occurrences	Length (km)	Known Gold Mines (includes feasibility-level projects)			Anticipated New Deposits by Confidence Level			Chance of Zero Deposits	EMINERS Projections (Out-Puts): Number of New Deposits, Global Resources									
										Number of Deposits	---------- Confidence Level ----------								
											10%			50%			90%		
			Closed	Producing	Planned	10%	50%	90%			Mt	g/t	Ounces	Mt	g/t	Ounces	Mt	g/t	Ounces
Al Wajd	North Segment 44 Southern Segment 19	200	0	0	0	4	3	2	no	2.9	170	1.35	7,394,661	55	1.82	3,215,070	7.7	1.35	739,466
Al Marasia	16	63	0	0	0	3	2	1	yes	1.9	120	1.42	5,465,619	33	1.79	1,896,891	1.1	4.73	167,184
Ash Shakhtaliyat	46	225	0	0	Wasemah, Umm Naam	4	3	2	no	2.9	180	1.33	7,716,168	57	1.93	3,536,577	12	2.58	996,672
Ghuzayyilat - Zalim	60	170	0	0	0	3	2	1	no	1.9	140	1.29	5,787,126	35	1.97	2,218,398	3.4	3.53	385,808
As Siham - Az Zeraib	60	200	0	As Suq	0	6	4	3	no	4.1	220	1.45	10,288,224	83	1.81	4,822,605	29	1.90	1,768,289
Nabitah: Mansourah Segment	16	175	0	0	Mansourah, Bi'r Tawilah, Masarah	4	3	2	no	2.9	180	1.33	7,716,168	57	1.93	3,536,577	13	2.38	996,672
Nabitah: Ad Duwayah-Dahlat Shabab Segment	18	165	0	Ad Duwayhi	0	5	4	3	no	3.8	210	1.38	9,323,703	77	1.82	4,501,098	28	1.96	1,768,289
Nabitah: Bishah Segment	25	175	0	0	Jibal Kutman	5	3	2	no	3.2	190	1.37	8,359,182	62	1.77	3,536,577	16	2.13	1,093,124
Tathlith	Main Belt 24 Cluster in Terrane 32	200 +	Hamdah Mine	0	0	3	2	1	no	1.9	140	1.29	5,787,126	35	1.94	2,186,248	2.9	4.14	385,808
Wadi Shwas	17	80	Al Hajar Mine	0	0	4	3	2	no	2.9	180	1.28	7,394,661	57	1.93	3,536,577	13	2.31	964,521
Wadi Bidah	32	130-140	0	0	0	6	4	2	no	3.9	220	1.36	9,645,210	79	1.90	4,822,605	22	1.91	1,350,329
Al Wuhayti - Umm ash Shalahib	31	165	0	0	0	6	4	2	no	3.9	220	1.41	9,966,717	79	1.77	4,501,098	22	2.00	1,414,631
Wadi Khiyam	22	55	0	0	0	2	1	1	yes	1.2	72	1.67	3,858,084	22	1.64	1,157,425	6.8	4.26	93,237
Sukhaybrah - As Safra	126	275	0	Sukhaybrah, Bulghah, Humaymah	0	12	9	6	no	8.6	390	1.46	18,325,899	210	1.62	10,931,238	83	1.93	5,144,112
CUMULATIVE TOTALS	**588**	**2,083**				**67**	**47**	**30**		**46**	**2,632**	**1.38**	**117,028,548**	**941**	**1.80**	**54,398,984**	**260**	**2.07**	**17,268,142**

Table 30
Base Case Gold Resource Allocation Summary by Mine Type Using EMINERS Projections

Mine Type	Number of Mines	Global Resources		Average Deposit		
		Tonnes (millions)	Ounces (millions)	Tonnes (millions)	g Au/t	Ounces (millions)
Open-Pit	36	853.4	39.9	23.7	1.45	1,108,069
Underground	13	87.6	14.5	6.7	5.15	1,116,040

The result produces OP mine grades that approximate what Ma'aden is mining at the moment and UG grades that are economically interesting.

3.1.6 TECHNICAL AND ECONOMIC VIABILITY OF PREDICTED UNDISCOVERED GOLD DEPOSITS

Introduction

The out-put from the EMINERS modeling was used as the basis for estimating the economic viability of the predicted new gold deposits. WGM used these outcomes which we believe are indicative however the probabilistic approach almost certainly under-estimates potential at the 50% and 90% levels of confidence. We believe some predictions are most likely at the 10% level of confidence. The primary reason for under-reporting is the fact that a probabilistic approach allows little or no influence by deposits that are outliers – the extremely large deposits. Because medium-sized deposits are more common in the sample population, these tend to have a very strong influence on overall results. It is not surprising therefore that the average grade of the EMINERS predictions decreases as confidence level is reduced because a greater number of smaller, lower grading deposits are taken into the sample population.

The undiscovered gold resources were allocated amongst the predicted number of deposits (Table 31). On the basis of geological evidence, WGM further subdivided the deposits into two groups: open-pitable deposits and those deposits likely to be mined predominantly as underground operations. The size and grade of the open pit deposits predicted by WGM was based on the evidence provided by the known deposits in Saudi Arabia and neighbouring countries that share portions of the Arabian-Nubian Shield. Following the allocation of these gold resources, the remaining resources were allocated to underground mines. In each case, the average grade was calculated to ensure that the grades were appropriate for the predicted types of mines. In this manner, the resources in the predicted underground mines were assigned a grade that was approximately 4-5 times higher than the resources assigned to an open pit operation.

Table 31
Summary of WGM's Allocation of 50% Confidence Level Resources to Undiscovered Mines for Viability Modelling

Name of Gold Belt	Undiscovered Open Pit Gold Mines					Undiscovered Underground Gold Mines				
	Number of Mines	Total Tonnes (millions)	Average Tonnes per Mine (millions)	Contained Ounces	Average Grade (g/t)	Number of Mines	Total Tonnes (millions)	Average Tonnes per Mine (millions)	Contained Ounces	Average Grade (g/t)
Al Wajd	1	36.7	**36.7**	1,004,709	**0.85**	2	18.3	**9.2**	2,210,361	**3.75**
Al Marasia	1	26.4	**26.4**	903,261	**1.06**	1	6.6	**6.6**	993,630	**4.68**
Ash Shakhtaliah	2	50.7	**25.3**	2,281,658	**1.40**	1	6.3	**6.3**	1,254,919	**6.16**
Ghuzayyilat - Zalim	2	35.0	**17.5**	2,218,398	**1.97**	0	----	**----**	----	n/a
As Siham - Az Zeraib	3	76.6	**25.5**	3,528,700	**1.43**	1	6.4	**6.4**	1,293,905	**6.30**
Nabitah: Mansourah Segment	3	7.0	**19.0**	3,536,577	**1.93**	0	----	**----**	----	n/a
Nabitah: Ad Duwayah-Dahlat Shabbab Segment	3	71.1	**23.7**	3,293,453	**1.44**	1	5.9	**5.9**	1,207,645	**6.34**
Nabitah: Bishah Segment	2	53.1	**17.7**	2,040,315	**1.19**	1	8.9	**4.4**	1,496,262	**5.25**
Tathlith	1	28.0	**28.0**	1,041,046	**1.16**	1	7.0	**7.0**	1,145,202	**5.09**
Wadi Shwas	2	50.7	**25.3**	2,281,658	**1.40**	1	6.3	**6.3**	1,254,919	**6.16**
Wadi Bidah	3	72.9	**24.3**	3,528,700	**1.51**	1	6.1	**6.1**	1,293,905	**6.62**
Al Wuhayti - Umm ash Shalahib	2	63.2	**31.6**	2,143,331	**1.05**	2	15.8	**7.9**	2,357,767	**4.64**
Wadi Khiyam	1	22.0	**22.0**	1,157,425	**1.64**	0	----	**----**	----	n/a
Sukhaybrah - As Safra	9	210.0	**23.3**	10,931,238	**1.62**	0	----	**----**	----	n/a
TOTALS / AVERAGES	**36**	**853.4**	**23.7**	**1,108,069**	**1.45**	**13**	**87.6**	**6.7**	**1,116,040**	**5.15**

The information summarized in the preceding table was provided to WGM's engineering group for further assessment such that a provisional mining schedule could be developed as a basis for determining what mining method might be appropriate given the "average" geometric configuration of such gold deposits. This was used as a basis for selecting and sizing equipment as well as estimating capital, operating and other cost factors.

Mining and Processing

In order to evaluate the undiscovered mines, cost estimates were prepared for a range of typical mines in the Kingdom. These are order-of-magnitude cost estimates, designed to get an initial idea concerning potential viability. WGM initially prepared personnel lists for typical small, medium and large mines, both open pit and underground: six lists in total.

The EMINERS output resulted in a predicted tonnage for each undiscovered mine. An annual throughput rate was selected that results in a mine life of approximately 10 years, although round numbers were chosen; for example 1 million tonnes per year or 750,000 tonnes per year. In the case of open pit mines, waste rock was modelled at a constant annual tonnage.

Mining and maintenance personnel quantities were estimated based on a mining fleet analysis. For each mine, a few positions were assigned international salaries; for all other jobs filled by Saudi Nationals, wages and benefit estimates were based on the 2014 SGS report "Directory of Mining Services Cost in Saudi Arabia". Quantities of consumables were prepared for each of the six models. Costs were prepared using information from WGM data sources and aligned for the Saudi context. Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine sites.

The following tables (Table 32 and 33) illustrate the equipment and personnel requirements for the Mining Department at a typical open pit mine. This mine is modelled at 1,500 t per day of ore with 7,500 t per day of waste rock (Stripping Ratio equals 5:1) for a total of 9,000 t mined per day, 7 days per week. The bench height could range from 5 m to 10 m and the haul road allowance is 25 m wide.

Capital cost estimates for mining were prepared for each cost model based on the SGS cost directory together with WGM and BBA data.

Table 32
Typical Major Equipment Fleet – Open Pit Gold Mine

Item	Description	Quantity
Excavator	$10m^3$	1
Wheel Loader	$11m^3$	1
Truck, Haulage	91t	6
Wheel Loader, stockpile, etc.	$3.5m^3$	1
Drill, Production	229 mm, medium capacity	1
Dozer, Track	39t	1
Grader	4.3m	1
Crawler Drill & Compressor	Perimeter drilling	1
Water Truck	Medium	1
Service Truck		1
Mechanic Truck		1
Pick-Up Truck		7
Lighting Tower		3

Table 33
Typical Personnel Roster – Open Pit Gold Mine

Responsibility Level	Number	Responsibility Level	Number
Mine Superintendent	1	Mine Engineer	2
Mine Foreman	4	Surveyor	2
Clerk	2	Mining Technician	2
Shovel/Excavator/Loader Operator	8	Geologist	2
Haul Truck Driver	24	Sampler	2
Production Drill Operator	4	Maintenance General Foreman	1
Production Drill Helper	4	Maintenance Foreman	4
Heavy Equipment Operator	20	Maintenance Planner	1
Relief Operator	6	Heavy Equipment Mechanic	9
Blaster	1	Welder	4
Blasting Crew	2	Light Vehicle Mechanic	2
Service Truck Driver	2	Tool Crib Attendant	4
Labourer	3	Maintenance Assistant	4
Mine Technical Superintendent	1	**Total - Mining - Open Pit**	**121**

The processing options considered were either whole ore cyanide-leaching or flotation followed by cyanide-leaching. Gravity recovery in the grinding circuit was included in both flowsheet options. In low grade cases heap leaching was considered as the processing option. In the absence of any metallurgical information, the whole ore cyanide leaching was used as the process option. In the interest of water conservation, 80% water recirculation was assumed along with filtration and dry stacking of tailings. Estimates for reagent consumption and major consumables for the process are based on industry norms. Processing and maintenance personnel requirements were based on international salaries in the lead and management roles and for all other jobs filled by Saudi nationals, wages and benefit estimates were based on the above-

mentioned SGS report. Consumables prices were estimated using information from WGM data. Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine site costs for Processing.

Processing capital cost estimates based on WGM and BBA data were prepared for each cost model.

General and Administration

Each mine was considered as a typical remote location and self-contained with an accommodation village for personnel and diesel power generation along with the facilities necessary to mine and process the deposit and carry out the associated maintenance.

General and administrative ("G&A") costs were estimated to reflect all the operating costs inside the mine gate including security, insurance, and environmental costs. Personnel costs and consumables costs were combined to provide an estimate of the operating cost per tonne for G&A.

G&A capital cost estimates were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM and BBA data.

Economic Modeling

The 12 general cost models (six mine types with two processing options) were then used to guide the preparation of individual cost models for 16 deposits that have advanced information on tonnes and grade. Some of these have recent Feasibility Studies or Preliminary Economic Estimates with estimated plant feed tonnage and grade, open pit waste:ore ratio, mining fleet based on haulage profiles, and/or reagent quantities based on industry averages.

For each gold belt, WGM's geologists provided a forecast of how many gold mines would be discovered, how many of these would be open pit mines, and how many would be underground mines. The 12 general and 16 specific cost models enabled comparison of mine size and type with capital cost, operating cost, number of employees, diesel fuel, electricity, water, grinding media, and reagents. This information was used to estimate the requirements for the undiscovered gold deposits.
The undiscovered gold projects are assumed to produce gold bullion which is sent to a refinery for final smelting and refining. The model assumes a 1% of revenue charge for the smelting and refining of the gold bullion.

Summary of Analysis

The following table summarizes the results of economic analysis of the Gold Belts at EMINERS' 50% confidence level.

Table 34
Results of Economic Evaluation of Gold Projects

Mineral Belt	Open Pit or Underground	Number of Mines	Number of Mines Above Cut	IRR (%)	Net Cash Flow		
					(/t ore)	($M)	Belt Total ($M)
Al Wajd	OP	1	0	-6.6%	($4.95)	($182)	$0
Al Wajd	UG	2	2	34.5%	$56.98	$522	$1,045
Al Marasia	OP	1	0	-1.4%	($1.27)	($33)	$0
Al Marasia	UG	1	1	41.8%	$76.28	$503	$503
Ash Shakhtaliah	OP	2	2	7.2%	$7.43	$188	$376
Ash Shakhtaliah	UG	1	1	56.7%	$117.16	$742	$742
Ghuzayyilat - Zalim	OP	2	2	15.4%	$19.39	$339	$679
As Siham - Az Zeraib	OP	3	3	8.1%	$8.51	$217	$652
As Siham - Az Zeraib	UG	1	1	60.4%	$127.53	$814	$814
Nabitah: Mansourah Segment	OP	3	3	14.9%	$18.09	$344	$1,031
Nabitah: Ad Duwayah-DS Segment	OP	3	3	7.5%	$7.92	$188	$563
Nabitah: Ad Duwayah-DS Segment	UG	1	1	58.7%	$122.33	$725	$725
Nabitah: Bishah Segment	OP	2	0	-2.0%	($1.81)	($32)	$0
Nabitah: Bishah Segment	UG	1	1	44.6%	$87.61	$388	$388
Tathlith	OP	1	1	0.3%	$0.32	$9	$9
Tathlith	UG	1	1	47.1%	$88.76	$621	$621
Wadi Shwas	OP	2	2	6.9%	$7.15	$181	$362
Wadi Shwas	UG	1	1	57.0%	$117.75	$746	$746
Wadi Bidah	OP	3	3	9.5%	$10.34	$251	$754
Wadi Bidah	UG	1	1	61.1%	$129.03	$784	$784
Al Wuhayti - Umm ash Shalahib	OP	2	0	-1.0%	($0.87)	($28)	$0
Al Wuhayti - Umm ash Shalahib	UG	2	2	41.5%	$74.39	$588	$1,175
Wadi Khiyam	OP	1	1	10.1%	$11.16	$246	$246
Sukhaybrah - As Safra	OP	9	9	10.1%	$11.10	$259	$2,331
TOTAL		**47**	**41**	**21.6%**	**$36.52**	**$356**	**$14,934**

Note: Projects with IRR below 0% have been cut out of the averages. The IRR is the average for each belt. The NCF per tonne is the average for the belt. The NCF ($M) is the total for each belt.

Table 35 is a sample summary of the inputs and results from a typical analysis of a projected undiscovered gold project, in this case at the 50% probability level for an open pit operation in the Ghuzayyilat-Zalim Gold Belt. It includes a calculation of the price of gold that would be required for the project to achieve IRR's of 10% and 15% as well as the base gold price. Table 36 provides a financial model for the same operation over its life of mine.

Table 35
Results of Economic Evaluation of Gold Projects

Project	**Ghuzayyilat - Zalim Gold Belt OP#1**			**Probability: 50%**
Number of Mines	2			
Ownership	na			
Location				
Resource Type	Potential Deposit			
Mine Type	Open Pit			
Proposed Start Date	na			
Resources	17,500,000 tonnes			
Major Commodities	Gold			
Grade(s)	1.97 g/t			
Production				
Annual	1,750,000 tpa			
Mine Life	10.0 Years			
	Annual	**Total**	**/tonne Ore**	
Gold Production (ozs)	99,827	998,271	1.77 g/t	
Revenue	M$121.0	M$1,210	$69.16	
Operating Costs	M$39.6	M$396	$22.62	
Capital Costs	**Total**	**/tonne Ore**		
Initial	M$262.8	$15.02		
Ongoing	M$92.0	$5.26		
Rehabilitation	M$26.3	$1.50		
Total	M$381.1	$21.77		
	Per Year	**Man Years**	**Tonnes/Man Year**	
Employment	322	3,220	5,435	
Material Consumption	**Per Year**	**Total**	**Per Tonne Ore**	
Diesel Fuel (l)	12,390,000	123,900,000	7.08	
Explosives (kg, 99% Anfo)	700,000	7,000,000	0.40	
Electricity (Kwh)	75,250,000	752,500,000	43.00	
Water (l)	638,750	6,387,500	0.365	
Taxes/Zakat Paid	**Per Year**	**Total**		
Zakat	na	na		
Severance Taxes	na	na		
Corporate Taxes	k$9,404	k$94,041		
Total Zakat & Taxes	k$9,404	k$94,041		
Internal Rate of Return	15.4%			
Net Cash Flow Discounted at	**0%**	**5%**	**10%**	**15%**
	k$339,371	k$174,303	k$71,017	k$4,592
Payback from Start of:	**Development**	**Production**		
	6.8 Years	4.8 Years		
	Commodity Prices			
Commodity	**Base**	**Price Req'd**	**Price Req'd**	**Price**
Price	**Price**	**for 10% IRR**	**for 15% IRR**	**Units**
Gold	$1,224.66	$1,051.77	$1,207.98	US$/oz

Table 36
Example Financial Model for an Open Pit Operation in the Ghuzayyilat-Zalim Gold Belt

Project --> Ghuzayyilat - Zalim Gold Belt OP#1	Units	Total/ Average	Year 1 -2	Year 2 -1	Year 3 +1	Year 4 +2	Year 5 +3	Year 6 +4	Year 7 +5	Year 8 +6	Year 9 +7	Year 10 +8	Year 11 +9	Year 12 +10
Metal Prices														
Gold	US$/oz	$1,225	-	-	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225
Production														
Ghuzayyilat - Zalim Gold Belt OP#1														
Waste Mined	kt	87,500	-	-	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750
Ore Mined	kt	17,500	-	-	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Ore Milled	kt	17,500	-	-	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Total Waste Mined	kt	87,500	-	-	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750	8,750
Total Ore Mined/Milled	kt	17,500	-	-	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Ore Grades														
Gold	g/t	1.97	-	-	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Gold Production														
Ghuzayyilat - Zalim Gold Belt OP#1														
Grade	g/t	1.97	-	-	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97	1.97
Recovery	%	90.0%	-	-	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
Production	ozs	998,271	-	-	99,827	99,827	99,827	99,827	99,827	99,827	99,827	99,827	99,827	99,827
Revenue	k$	1,222,547	-	-	122,255	122,255	122,255	122,255	122,255	122,255	122,255	122,255	122,255	122,255
Total Gold Revenue	k$	1,222,547	-	-	122,255	122,255	122,255	122,255	122,255	122,255	122,255	122,255	122,255	122,255
Less: Refining Costs	k$	-12,225	-	-	-1,223	-1,223	-1,223	-1,223	-1,223	-1,223	-1,223	-1,223	-1,223	-1,223
Net Gold Revenue	k$	1,210,321	-	-	121,032	121,032	121,032	121,032	121,032	121,032	121,032	121,032	121,032	121,032
Total Revenue	k$	1,210,321	-	-	121,032	121,032	121,032	121,032	121,032	121,032	121,032	121,032	121,032	121,032
Operating Costs														
Waste Mining	k$	198,625	-	-	19,863	19,863	19,863	19,863	19,863	19,863	19,863	19,863	19,863	19,863
Mining	k$	39,725	-	-	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973	3,973
Processing	k$	110,600	-	-	11,060	11,060	11,060	11,060	11,060	11,060	11,060	11,060	11,060	11,060
G&A	k$	46,900	-	-	4,690	4,690	4,690	4,690	4,690	4,690	4,690	4,690	4,690	4,690
Total Operating Costs	k$	395,850	-	-	39,585	39,585	39,585	39,585	39,585	39,585	39,585	39,585	39,585	39,585
EBITDA	k$	814,471	-	-	81,447	81,447	81,447	81,447	81,447	81,447	81,447	81,447	81,447	81,447
Capital Cost Schedule														
Mining	k$	50,000	25,000	25,000	-	-	-	-						
Processing	k$	190,000	95,000	95,000	-	-	-	-						
Infrastructure	k$	22,800	11,400	11,400	-	-	-	-						
Total Initial Capital	k$	262,800	131,400	131,400	-									
Ongoing Capital	k$	91,980	-	-	-	13,140	13,140	13,140	13,140	13,140	13,140	13,140	-	-
Rehabilitation/Restoration	k$	26,280		-	-	-	-	-	-	-	-	8,760	8,760	8,760
Total Capital	k$	381,060	131,400	131,400	-	13,140	13,140	13,140	13,140	13,140	13,140	21,900	8,760	8,760
Less: Depreciation (UOP)	k$	381,060	-	-	26,280	27,740	29,383	31,260	33,450	36,078	39,363	46,663	51,043	59,803
Saudi Corporate Taxes	k$	94,041	-	-	11,033	10,771	10,508	10,245	9,982	9,719	9,457	7,442	7,442	7,442
Net Income After Taxes & Depr.	k$	339,371	-	-	44,134	42,937	41,557	39,942	38,015	35,650	32,628	27,343	22,963	14,203
NET CASH FLOW to PROJECT														
Net Income After Taxes & Depr.	k$	339,371	-	-	44,134	42,937	41,557	39,942	38,015	35,650	32,628	27,343	22,963	14,203
Plus: Depreciation	k$	381,060	-	-	26,280	27,740	29,383	31,260	33,450	36,078	39,363	46,663	51,043	59,803
Less: Capital Investment	$	-381,060	-131,400	-131,400	-	-13,140	-13,140	-13,140	-13,140	-13,140	-13,140	-21,900	-8,760	-8,760
Working Capital	k$	-	-	-	-25,583	-	-	-	-	-	-	-	-	25,583
Net Cash Flow to Project	k$	339,371	-131,400	-131,400	44,831	57,537	57,799	58,062	58,325	58,588	58,851	52,105	65,245	90,828
Accum. NCF to Project	k$	339,371	-131,400	-262,800	-217,969	-160,433	-102,633	-44,571	13,754	72,342	131,192	183,297	248,543	339,371
Project Metrics	various		Internal Rate of Return (IRR)		15.4%				EBITDA/Capital		2.14			
Project Net Present Value	M$		@5% -	$174.3M		@10% -	$71.0M		@15% -	$4.6M				
Project Payback Period	Years		6.8 Years after Start of Development					4.8 Years after Start of Production						

Of the 47 gold mines modelled 41 exceeded a 10% internal rate of return ("IRR"), ranging from 10.1% to 61.1%. These 41 mines had an average IRR of 21.6%, with an average net cash flow ("NCF") of approximately US $36.52 per tonne of ore and an average life-of-mine net cash flow of $356 million, or a total of $14.9 billion for all projects.

The following Spider diagrams examine the sensitivity of the project IRR, NCF and Discounted NCF to changes in metal prices and operating and capital costs (Charts 1 to 3). They are run from -40% to +40% to reflect the accuracy of the input data and to determine how robust each project is. While the sample project above has an "Base Case" IRR of 15.4% (Chart 1), the IRR remains positive until the gold price is reduced by approximately 35% to $800. In other words, even at $800 gold, the project would break even

and the original capital investment returned. The project is less sensitive to operating and capital costs and if either is raised by 40% the IRR would still be approximately 10%.

The changes in Capital Costs have a greater impact when discounting as most of the capital costs are incurred at the beginning of the project. Thus while impact of changing operating and capital costs is virtually identical in the case of the NCF (the lines overlap each other), in the case of the IRR there is a noticeable divergence. This divergence can also be seen in Chart 3 where the NCF is discounted by 10%.

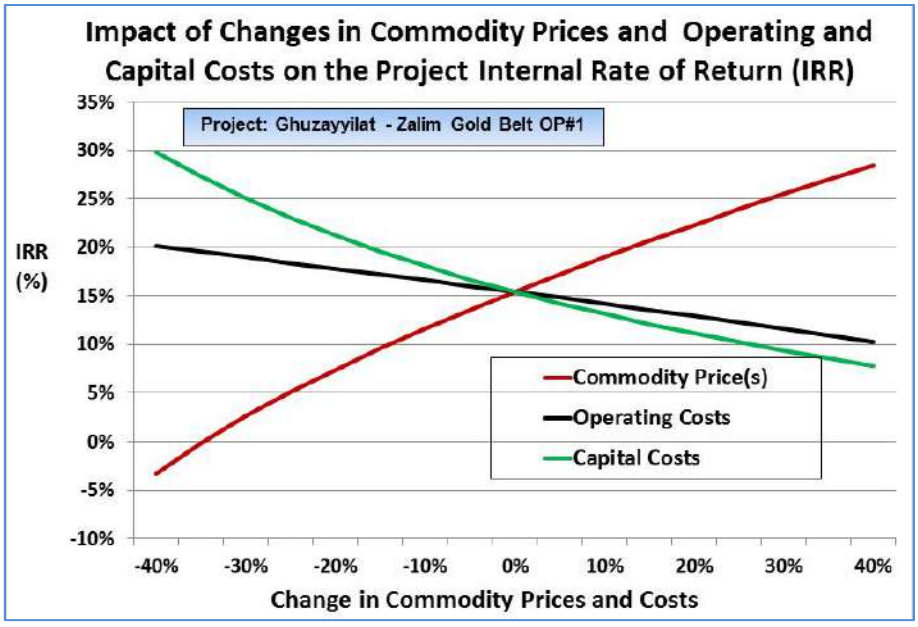


Chart 1: Example Spider Diagram of IRR Sensitivity Analysis

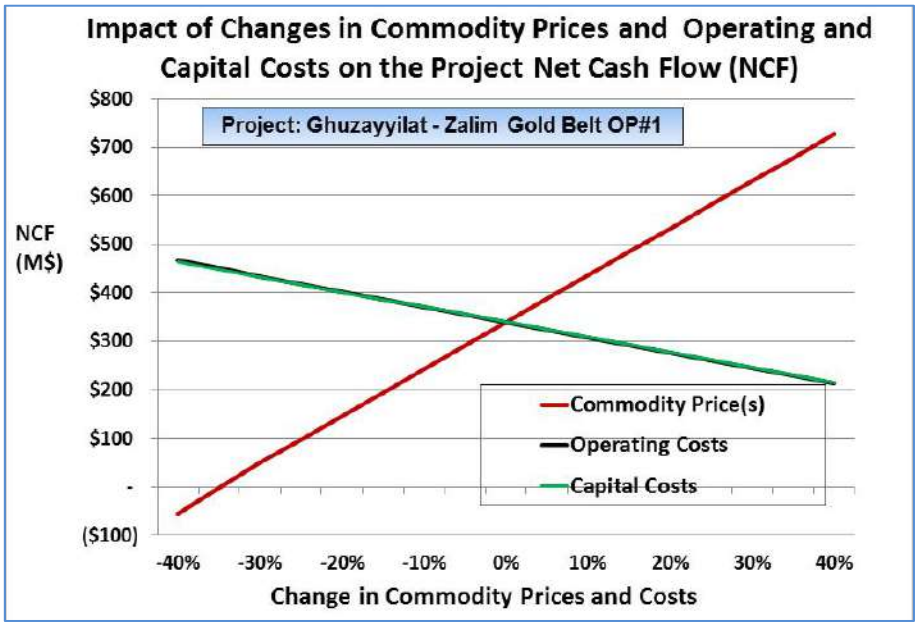


Chart 2: Example Spider Diagram of NCF Sensitivity Analysis

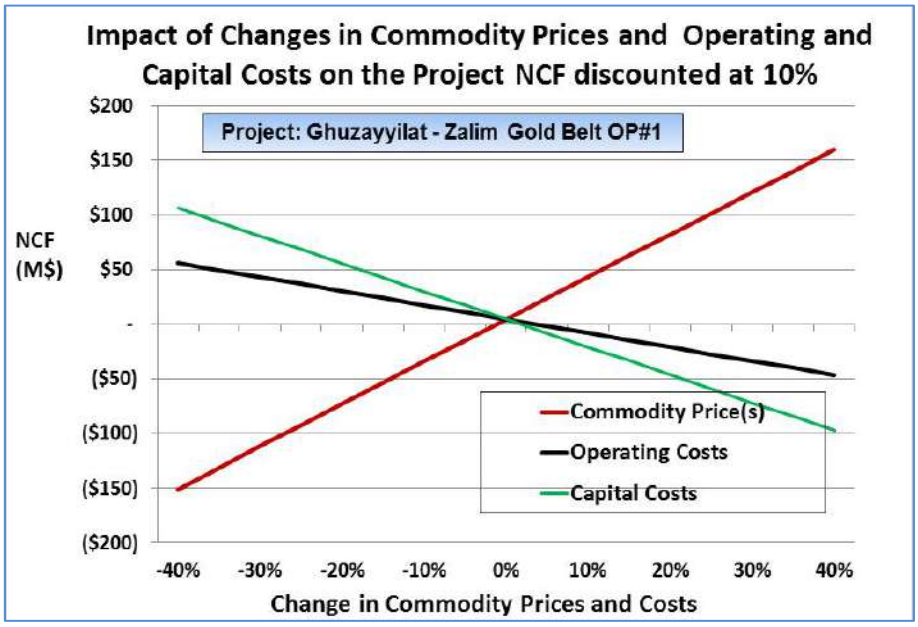


Chart 3: Example Spider Diagram of Discounted NCF Sensitivity Analysis

Overall, the gold projects are very robust when the gold price is reduced or the operating and capital costs are increased. Even with a 40% gold price reduction (equivalent to $735/oz.) 14 of the original 42 gold projects still remain positive. More importantly, a 40% increase in operating costs eliminates only 4 mines, and the same increase in capital costs eliminates 3 on the basis of IRR. Put another way, an increase of 40% in the operating or capital costs only moves four or three projects, respectively, into negative IRR territory. WGM's analysis shows that raising the gold price above the current price quickly moves the lower value projects into positive IRR territory. For instance, increasing the gold price by 10% adds 6 more positive projects and any gold price over 20% above the base price ensures that all of the gold projects have a positive IRR.

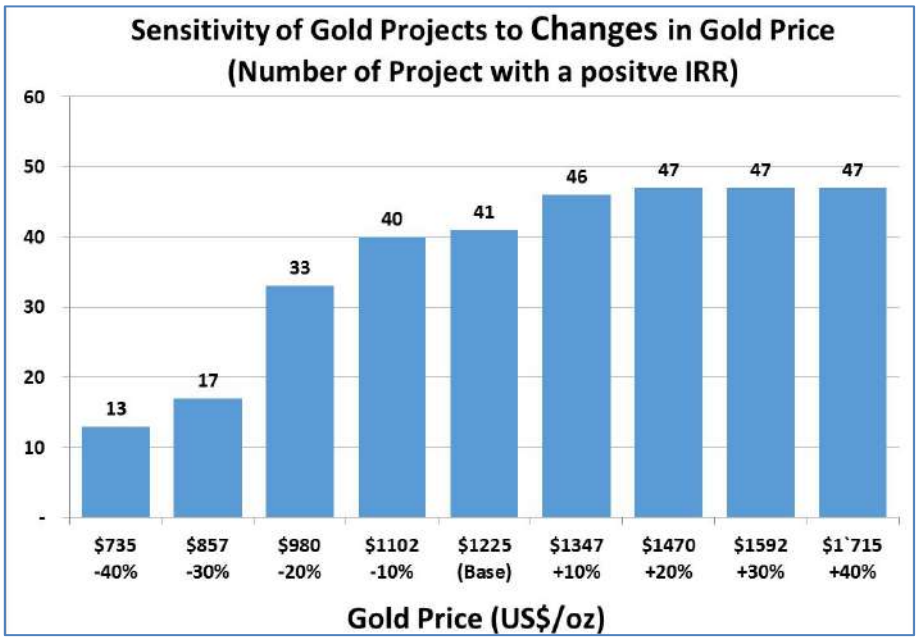


Chart 4: Example Spider Diagram of Discounted NCF Sensitivity Analysis

3.2 VMS DEPOSITS

3.2.1 METALLOGENIC MODEL AND EXISTING MINES

Volcanogenic massive sulphide ("**VMS**") deposits are accumulations of polymetallic massive and disseminated sulphides that form at or near the seafloor in submarine volcanic environments and in extensional environments. They form by focussed discharge of metalliferous hydrothermal solutions. Originally it was thought that the deposits formed by exhalative processes but recently replacement has been recognized as an important factor so that many deposits may be formed by a combination of both processes (Piercey, 2015). A generalized section of a typical VMS deposit is shown in Figure 52.

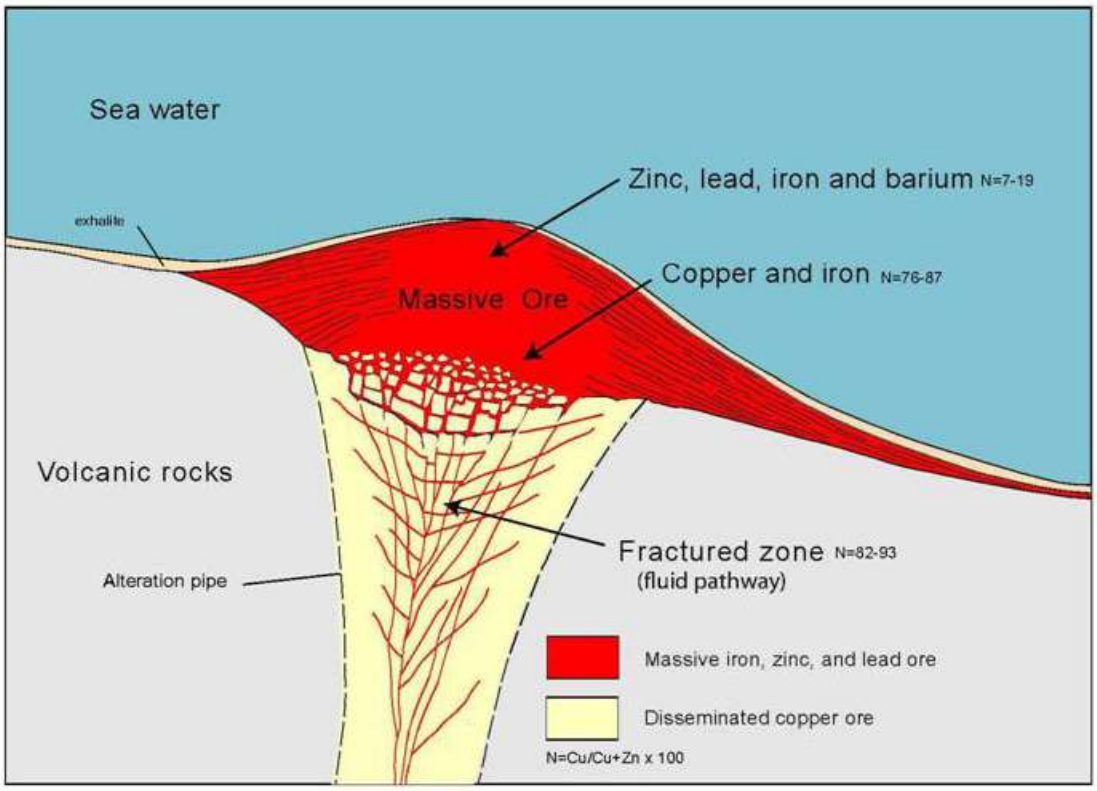
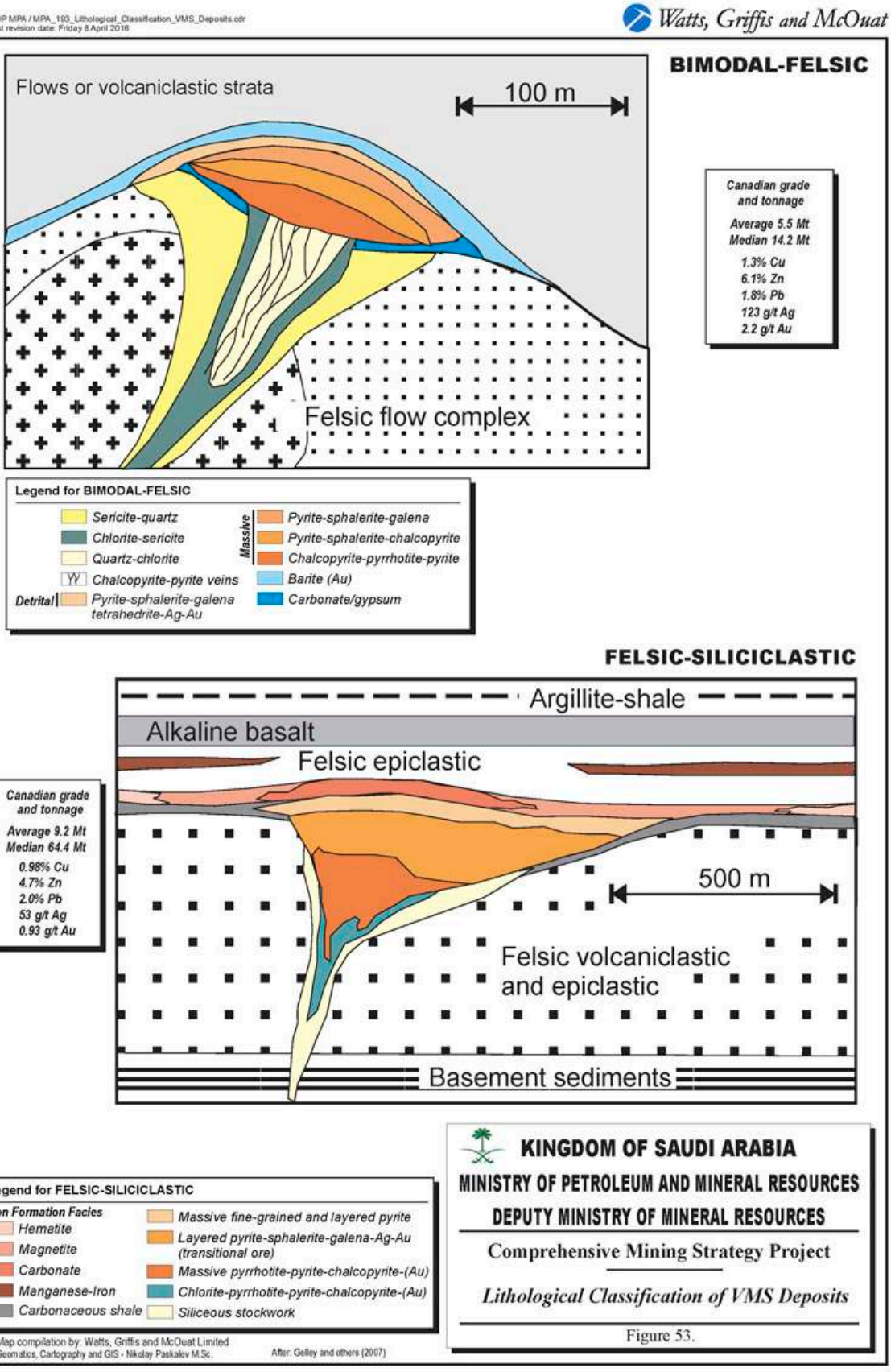


Figure 52: Schematic Section Through a VMS Deposit

Typically VMS deposits collectively form districts containing deposit clusters possibly derived from a common heat source and are underlain by a discordant stringer/alteration zone (proximal) that may be related to more extensive sub conformable alteration zones. Distal deposits may form without a discernible alteration zone directly below. They have been classified into six divisions (Franklin et al 2005) according to host rock lithology but the most common in the Arabian shield are the Bimodal – Felsic and the Felsic – Siliclastic varieties. The generalized character of each type along with the average Canadian size and grade is shown in Figure 53.

ıd others, 2007)



VMS deposits are often confined to narrow chrono-stratigraphic horizons and may be capped by a chert/ironstone/carbonate/barite rich horizon that can extend for considerable distances within a mineral belt and form a marker horizon that can be used to determine permissive stratigraphic intervals. (e.g. Wadi Bidah Mineral Belt).

VMS deposits are by definition accumulations of massive sulphides and are amenable to discovery by a number of exploration methodologies. These deposits typically form clusters that are restricted to linear rifts or calderas where extension is taking place. VMS mineral belts have regional and proximal alteration zones associated with them. The stratiform or district scale alteration zones can have strike lengths of 5 km to 50 km and thicknesses of 1 to 3 km (Galley et al., 2007) These alteration zones exhibit increases in Ca-Si, Ca-Si-Fe, Na or K-Mg. Proximal alteration zones are discordant to stratigraphy, underlie the sulphide deposits and are strongly depleted in Na and Ca. Whole rock chemical analysis can detect these alteration zones and help vector exploration efforts.

Permissive terranes are characterized by bimodal volcanism and the felsic volcanics within them are characterized by low Zr/Y (<7) and low (La/Yb) (<6) ratios as well as high Zr (>200 ppm) and Y (>30 ppm) and elevated LREE and HREE (Galley et al. 2007). Multi element geochemical analyses can be used to differentiate permissive felsic assemblages from barren assemblages in a mineral belt.

Geophysical methods are commonly used and the most effective include electromagnetic and magnetic methods. Airborne variants are commonly employed to cover large areas in a cost effective manner. Many mineral belt borders in Saudi Arabia are covered by harrats or unconsolidated Quaternary cover and geophysics is the best option for looking through these cover materials to permissive stratigraphy below. Recent advances in airborne electromagnetic surveys permit the accurate imaging of a conductive source in 2D and 3D space such that drilling of targets is possible without the use of follow-up ground surveys.

Large VMS deposits can respond to gravity surveys and airborne tensor gravimetry and magnetics can detect these deposits at depths of 1-2 km (Ford et al. 2007).

Rapid and cost effective age dating techniques have been developed that are very useful in delineating the chrono-stratigraphy of a mineral belt. This can outline prospective horizons for VMS accumulation as the deposits tend to form during relatively narrow time intervals.

The use of drone technology has exploded in many disciplines in recent years and the minerals industry is no exception. Magnetometer surveys using drones are now a reality such that detailed magnetic maps are a cost effective tool for exploration at the prospect scale. In addition, reasonably accurate DEM and DTM models can be constructed using drone based photogrammetry combined with commercially available photo modelling software to provide up to date base maps for prospect scale work.

Geophysical methods may often outline a large number of prospective targets in a mineral belt and surface geochemical methods can be used sort through the anomalies to select targets with the highest potential.

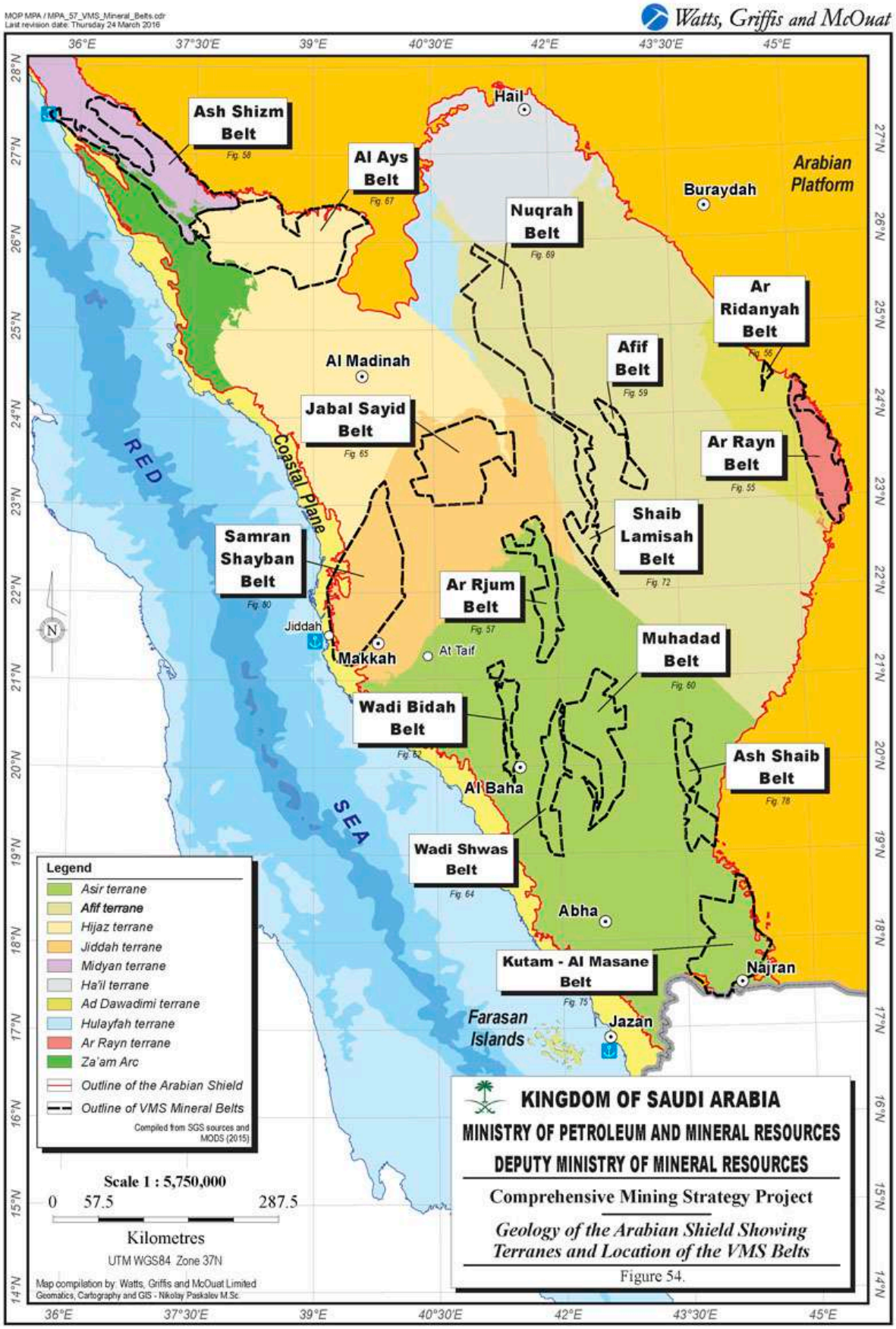
These techniques include spatiotemporal geochemical hydrocarbons (**SGH**), organo-sulphur geochemistry (**OSG**), enzyme leach extractions (**ESE**) and mobile metallic ions (**MMI**). It is very important that orientation surveys are conducted prior to using one of these methods in order to determine which are most effective.

Hand held XRF analytical units and NIR spectrometer mineralogical identification instrumentation have recently been developed that provide accurate, rapid and relatively low cost results that can be employed to good advantage in all stages in exploration from grassroots to drilling.

The geological model for a mineral belt will become more refined over time as exploration programs are undertaken and new scientific studies add valuable understanding to the data base. Ongoing compilation and assessment of the data may result in additional discoveries as exploration programs become more focussed on prospective localities. Therefore, one of the most effective techniques for successful exploration in a mineral belt is persistence over long periods of time. This trait cannot be overemphasized as the accompanying table of VMS discoveries for the prolific Noranda VMS camp (mineral belt) in Canada shows (Table 37).

Table 37
Summary of Selected VMS Deposit Discoveries

Deposit name	Discovery Date	Depth (m)	Discovery Method	Size (Mt)	Cu (%)	Zn (%)	Au (g/t)	Ag (g/t)
Horne	1923	surface	Prospecting	54.3	2.22	----	6.1	13.0
Aldermac	1925	9	Geophysics, Prospecting	2.86	1.54	4.12	0.48	31.2
Amulet A	1925	surface	Prospecting	0.19	2.37	6.12	2.0	46.0
Amulet C	1925	surface	Prospecting, Geology	0.57	2.2	8.5	0.6	86.7
Old Waite	1925	surface	Prospecting	1.12	4.7	2.98	1.1	22.0
Amulet F	1929	38	Geology	0.27	3.4	8.6	0.3	46.3
Amulet A Lower	1938	213	Geology	4.69	5.14	5.28	1.43	44.1
Gallen	1944	7	Geophysics	8.1	0.08	3.36	0.06	2.4
Quemont	1945	61	Geophysics	16.65	1.2	1.8	5.5	18.0
Bedford	1945	surface	Prospecting	0.9	0.89	----	----	----
Deldona	1947	152	Geology	0.09	0.3	5.0	4.1	26.0
Mobrun	1956	9	Geophysics	1.35	0.7	2.51	2.27	27.67
Vauze	1957	7	Geology	0.35	2.9	0.94	0.70	24.0
Norbec	1961	335	Geology	4.47	2.75	4.75	0.91	44.3
Delbridge	1965	91	Geology	0.36	0.55	8.6	2.4	68.6
Millenbach	1966	700	Geology	3.56	3.46	4.33	1.0	56.2
Magusi river	1972	15	Geophysics	3.73	1.2	3.56	1.1	31.2
New Insco	1973	15	Geophysics	0.89	2.59	----	0.9	20.57
Corbet	1974	700	Geology-Geochemistry	2.78	2.92	1.62	1.0	21.0
Ansil	1980	1280	Geology	1.58	7.22	0.94	1.6	26.5
Bouchard-Herbert	1988	??	Geology	11.5	0.77	5.42	1.48	36.9
West Ansil	2003	250	Geology-Computer Modelling	n.a.	n.a.	n.a.	n.a.	n.a.
Montbray	2004	110	Geophysics	n.a.	n.a.	n.a.	n.a.	n.a.
Pinkos 3	2007	??	Geology	n.a.	n.a.	n.a.	n.a.	n.a.
Lac Herve	2014	400	Geophysics	n.a.	n.a.	n.a.	n.a.	n.a.


MOP MPA / MPA_57_VMS_Mineral_Belts.cdr
Last revision date: Thursday 24 March 2016
Watts, Griffis and McOuat
Ash Shizm Belt
Fig. 58
Al Ays Belt
Fig. 67
Hail
Buraydah
Arabian Platform
Nuqrah Belt
Fig. 69
Ar Ridanyah Belt
Fig. 56
Afif Belt
Fig. 59
Al Madinah
Jabal Sayid Belt
Fig. 65
Ar Rayn Belt
Fig. 55
Shaib Lamisah Belt
Fig. 72
Samran Shayban Belt
Fig. 80
Ar Rjum Belt
Fig. 57
Jiddah
Makkah
At Taif
Muhadad Belt
Fig. 60
Wadi Bidah Belt
Fig. 62
Ash Shaib Belt
Fig. 78
Al Baha
Wadi Shwas Belt
Fig. 64
Abha
Kutam - Al Masane Belt
Fig. 75
Najran
Farasan Islands
Jazan
RED SEA
Coastal Plane
Legend
Asir terrane
Afif terrane
Hijaz terrane
Jiddah terrane
Midyan terrane
Ha'il terrane
Ad Dawadimi terrane
Hulayfah terrane
Ar Rayn terrane
Za'am Arc
Outline of the Arabian Shield
Outline of VMS Mineral Belts
Compiled from SGS sources and MODS (2015)
Scale 1 : 5,750,000
0 57.5 287.5
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Arabian Shield Showing Terranes and Location of the VMS Belts
Figure 54.

3.2.2 DISTRIBUTION OF DEPOSITS

As stated in the foregoing, volcanogenic massive sulphide ("**VMS**") deposits are typically found in favourable rock sequences that are commonly referred to as "belts". Mineral belts are tracts of permissive land in which the geology permits the occurrence of undiscovered deposits of the specified type Singer (2007) – in this case volcanogenic massive sulphide deposits. Mineral deposit models are used to provide the links between permissive geological settings and the deposit type.

A total of fifteen (15) VMS mineral belts have been outlined in the Arabian shield and their locations are shown on Figure 54. The outline of the various belts has been delineated on the basis of permissive lithologies and metallogenic contents using mainly the 1:250,000 compilations and supplemented by more detailed maps at various scales where available. VMS mineral belts in Canada are circular to oval in shape and average about 32 km in diameter (Sangster 1980). Most of the belts in the Arabian shield are elongate and much larger than their Canadian analogues due to the tectonostratigraphic history of the Arabian Shield and the level of detail available on the compilation maps. The size and shapes of the belts would likely change significantly as additional mapping is carried out and more detailed district compilations become available.

3.2.3 PROSPECTIVE MINERAL BELTS AND VMS OCCURRENCES

3.2.3.1 Ar Rayn VMS Belt

Location, History and Status

The Ar Rayn mineral belt is bounded on the west by the Al Amar-Idsas fault and on the east by Phanerozoic cover rocks and it lies within the Ar Rayn Terrane (Figure 55). It covers an area of about 5,379 km^2. This terrane is comprised of volcanic and sedimentary rocks of the Al Amar Group intruded by granodiorite, tonalite and trondhjemite and was accreted to the Arabian shield around 600 Ma.

The mineral belt outline encloses the Shalahib Formation which contains all the known VMS deposits/occurrences in the Ar Rayn Terrane. This formation is a bimodal mafic to felsic volcanic assemblage. The principal VMS deposits located in the Al Ar Rayn mineral belt are listed below in Table 38.

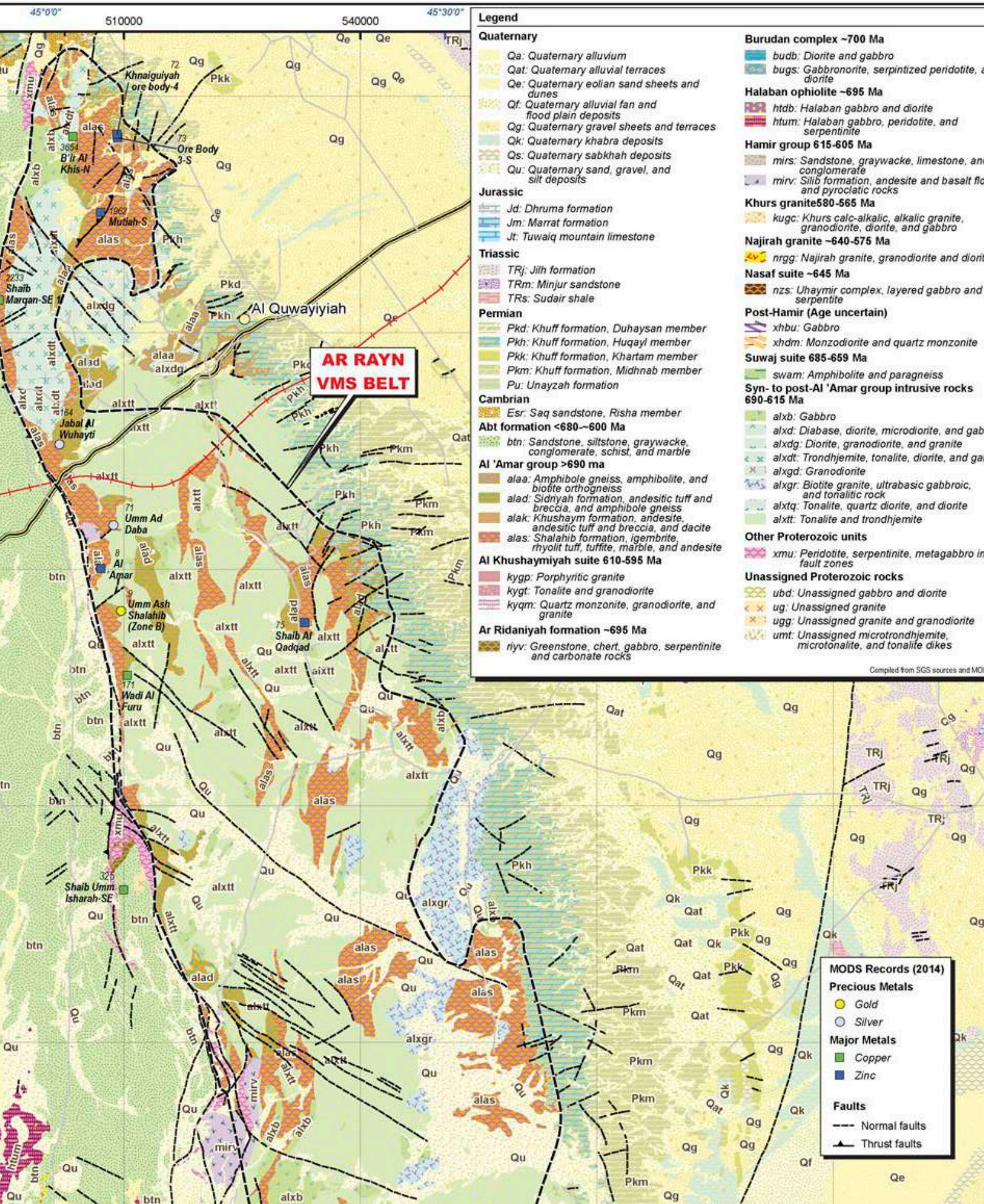
Table 38
VMS Deposits in the Ar Rayn VMS Belt

MODS	New Name	Old Name	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0072, 0073	Khnaiguiyah	Khnaiguiyah	Zn	45.0909000	24.2755560	Al Quway'iyah	High	lenses, stratiform
0008	Al Amar	Al Amar **	Zn	45.0695440	23.7816140	Al Quway'iyah	Very High	veins
0325	Wadi Khiyam N	!Jabal Bitran	Cu	45.0974170	23.4138330	Al Quway'iyah	Medium	dd, veins
0071	Umm ad Daba SE	Umm Ad Dabah	Cu	45.0914000	23.7969000	Al Quway'iyah	Low	veins
0009	Umm ash Shalib	Umm Ash Shalib	Cu	45.0889110	23.7139500	Al Quway'iyah	Medium	veins
2233	Shaib Marjan	Marjan *	Cu	44.9426920	24.0894440	Al Quway'iyah	Very low	dd, stratiform
3654	Bir Al Khis-N	Bir Al Khais *	Cu	45.0345830	24.2767780	Al Quway'iyah	Medium	lenses, stratiform
1962	Muitah-S	Muitag *	Zn	45.0694170	24.1902220	Al Quway'iyah	Medium	dd, stratiform
0164	Jabal Al Wuhayti	At Taybi *	Ag	45.0177780	23.9238330	Al Quway'iyah	Medium	undetermined
0075	Shaib al Qadqad	Qid Qad *	Zn	45.3233060	23.7195560	Al Quway'iyah	Low	stratiform
0171	Wadi Al Furu	Wadi Ar Rufia	Cu	45.1022250	23.6592250	Al Quway'iyah	Low	veins

NOTES: * No published resource estimates but considered to be VMS style based on descriptions given
** Al Amar included as VMS based on recent work
! resource estimate from Surour and Bakhsh, 2013
!! proven and probable resource estimate (Alara Resources, press release 2013)
dd = disseminated

The Al Amar deposit is an epithermal vein style deposit but recent work by Surour and Bakhsh (2014) described conformable VMS style mineralization on the 640 level of the mine suggesting that the vein type mineralization may be remobilized VMS sulphide mineralization at depth. For this reason the Al Amar deposit is included in the VMS category.

For several decades, one of the most promising prospects in the belt has been the Khnaiguiyah deposit. The area surrounding Khnaiguiyah has been the scene of many varied exploration programs by the BRGM, starting in 1966 when Eijkelboom carried out 1:100,000-scale mapping in the area. This was followed by several more detailed programs of mapping during 1972-74 as well as geophysical surveying (SP, mag, Turam, IP-resistivity). Following additional geophysical surveying in 1975, 24 drill holes were drilled and 45 additional drill holes were completed after an INPUT survey in 1976. More geophysical surveying followed each year during the period from 1978 through 1981 and in each of 1978, 1979 and 1980 additional drilling totalling 110 holes was carried out. A resource estimate and metallurgical studies were initiated in 1982. Additional mapping and wadi sediment geochemical sampling followed in an attempt to enlarge the prospect / target area when the results were found to be insufficient to support a positive outcome to a feasibility study. The BRGM's estimates of the Khnaiguiyah resources produced figures showing total geologic resources of 49.5 Mt grading 3.0% Zn and 13.3 Mt grading 0.63% Cu. Testard (1983). Although the resources were seen to be sub-economic, Prevot (1984) indicated that discrete high grade zones were present as shown by his calculation of "best Zn ore" which yielded 3.11 Mt grading 13.0% Zn. Several holes intersected very rich material further reinforcing the concept of discrete high-grade zones within the larger lower grade masses. For example, hole KNCll (Area 1 North) returned values of 30.98% Zn and 1.2% Cu (134-136 m) and 32.87% Zn and 1.03% Cu (142.5-145.5 m).


45°0'0"
510000
540000
45°30'0"
AR RAYN
VMS BELT
Al Quwayiyiah
Khnaiguiyah ore body-4
Ore Body 3-S
B'ir Al Khis-N
Mutiah-S
Shaib Marqan-SE 1
Jabal Al Wuhayti
Umm Ad Daba
Al 'Amar
Umm Ash Shalahib (Zone B)
Shaib Al Qadqad
Wadi Al Furu
Shaib Umm Isharah-SE
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Jurassic
Jd: Dhruma formation
Jm: Marrat formation
Jt: Tuwaiq mountain limestone
Triassic
TRj: Jilh formation
TRm: Minjur sandstone
TRs: Sudair shale
Permian
Pkd: Khuff formation, Duhaysan member
Pkh: Khuff formation, Huqayl member
Pkk: Khuff formation, Khartam member
Pkm: Khuff formation, Midhnab member
Pu: Unayzah formation
Cambrian
Esr: Saq sandstone, Risha member
Abt formation <680-~600 Ma
btn: Sandstone, siltstone, graywacke, conglomerate, schist, and marble
Al 'Amar group >690 ma
alaa: Amphibole gneiss, amphibolite, and biotite orthogneiss
alad: Sidriyah formation, andesitic tuff and breccia, and amphibole gneiss
alak: Khushaym formation, andesite, andesitic tuff and breccia, and dacite
alas: Shalahib formation, igembrite, rhyolit tuff, tuffite, marble, and andesite
Al Khushaymiyah suite 610-595 Ma
kygp: Porphyritic granite
kygt: Tonalite and granodiorite
kyqm: Quartz monzonite, granodiorite, and granite
Ar Ridaniyah formation ~695 Ma
riyv: Greenstone, chert, gabbro, serpentinite and carbonate rocks
Burudan complex ~700 Ma
budb: Diorite and gabbro
bugs: Gabbronorite, serpintized peridotite, a diorite
Halaban ophiolite ~695 Ma
htdb: Halaban gabbro and diorite
htum: Halaban gabbro, peridotite, and serpentinite
Hamir group 615-605 Ma
mirs: Sandstone, graywacke, limestone, an conglomerate
mirv: Silib formation, andesite and basalt flo and pyroclatic rocks
Khurs granite580-565 Ma
kugc: Khurs calc-alkalic, alkalic granite, granodiorite, diorite, and gabbro
Najirah granite ~640-575 Ma
nrgg: Najirah granite, granodiorite and diorit
Nasaf suite ~645 Ma
nzs: Uhaymir complex, layered gabbro and serpentite
Post-Hamir (Age uncertain)
xhbu: Gabbro
xhdm: Monzodiorite and quartz monzonite
Suwaj suite 685-659 Ma
swam: Amphibolite and paragneiss
Syn- to post-Al 'Amar group intrusive rocks 690-615 Ma
alxb: Gabbro
alxd: Diabase, diorite, microdiorite, and gab
alxdg: Diorite, granodiorite, and granite
alxdt: Trondhjemite, tonalite, diorite, and ga
alxgd: Granodiorite
alxgr: Biotite granite, ultrabasic gabbroic, and tonalitic rock
alxtq: Tonalite, quartz diorite, and diorite
alxtt: Tonalite and trondhjemite
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ubd: Unassigned gabbro and diorite
ug: Unassigned granite
ugg: Unassigned granite and granodiorite
umt: Unassigned microtrondhjemite, microtonalite, and tonalite dikes
Compiled from SGS sources and MOD
MODS Records (2014)
Precious Metals
Gold
Silver
Major Metals
Copper
Zinc
Faults
Normal faults
Thrust faults

Cottard and others recalculated the zinc resource at Khnaiguiyah as 4.7 Mt grading 9.84% Zn (BRGM, 1990). The authors recommended a core drilling program to define the limits of the high grade resources. Recent work by Alara Resources produced an estimate classified as Proven and Probable Reserves of 26.1 Mt grading 0.24% Cu and 3.3% Zn (Alara Resources, press release 2013).

Geology

The most promising prospect in the Ar Rayn belt (other than the operating Al Amar mine) is the Khnaiguiyah deposit. The Khnaiguiyah Zn-Cu deposits (MODS 0072, 0073) are located in the extreme north end of the Ar Rayn Terrane within a volcanosedimentary sequence of ignimbritic lavas and tuffs with intercalated carbonate and chert members. The volcanic facies of this sequence exhibits a distinctly alkaline chemical affinity. Prevot (1984) divided the stratigraphic succession at Khnaiguiyah into four volcanic cycles (V1-V4) as follows:

- Vl Intermediate volcanic rocks of volcanism 1 with banded ignimbrites of volcanism 2 form the footwall of mineralization Ml.
- V2 Fissural silicic lavas and associated carbonate lenses (“volcanogenic” carbonates) forming NE-trending ridges with lateral basins hosting Ml mineralization.
- V3 Thick flame-structured ignimbritic flows and their lateral tuffaceous equivalents forming the hanging wall of mineralization Ml, and hosting mineralization M2 towards their stratigraphic top and in the most tuffaceous areas (basins). These flows seem to originate from the north part of the Khnaiguiyah area.
- V4 After a period of tilting and erosion, ignimbrite and lahars of volcanism V4 disconformably overlie the previous sequences, usually following north and northwest-trending paleovalleys, and originating from several volcanic domes located in the south half of the Khnaiguiyah area.

Prevot also correlated the early episodes of volcanism to periods of extensional tectonics dominated by normal faulting, generally in a northeast-southwest direction. This was followed by a period of uplift, caldera development, and ignimbritic volcanism controlled to a large extent by paleotopographic features. Nine separate prospect/occurrences containing at least 20 different mineralized zones (2 main types of mineralization) have been found in the Khnaiguiyah area.

Type 1 mineralization occurs as stratiform lenses composed primarily of magnetite, hematite, pyrite, sphalerite, chalcopyrite, and galena. The lenses are often zoned both vertically and laterally. A carbonate assemblage generally overlies the sulfide mineralization. The carbonates thin laterally and exhibit a lateral metal zonation. Stringer and stockwork zones sometimes cut the footwall rock underlying the mineralized lenses.

Type 2 mineralization is composed mainly of pyrite, chalcopyrite, hematite, and sphalerite ± Pb and Bi tellurides, enargite and aikinite. This type of mineralization is not widespread and is associated with felsic volcanic domes. Zoned variations are somewhat similar to those shown by Type 1 mineralization. Hydrothermal alteration commonly accompanies both types of mineralization. Alteration associated with

type 1 mineralization consists of epidote, garnet, amphibole, pyroxene, and chlorite. The main alteration facies associated with Type 2 mineralization consists of quartz, sericite, and pyrite.

Recommendations

WGM is not aware of the details of the work carried out by Alara, but with a proven reserve for the project should advance it to the mid-level feasibility stage. We believe that the resource estimate complies with international standards however WGM has not seen an details concerning its method of estimation. All of the mineralized bodies comprising Khnaiguiyah require systematic drilling to confirm and expand the known resource.

The exploration recommendations outlined in CR-11-12 (1992) both at the prospect scale and at the regional scale are still current unless superseded by recent work of which WGM is not aware. The airborne survey recommended by WGM should be expanded to extend over the Phanerozoic cover rocks to the east as modern technologies can be expected to see through these rocks to the permissive lithologies below.

3.2.3.2 Ar Ridanyah VMS Belt

Location, History and Status

The Ar Ridanyah VMS Belt is very small comprising an area of only 208 sq. km. (Figure 56). It is made up of a series of volcanic rocks that have been identified as the Ar Ridanyah Formation belonging to the Abt Group and dated at about 695 Ma. This mineral Belt is located in the Ad Dawadimi Terrane and it is bounded on the west by a thrust fault and on the north and northeast it disappears under Phanerozoic cover rocks and unconsolidated Quaternary cover and is therefore likely much larger than the current exposure limits. The most significant VMS deposit is the Ar Ridanyah deposit (MODS 2070). This deposit is hosted by a marble unit in biotite schist and is composed of stratiform pyrrhotite and sphalerite. (Elsass 1981).

A listing of the VMS type deposits and occurrences in this mineral Belt is presented in Table 39, and their locations are shown in Figure 56.

Table 39
VMS Occurrences in the Ar Ridanyah Mineral Belt

MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
2072	Ar Ridanyah	Ar Ridanyah	Pb	44.6655000	24.3865000	Ad Duwadimi	Medium	dd, stratiform
3205	Jibal Rik al Hamar	*Jabal Rik Al Hamar	pyrite	41.4071110	25.3687220	Al Hinakiyah	Low	dd
0806	Ar Ridanyah NE1	*Ar Ridanyah NE1	Cu	44.6958330	24.3922220	Ad Duwadimi	Medium	dd, stratiform
3649	Ar Ridanyah S2	*Ar Ridanyah S2	Cu	44.6611110	24.3438890	Ad Duwadimi	Low	undetermined
2070	Ar Ridanyah N1	*Ar Ridanyah N1	Zn	44.6543610	24.3813060	Ad Duwadimi	Medium	lenses, stratabound
2071	Shaib As Safani	*Anomaly B	pyrite	44.7294440	24.4022220	Ad Duwadimi	Medium	dd, lenses, stratiform

* NOTE: No resource calculation available but believed to be of VMS origin based on available descriptions

The Ar Ridanyah prospect is located about 30 km east-southeast of the town of Ad Dawadimi. The Main (MODS 2070) and related prospects (2071, 2072 and 3205) are the most thoroughly explored Pb-Zn-Ag prospects within the belt.

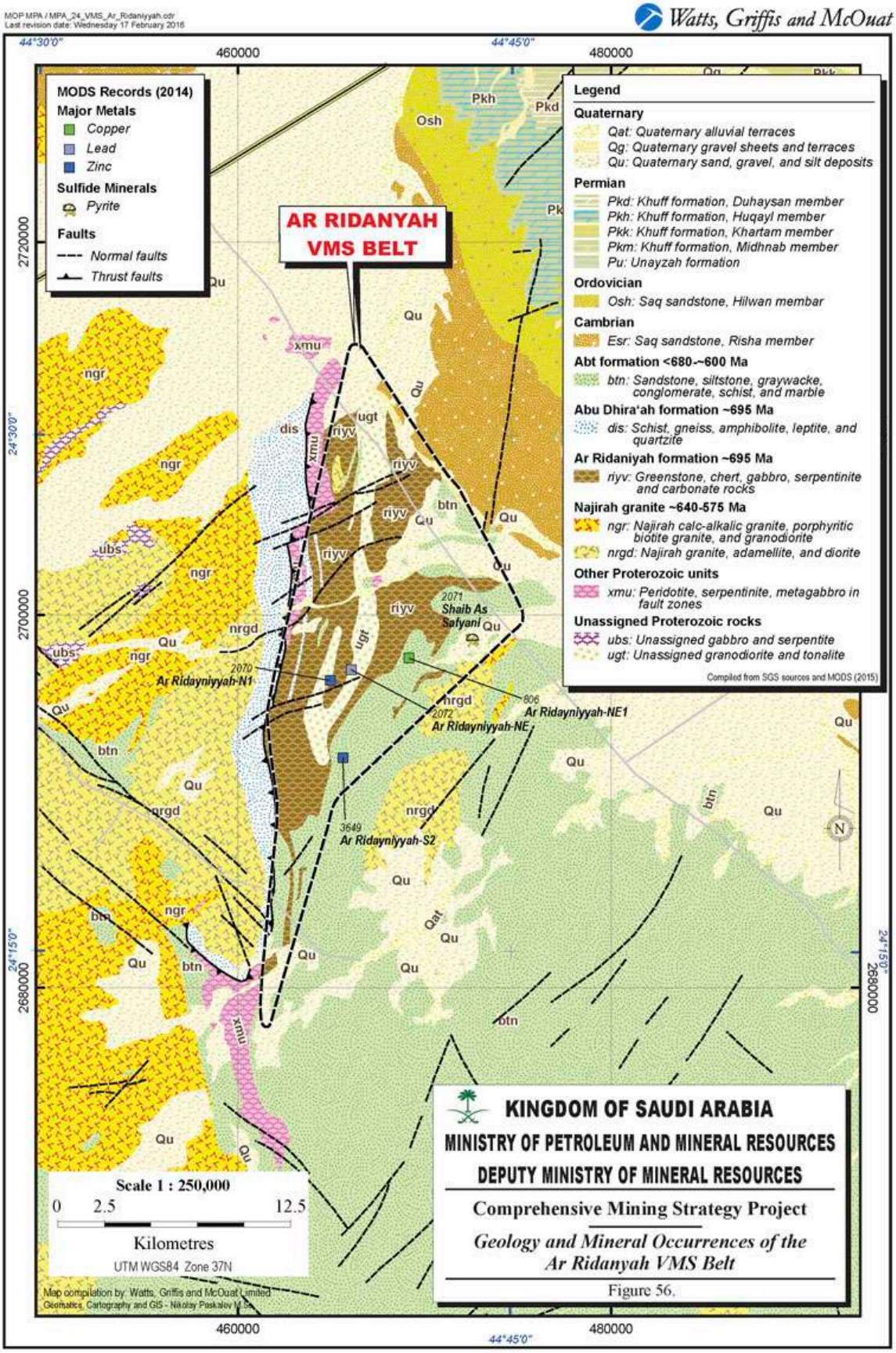
Previous Work

Ar Ridanyah Southwest (0146), prospect GV-22 (0783) and prospect GV-23 (0784) are the sites of ancient workings where quartz-carbonate and sphalerite-galena-pyrite-pyrrhotite veins cut the Abt schist and lower amphibolite units. The Ar Ridanyah area was mapped by BRGM during 1967-68 at 1:20,000 scale and selected areas were mapped at 1:2,000 scale and investigated by ground geophysics and diamond drilling. Two holes were drilled at INPUT Anomaly A (the main gossan) and Anomaly G. Holes AR1 and AR2 were drilled to explore down dip from the gossan and intersected several calcareous layers rich in pyrite, pyrrhotite, and sphalerite. The mineralized intervals totalled 15.5 m at 6.1% Zn in drill hole AR1 and 16 m at 4.5% Zn in AR2. Lead, copper and silver values were very low and no gold was reported. The AR3 and AR4 drill holes at Anomaly G intersected no interesting gold values. The site was abandoned for about 10 years after which the BRGM undertook intensive exploration during the late 1970s at the main gossan, the PL4 (Ar Ridanyah Southwest area) and Ar Ridanyah East (North Area) as well as the GV-22 and GV-23 occurrences. Also tested were the INPUT anomalies G and B located nearby. Based on the results from 2 diamond drill (cored) holes and 8 percussion holes (1,757 m), the BRGM estimated that the main gossan zone contained 1.5 Mt of mineralization averaging 4.65% Zn and 20.0 g Ag/t to a depth of 130 m (Elsass (1981). The best drill intersection at Ar Ridanyah East gave values of 1.32% Pb and 2.46% Zn over 3 m. A cored hole at GV-22 intersected a chloritized and silicified zone with veinlets of sphalerite, galena, magnetite, and pyrite, and a 1.10 m section within this zone assayed 4.27% Pb, 1.67% Zn and 20.0 g Ag/t. A percussion hole at GV-23 intersected disseminated pyrite, sphalerite, and galena but assay results were low at 0.85% Pb and 0.70% Zn over a length of 3 m. Anomaly G and B were explored by ground geophysics, soil geochemistry and trenching. At the latter site, 14 percussion holes (2,022 m) were completed which showed the anomaly to be the result of pyrrhotite and graphite within a black shale unit;

the best drill intersection was 15 m grading 14.0 g Ag/t. Anomaly C was located by follow-up ground geophysical surveys but soil geochemistry detected no significant base-metal values.

Geology

At the main Ar Ridanyah prospect, stratiform and stratabound lenses of pyrrhotite-sphalerite and pyrrhotite-sphalerite-galena occur in a basal member of the Abt schist that was mapped as the Ar Ridanyah Formation (Eijkelboom, 1966b). The units strike north, dip 35-50°E., and probably face east. The sulfide lenses are associated with marble at a mica schist-amphibolite contact and overlie disseminated sulfides with attendant biotite-chlorite alteration. Al Shanti (1976b), in a study of the main gossan, identified post-metamorphic pyrrhotite-sphalerite and minor cassiterite-stannite mineralization in discordant veinlets, and Riofinex (Lofts, 1984a) confirmed the presence of tin in prospects adjacent to the main gossan zone. The Ar Ridanyah East prospect (MODS 2072) comprises a gossanous calcareous tuff (tactile) unit which outcrops about 1 km northeast of the main prospect. This unit is characterized by amphibole-epidote-calcite-garnet assemblages containing disseminated pyrite, sphalerite. Ar Ridanyah anomaly B (MODS 2071) is situated within the Abt schist about 9 km east-northeast of the main prospect. Anomaly C (MODS 3206) is situated within the Ar Ridanyah Formation about 9 km northeast of the main prospect.


MOP MPA / MPA_24_VMS_Ar_Ridaniyyah.cdr
Last revision date: Wednesday 17 February 2016
Watts, Griffis and McOuat
44°30'0"
460000
44°45'0"
480000
2720000
24°30'0"
2700000
24°15'0"
2680000
MODS Records (2014)
Major Metals
Copper
Lead
Zinc
Sulfide Minerals
Pyrite
Faults
Normal faults
Thrust faults
AR RIDANYAH
VMS BELT
Legend
Quaternary
Qat: Quaternary alluvial terraces
Qg: Quaternary gravel sheets and terraces
Qu: Quaternary sand, gravel, and silt deposits
Permian
Pkd: Khuff formation, Duhaysan member
Pkh: Khuff formation, Huqayl member
Pkk: Khuff formation, Khartam member
Pkm: Khuff formation, Midhnab member
Pu: Unayzah formation
Ordovician
Osh: Saq sandstone, Hilwan membar
Cambrian
Esr: Saq sandstone, Risha member
Abt formation <680-~600 Ma
btn: Sandstone, siltstone, graywacke, conglomerate, schist, and marble
Abu Dhira'ah formation ~695 Ma
dis: Schist, gneiss, amphibolite, leptite, and quartzite
Ar Ridaniyah formation ~695 Ma
riyv: Greenstone, chert, gabbro, serpentinite and carbonate rocks
Najirah granite ~640-575 Ma
ngr: Najirah calc-alkalic granite, porphyritic biotite granite, and granodiorite
nrgd: Najirah granite, adamellite, and diorite
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ubs: Unassigned gabbro and serpentite
ugt: Unassigned granodiorite and tonalite
Compiled from SGS sources and MODS (2015)
2071
Shaib As Safyani
2070
Ar Ridayniyyah-N1
2072
Ar Ridayniyyah-NE
806
Ar Ridayniyyah-NE1
3649
Ar Ridayniyyah-S2
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Poskalev M.Sc.
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology and Mineral Occurrences of the Ar Ridanyah VMS Belt
Figure 56.

Recommendations

In its previous study carried out during 1989-1992, WGM proposed the following work program for the area and these recommendations are still considered valid:

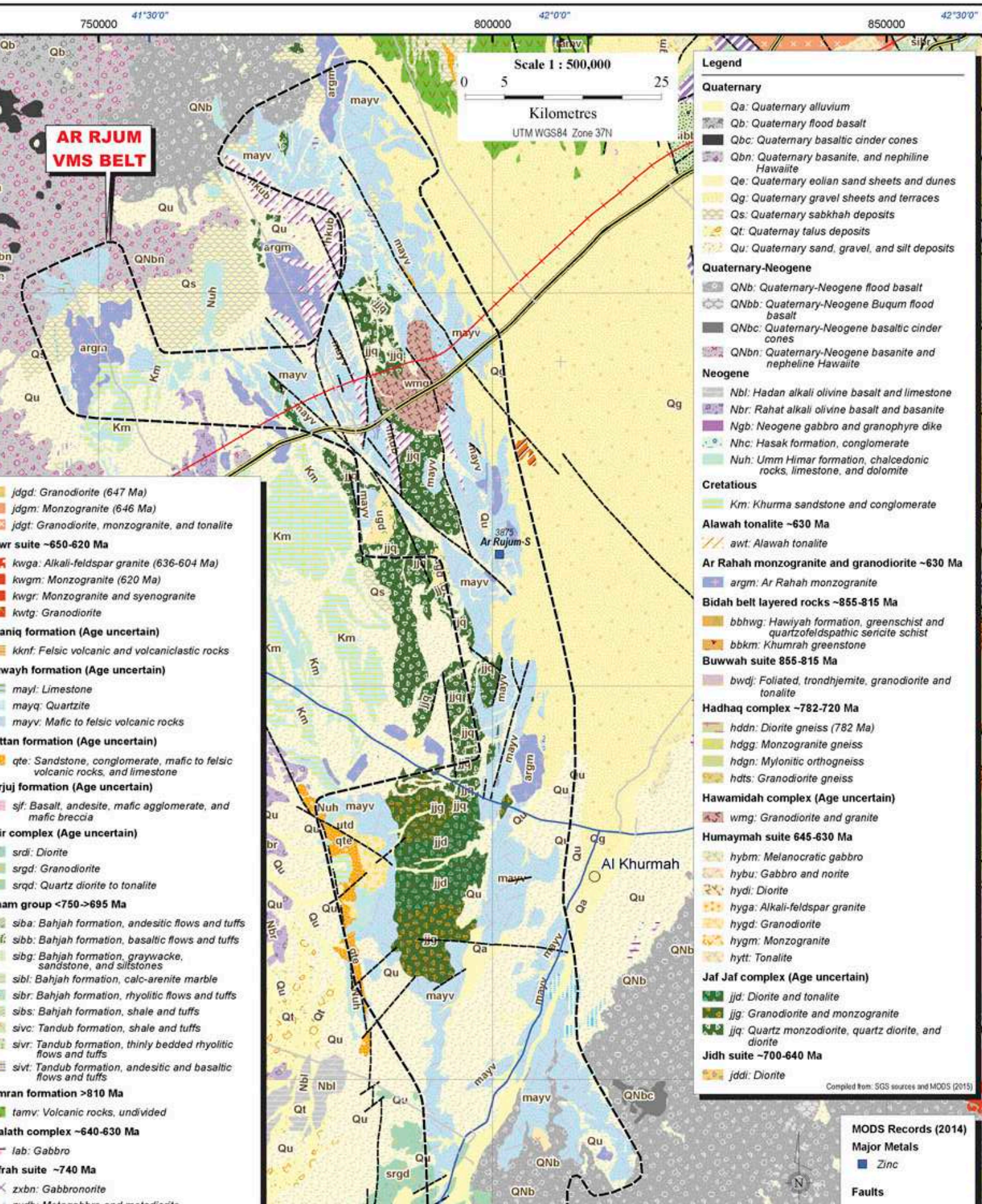
- compilation of all previous field work on the BRGM 1:20,000-scale geological map incorporating the 1:2,000 and 1:5,000-scale geology maps;
- a ground magnetic survey to cover the strike extensions of the limestone units in the Northern prospective area to aid in the interpretation of geology beneath alluvial cover;
- a HLEM survey (or similar) on a 50 x 50 m grid over the Main prospect area and on a 100 x 50 m grid on extensions of the zone to outline sulfide zones at the limestone-amphibolite contacts;
- detailed mapping (1:2,000-scale) of the geology of any anomalous zones in the Northern prospective area focusing on anomalous areas identified by the HLEM surveying;
- initial diamond drilling (phase 1) starting at the Main and East prospects with a budget for at least 35 diamond drill holes on 80 m centers to determine the limits of the currently known sulfide lenses at the Main prospect in order to accurately estimate the Pb-Zn-Ag-Sn resource. The program would entail 4, 700 m of core drilling to test the zone to a depth of 300 m. All sulfide sections should be assayed for Pb-Zn-Ag, Au (by fire assay) and Sn; and,
- 20 additional drill holes of 200 m each to test new conductive zones outlined by the extended ground geophysical surveys over the favorable strata in the Main prospect area and the Northern Prospective area and to test the East prospect at 80 m intervals.

After all diamond drill and assay information has been compiled and assessed for the initial program, then phase 2, a more detailed diamond drilling program may be warranted. WGM considered that assays of Pb+ Zn should be at least 10% across mining widths, but that precious metal values should be considered in the evaluation of such data. Should significant lenses of Pb-Zn sulfide be outlined at the Main prospect, an estimated 12,000 m of detailed diamond drilling would be required to close the grid to 40 m and drill to 300 m depths to generate the necessary data for mineral resource estimates. Lastly, although the area has been flown previously (EM and Mag), it would benefit from a new survey that would not only cover the exposed portions of the belt but also the possible extensions under cover to the north and northeast which is now possible because of improvement in EM survey technology.

3.2.3.3 Ar Rjum VMS Belt

Location, Previous Work and Status

The Ar Rjum belt is located in the Asir Terrane and covers an area of approximately 4,230 sq. km. (Figure 57). It encompasses the Muwayh Formation comprised mafic to felsic volcanic rocks with subordinate limestone and quartzite all of uncertain age. This mineral belt is surrounded on all sides by unconsolidated Quaternary cover and Harrats (Hadn, An Nawasif, Kishib, and Al Buqum). Thus the limits of this permissive mineral belt are uncertain.


750000
41°30'0"
800000
42°0'0"
850000
42°30'0"
Scale 1 : 500,000
0 5 25
Kilometres
UTM WGS84 Zone 37N
AR RJUM
VMS BELT
Ar Rujum-S
3875
Al Khurmah
Legend
Quaternary
Qa: Quaternary alluvium
Qb: Quaternary flood basalt
Qbc: Quaternary basaltic cinder cones
Qbn: Quaternary basanite, and nephiline Hawaiite
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qt: Quaternay talus deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
QNbb: Quaternary-Neogene Buqum flood basalt
QNbc: Quaternary-Neogene basaltic cinder cones
QNbn: Quaternary-Neogene basanite and nepheline Hawaiite
Neogene
Nbl: Hadan alkali olivine basalt and limestone
Nbr: Rahat alkali olivine basalt and basanite
Ngb: Neogene gabbro and granophyre dike
Nhc: Hasak formation, conglomerate
Nuh: Umm Himar formation, chalcedonic rocks, limestone, and dolomite
Cretatious
Km: Khurma sandstone and conglomerate
Alawah tonalite ~630 Ma
awt: Alawah tonalite
Ar Rahah monzogranite and granodiorite ~630 Ma
argm: Ar Rahah monzogranite
Bidah belt layered rocks ~855-815 Ma
bbhwg: Hawiyah formation, greenschist and quartzofeldspathic sericite schist
bbkm: Khumrah greenstone
Buwwah suite 855-815 Ma
bwdj: Foliated, trondhjemite, granodiorite and tonalite
Hadhaq complex ~782-720 Ma
hddn: Diorite gneiss (782 Ma)
hdgg: Monzogranite gneiss
hdgn: Mylonitic orthogneiss
hdts: Granodiorite gneiss
Hawamidah complex (Age uncertain)
wmg: Granodiorite and granite
Humaymah suite 645-630 Ma
hybm: Melanocratic gabbro
hybu: Gabbro and norite
hydi: Diorite
hyga: Alkali-feldspar granite
hygd: Granodiorite
hygm: Monzogranite
hytt: Tonalite
Jaf Jaf complex (Age uncertain)
jjd: Diorite and tonalite
jjg: Granodiorite and monzogranite
jjq: Quartz monzodiorite, quartz diorite, and diorite
Jidh suite ~700-640 Ma
jddi: Diorite
Compiled from: SGS sources and MODS (2015)
jdgd: Granodiorite (647 Ma)
jdgm: Monzogranite (646 Ma)
jdgt: Granodiorite, monzogranite, and tonalite
wr suite ~650-620 Ma
kwga: Alkali-feldspar granite (636-604 Ma)
kwgm: Monzogranite (620 Ma)
kwgr: Monzogranite and syenogranite
kwtg: Granodiorite
aniq formation (Age uncertain)
kknf: Felsic volcanic and volcaniclastic rocks
wayh formation (Age uncertain)
mayl: Limestone
mayq: Quartzite
mayv: Mafic to felsic volcanic rocks
ttan formation (Age uncertain)
qte: Sandstone, conglomerate, mafic to felsic volcanic rocks, and limestone
rjuj formation (Age uncertain)
sjf: Basalt, andesite, mafic agglomerate, and mafic breccia
ir complex (Age uncertain)
srdi: Diorite
srgd: Granodiorite
srqd: Quartz diorite to tonalite
am group <750->695 Ma
siba: Bahjah formation, andesitic flows and tuffs
sibb: Bahjah formation, basaltic flows and tuffs
sibg: Bahjah formation, graywacke, sandstone, and siltstones
sibl: Bahjah formation, calc-arenite marble
sibr: Bahjah formation, rhyolitic flows and tuffs
sibs: Bahjah formation, shale and tuffs
sivc: Tandub formation, shale and tuffs
sivr: Tandub formation, thinly bedded rhyolitic flows and tuffs
sivt: Tandub formation, andesitic and basaltic flows and tuffs
mran formation >810 Ma
tamv: Volcanic rocks, undivided
alath complex ~640-630 Ma
lab: Gabbro
frah suite ~740 Ma
zxbn: Gabbronorite
MODS Records (2014)
Major Metals
Zinc
Faults
N

There are no known VMS occurrences with any published reserves/resources in the belt, and the only known occurrence with a VMS affinity is the Ar Rjum zinc prospect (MODS 3875). One drill hole intersecting this prospect returned an economically significant intercept of 6.15 m grading 5.19% Zn, 0.79% Cu, 79.4 g/t Ag and 1.71 g/t Au (BRGM 1985b). During 1984-85, the prospect was mapped by BRGM at a scale of 1:5,000 and a soil geochemical survey was carried out on a 50 x 25 m grid. Anomalies were defined coincident with mineralized carbonate units in the northwest and southeast portion of the survey area. Three trenches totalling 300 m were cut across gossans and one gave significant Cu-Zn Ag-Au values. Three very shallow percussion drill holes totalling 165 m were drilled to test the down dip extension of the mineralization, and hole P23 encountered significant Cu-Zn-Ag-Au values. A short cored hole, 63 m in length, was drilled to follow up this mineralization and a 2.95 m intersection assayed 8.04% Zn, 1.23% Cu, 0.71% Pb, 130 g Ag/t and 2.77 g Au/t.

Geology

The prospect Ar Rjum prospect consists of disseminated and massive Zn-Pb-Cu sulfides with pyrite at a felsic-mafic volcanic contact within the Hulayfah Group. A diorite pluton intrudes the volcanic pile within 1 km of the zinc prospect.

Recommendations

The recommendations previous made by WGM in its report (WGM-CR-11-12) remain valid for the AR Rjum occurrence, and this area requires additional exploration by geophysical surveying, geochemical sampling and diamond drilling. WGM recommended a horizontal loop electromagnetic (HLEM)-magnetic survey on a 100 x 25 m grid covering the grid area at BMJ 07 and extending 3 km to the northwest along strike to the newly discovered occurrence. This survey would help to map (or trace) the stratigraphy by detecting graphitic beds and the survey would also detect massive sulfide accumulations. A soil geochemical survey covering the unsampled portions of the area was proposed to seek base-metal anomalies, to discriminate between graphitic and sulfide conductors, and to identify drill targets. Although the original survey envisioned conventional sampling and analytical methods the development of partial or selective leach technologies now allows explorationists to detect subtle anomalies generated from sulphide deposits buried well below the surface. These techniques would be favoured over conventional sampling and analysis. The extent of mineralization intersected in holes C1 and P23 should be investigated further by core drilling along drill sections spaced about 50 m apart. A drilling program designed to trace the extent of the known mineralization and to probe additional drill targets outlined by other surveys would require an estimated 1,500 m of core drilling. Lithogeochemical sampling of the core to detect and define alteration facies associated with the mineralization is also recommended.

3.2.3.4 Ash Shizm VMS Belt

Location, History and Status

This belt lies within the Midyan Terrane and it covers an area of 10,272 sq. km. The principal lithologies comprising this belt are mafic to felsic volcanic rocks along with a minor sedimentary component all belonging to the Bayda Group which is of uncertain age. The distribution of prospects is shown on the geological map that follows (Figure 58).

The Ash Shizm deposit is the only one with a resource estimate attached in this mineral belt. A listing of the possible VMS occurrences in the Ash Shizm VMS mineral belt is presented in Table 40.

Detailed 1:1,000 scale mapping and geophysical surveys at Jabal ash Shizm were carried out over an area limited essentially to outcroppings of the favorable stratigraphy. Subsequent regional mapping was done at scales of 1:20,000 to 1:60,000 and published at a scale of 1:50,000. A drilling program comprising 16 diamond drill holes was carried out in the central prospect area (Area 1) with individual holes ranging in length from 109 to 400 m. The holes were generally steeply inclined (-67° to -85°) to vertical, and oriented in a westerly direction with the objective of intersecting gently to moderately dipping, conformable massive sulphide horizons. Seven of the holes cut significant stockwork mineralization. The remaining holes were evidently beyond the limits of the alteration zone and intersected very little mineralization. Consequently, the results varied widely from a long, low-grade interval in drill hole SZ-2 (0.4% Cu + Zn + Pb across 80 m), to a long interval of copper enrichment in drill hole SZ-3 (3.35% Cu + Pb + Zn across 56 m) to relatively shorter intersections in other holes. These results are the unavoidable result of steeply dipping drill holes intersecting a steeply dipping geological body with finite vertical dimensions and an irregular outline. Drill hole SZ-3 may have passed through part of the core of the stockwork zone, whereas drill hole SZ-2 may have cut the edge of it. From the drill hole intersections, the BRGM calculated resources using three different concepts (models) of the deposit. The estimates vary from 550,000 tonnes to 1.6 Mt grading from 2.85% to 2.92% Cu, 0.75% to 1.02% Zn, 0.14% Pb and 18 to 25 ppm Ag (Donzeau, 1980b). Fifteen 100 m long percussion holes were put down around Area VIII where alteration (chloritization) is widespread, but sulfides are uncommon. Only one hole (SZP5) intersected significant base metals (1,441 ppm Cu, 1,124 ppm Pb and 1,365 ppm Zn over 36 m) in a chloritized rhyodacite zone without sulphides. All other holes intersected maximum values of approximately 0.22% Cu, 0.26% Zn, and 0.06% Pb.

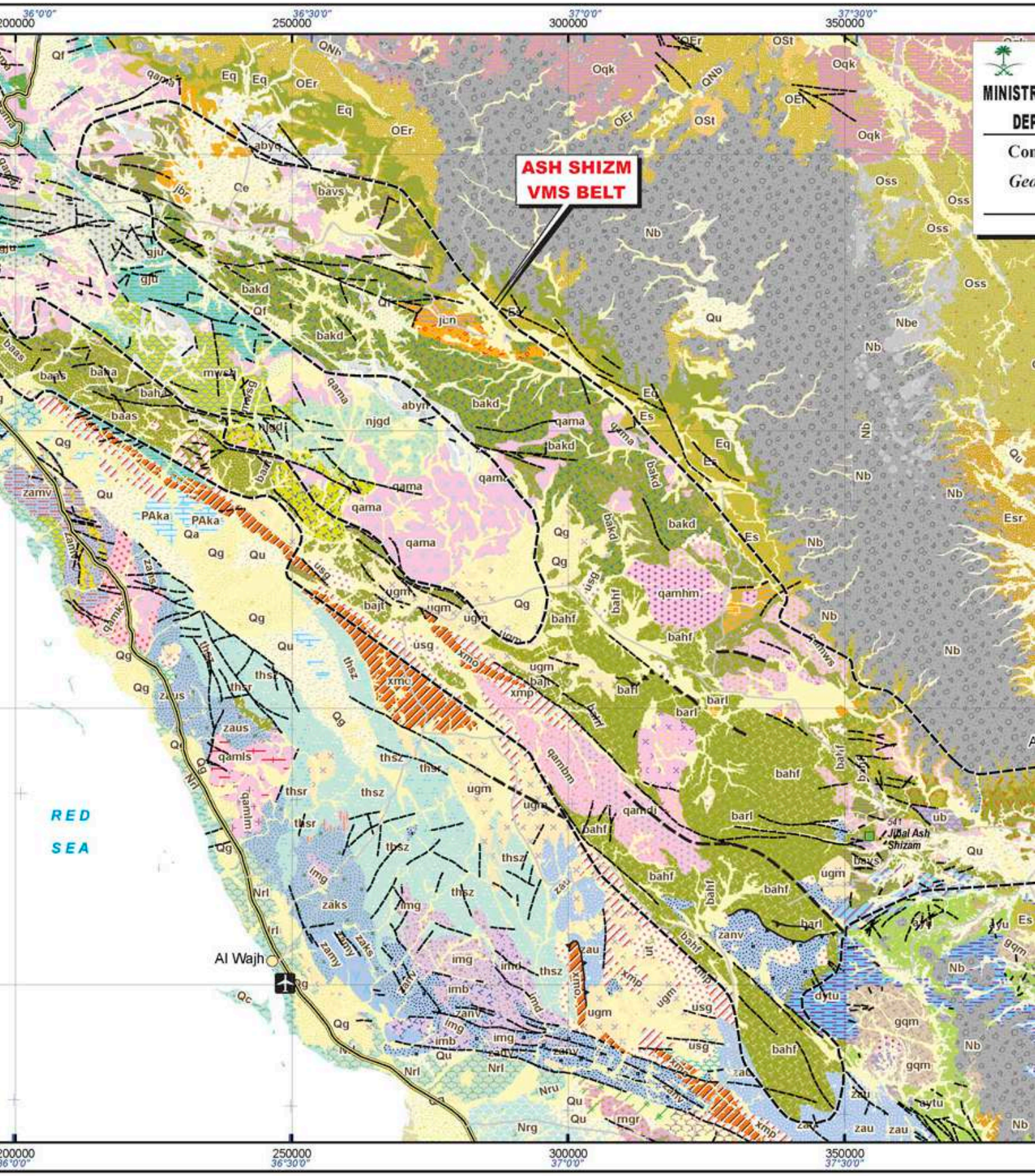

ASH SHIZM
VMS BELT
RED
SEA
Al Wajh
Jabal Ash Shizam
MINISTR
DEP

Table 40
Listing of VMS occurrences in the Ash Shizm mineral belt

MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0541	Jabal Ash Shizam	Ash Shizm	Cu	37.5404170	26.4545830	Al 'Ula	Medium	dd, lenses, stwk v
2010	Jibal Ijal	*Wadi Ajal	Cu	38.2575000	26.1774170	Al 'Ula	Medium	lense
2223	Shaib Unaym	*Wadi Ajal S	Cu	38.3576390	26.0443060	Al 'Ula	Medium	lenses
2224	Jibal Nahar	*Jabal Nahr	Fe	38.3275560	26.0303890	Al 'Ula	Low	lenses
2225	Sahl Mutran	*Sahl al Matran	Fe	38.2877220	26.2611110	Al 'Ula	Medium	stratiform
none	**Wadi Jadh E	**Wadi Jadh E	Cu ?	uncertain		unknown	Low ??	uncertain
none	**Al Quayrah E	**Al Quayrah E	Cu ?	uncertain		unknown	Low ??	uncertain
none	**Wadi Thulul	**Wadi Thulul	Cu ?	uncertain		unknown	Low ??	uncertain
none	**Wadi abu Tarrah	**Wadi abu Tarrah	Cu ?	uncertain		unknown	Low ??	uncertain
none	**Wadi Ashiran	**Wadi Ashiran	Cu ?	uncertain		unknown	Low ??	uncertain
none	**Wadi Zubayidah	**Wadi Zubayidah	Cu ?	uncertain		unknown	Low ??	uncertain

NOTES: * ascribed to VMS origin based on limited description

** no MODS, all in Ash Shizm area but classified as VMS based on limited description (Donzeau, 1981)

V=veins, dd = disseminated; stwk = stockwork

Geology

The Jabal ash Shizm prospect lies at the southern end of a 2.6 km^2 area of interpreted Farri Group volcanic strata which generally dips moderately north to north-westerly. To the west and northwest, the sequence is unconformably overlain by interpreted Al Ays Group sedimentary rocks including a thick basal conglomerate (Donzeau, 1980b). The Farri rocks are further truncated by granodiorite and gabbro batholiths to the north, east and south as well as by the Wadi ash Shizm Fault to the south, but their regional distribution may be more widespread than presently known. Mineralization consists of copper and zinc-bearing sulphide stockworks mainly carrying chalcopyrite, malachite and sphalerite. The exploration to date was focused on the discovery of stratiform massive sulphides in the Farri Group. Although no evidence of VMS mineralization has yet been found, the exploration model remains valid.

Recommendations

The recommendations put forth in WGM CR-11-10 are still valid for Ash Shizm VMS mineral belt. The occurrences listed in Table 40 which do not have a MODS index should be further investigated by mapping at scales of 1:2,000 to 1:5,000 as appropriate and any mineralization areas should be thoroughly sampled to evaluate their origin and significance in terms of the VMS deposit model.

Although the geological mapping in the vicinity of the Jabal ash Shizm prospect is of sufficient quality, the BRGM grid area only covers the southern half of the volcanic and sedimentary formations, and detailed

mapping should be extended to cover the entire northern area. In order to facilitate geochemical and subsequent work programs, and to relate results directly to previous BRGM surveys, the grid used by BRGM should be re-established as close to the original as possible, and extended to cover the entire volcanic and sedimentary sequences. The new grid area should be geologically mapped in detail. Although the BRGM completed petrographic/mineralogical studies of the Farri Group volcanic rocks, no bedrock lithogeochemistry was done. Therefore, in conjunction with the mapping, whole-rock and trace element (including REE) analyses of samples of the Farri Group volcanic assemblages should be carried out on both drill core and unweathered surface exposures. The drill core should also be relogged. The principal target of the BRGM was massive sulfide mineralization. It is apparent from some of the drill hole intersections that the potential of the stockwork zone may have been underestimated. The geometry of the alteration pipe and the enclosed stockwork zone should be resolved: the construction of a 3D model would be of great use in orienting future drill holes into the zone. Before additional drilling is done, WGM recommends that the prospect be thoroughly surveyed with time-domain EM on an 80 x 40 m grid pattern. Available drill holes should also be tested using time-domain EM to extend the depth of exploration. Further diamond drill testing of the main prospect area (the stockwork deposit) is recommended since only six (6) drill holes have actually intersected the zone at varying levels. Deep diamond drilling on the broad pyritic alteration zone of the BRGM's Area VIII is also recommended.

3.2.3.5 Afif VMS Belt

Location, History and Status

This mineral belt lies within the Afif Terrane and it covers an area of approximately 1554 sq. km. It overlies an assemblage of greenschist facies intermediate to felsic volcanic rocks and sediments all belonging to the Siham Group dated at 750-685 Ma (Figure 59).

There are no VMS deposits with a reserve/resource in the belt. The most explored VMS type occurrence is the Afif Main prospect where the best intercept from past drilling was 9.0 m grading 2.4% Pb, 2.3% Zn and 11 g Ag/t. The only other VMS type occurrence in this belt is Afif SE (MODS 3462). The known VMS type prospects in the Afif Mineral Belt are listed in Table 41.

Table 41
Listing of VMS occurrences in the Afif VMS belt

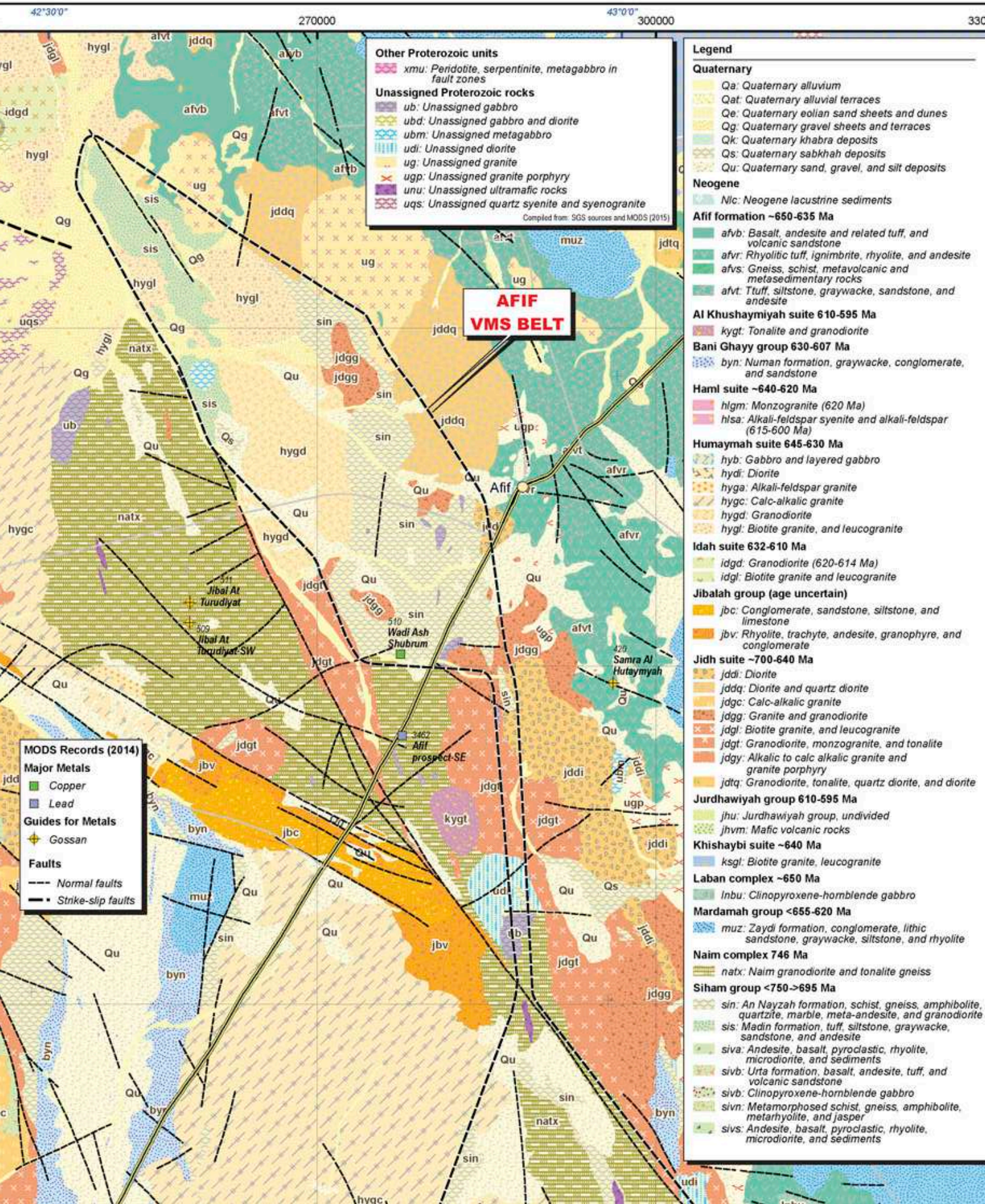
MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0510	Wadi Ash Shubrum	Afif Main	Cu	42.8152500	23.7753060	'Afif	Medium	Lenses
3462	Afif SE	Afif SE	Pb	42.8177780	23.7098330	'Afif	Very low	Lenses

NOTES: * ascribed to VMS origin based on limited description

** no MODS, all in Ash Shizm area but classified as VMS based on limited description (Donzeau, 1981)
V=veins, dd = disseminated

Geology

The Afif area is underlain by metavolcanic and metasedimentary rocks of the An Nayzah Formation which are exposed along a NNW-trending belt approximately 70 km in length and up to 35 km in width. From west to east, these rocks comprise Unit A (amphibolite gneiss, quartzite, amphibole-epidote gneiss, mica schist and carbonate), Unit B (sericitic quartzite, schist, rhyolitic porphyry and minor silicic tuft) and Unit C (sericitic tuff, rhyolite porphyry, phyllitic gneiss, mica schist, amphibole lava, banded impure quartzite, graywacke, polymictic conglomerate, sandstone, siltstone and silicic pyroclastics). Quartzite in Unit B is the main host to base metals mineralization localized at or near the contact with rhyolitic porphyry, however, some of the best assays have been obtained from a marble unit within the metamorphic assemblage. A SE-striking altered zone is present which is rich in ankerite, hematite and manganese, approximately 2,720 m long and 75 to 500 m wide, and in which mineralized veins occur at the Afif Main prospect (Chaumont, 1976a). Sampling has produced composite assays of up to 3.4% Pb, 1.6% Zn, and 0.7% Cu.


42°30'0"
270000
43°0'0"
300000
330
AFIF
VMS BELT
Afif
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubd: Unassigned gabbro and diorite
ubm: Unassigned metagabbro
udi: Unassigned diorite
ug: Unassigned granite
ugp: Unassigned granite porphyry
unu: Unassigned ultramafic rocks
uqs: Unassigned quartz syenite and syenogranite
Compiled from: SGS sources and MODS (2015)
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Neogene
Nlc: Neogene lacustrine sediments
Afif formation ~650-635 Ma
afvb: Basalt, andesite and related tuff, and volcanic sandstone
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
afvs: Gneiss, schist, metavolcanic and metasedimentary rocks
afvt: Ttuff, siltstone, graywacke, sandstone, and andesite
Al Khushaymiyah suite 610-595 Ma
kygt: Tonalite and granodiorite
Bani Ghayy group 630-607 Ma
byn: Numan formation, graywacke, conglomerate, and sandstone
Haml suite ~640-620 Ma
hlgm: Monzogranite (620 Ma)
hlsa: Alkali-feldspar syenite and alkali-feldspar (615-600 Ma)
Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hydi: Diorite
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygl: Biotite granite, and leucogranite
Idah suite 632-610 Ma
idgd: Granodiorite (620-614 Ma)
idgl: Biotite granite and leucogranite
Jibalah group (age uncertain)
jbc: Conglomerate, sandstone, siltstone, and limestone
jbv: Rhyolite, trachyte, andesite, granophyre, and conglomerate
Jidh suite ~700-640 Ma
jddi: Diorite
jddq: Diorite and quartz diorite
jdgc: Calc-alkalic granite
jdgg: Granite and granodiorite
jdgl: Biotite granite, and leucogranite
jdgt: Granodiorite, monzogranite, and tonalite
jdgy: Alkalic to calc alkalic granite and granite porphyry
jdtq: Granodiorite, tonalite, quartz diorite, and diorite
Jurdhawiyah group 610-595 Ma
jhu: Jurdhawiyah group, undivided
jhvm: Mafic volcanic rocks
Khishaybi suite ~640 Ma
ksgl: Biotite granite, leucogranite
Laban complex ~650 Ma
lnbu: Clinopyroxene-hornblende gabbro
Mardamah group <655-620 Ma
muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
Naim complex 746 Ma
natx: Naim granodiorite and tonalite gneiss
Siham group <750->695 Ma
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, meta-andesite, and granodiorite
sis: Madin formation, tuff, siltstone, graywacke, sandstone, and andesite
siva: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
sivb: Urta formation, basalt, andesite, tuff, and volcanic sandstone
sivb: Clinopyroxene-hornblende gabbro
sivn: Metamorphosed schist, gneiss, amphibolite, metarhyolite, and jasper
sivs: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
MODS Records (2014)
Major Metals
Copper
Lead
Guides for Metals
Gossan
Faults
Normal faults
Strike-slip faults
511 Jibal At Turudiyat
509 Jibal At Toqudiyat SW
510 Wadi Ash Shubrum
420 Samra Al Hutaymyah
3462 Afif prospect-SE

Recommendations

The recommendations set forth in WGM's previous review in 1989-1992 remain valid for the Afif Belt. Mapping, and soil sampling followed by drilling on the Afif main and SE prospects is warranted and mapping and sampling for the other gossanous occurrences are warranted as well as an airborne survey using modern equipment and techniques. In detail, the following recommendations should be carried out:

- the results of all previous work should be compiled and additional geochemical samples taken in areas of geologic complexity, particularly folding and anomalous base-metal values;
- the Afif Main and Afif South prospect areas should be mapped at a scale of 1 :5,000 on 200 x 50 m grids;
- the recommendations of Billa and others (1985) that microgravity surveys be done in anomalous areas, and areas of folded carbonate rocks should be studied in detail;
- areas of mineralization or anomalous geochemical values should be exposed by trenching and sampled at no greater than one meter intervals;
- affirmed zones of merit, including EM and gravity anomalies, should be tested by diamond drill holes - the amount of drilling would be determined by the number of targets resulting from such survey work;
- the data should be compiled on a map of the greater Afif area at 1:10,000 scale.
- prospecting and 1:10,000 scale geological mapping should be carried out with all reference points surveyed by GPS for location control; and,
- an airborne EM-Mag survey of the belt using state-of-the-art equipment should be carried out to trace bedrock formations by their magnetic response and to identify and trace EM conductors potentially associated with stratabound base metals mineralization.

3.2.3.6 Muhadad VMS Belt

Location, History and Status

The Muhadad VMS belt lies within the Asir Terrane and comprises a belt of rocks identified as the Tayyah belt dated at >815 Ma and covering an area of 7,720 km^2 (Figure 60). These rocks are comprised of a mixture of mafic to intermediate volcanic rocks and volcaniclastic sediments with a minor felsic component in the northern sector. The southern extension of the Tayyah belt is composed mainly of sediments and mafic volcanics and is in marked contrast to the northern sector where more felsic assemblages appear. Unequivocally identified VMS mineralization in this belt is fairly rare. A listing of the VMS related mineral prospects in this belt is presented in Table 42.

The only VMS prospect that has a resource is the Muhadad prospect (MODS 1349). The local geology of the prospect is shown in Figure 61. The mineralization consists of disseminated sulphides associated with a marble-chert horizon (exhalite) near a subvolcanic quartz porphyry intrusion (Smith 1981). Therefore, the limits of this mineral belt have been confined to the northern portion of the Tayyah Group rocks where favourable lithologies and prospective mineral occurrences have been identified.

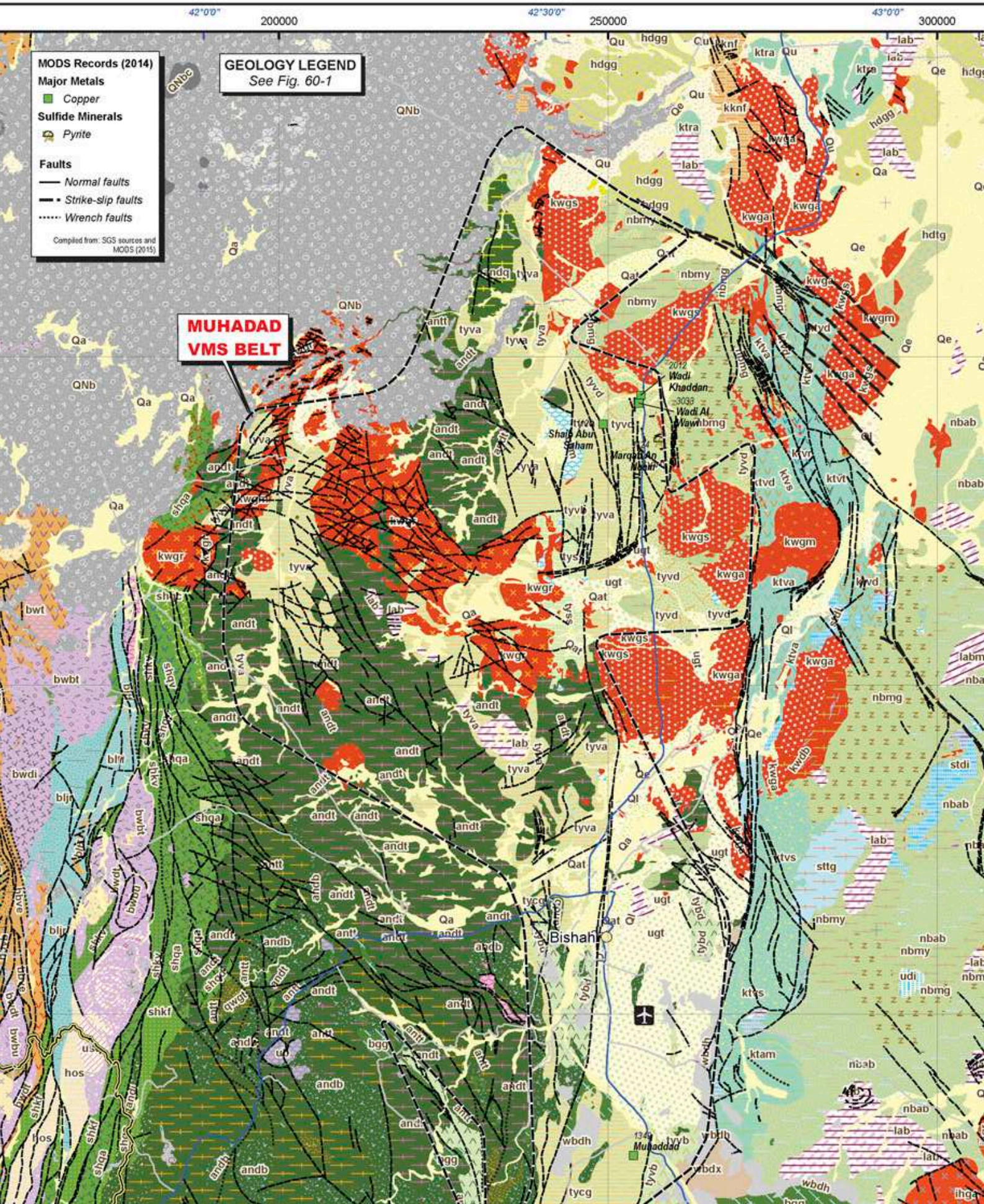

42°0'0"
200000
42°30'0"
250000
43°0'0"
300000
MODS Records (2014)
Major Metals
Copper
Sulfide Minerals
Pyrite
Faults
Normal faults
Strike-slip faults
Wrench faults
Compiled from: SGS sources and MODS (2015)
GEOLOGY LEGEND
See Fig. 60-1
MUHADAD
VMS BELT
Bishah
Wadi Khaddan
Wadi Al Mawh
Shaib Abu Saham
Muhaddad

Table 42
Summary of Main Prospects in the Muhadad VMS Belt

MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
1349	Muhadad	Muhadad	Cu	42.6521940	19.6860830	Bishah	Medium	v
1120	Shaib Abu Saham	*Hishashat Al Hawi	Cu	42.5924440	20.6901110	Ranyah	Medium	lenses, v
2012	Wadi Khaddan	*Wadi Al Miyah	Cu	42.6467780	20.7306110	Ranyah	Very low	stratiform
3033	Wadi Al miyah	*Al Miyah	Cu	42.6441110	20.7197780	Ranyah	Medium	lenses, v
1124	Marqab An Naan	Hishashat Al Hawi	Pyrite	42.6744440	20.6707220	Ranyah	Very low	dd, stratiform

NOTES: 1) ranking according to MODS 2) V=veins, dd = disseminated
* classified as VMS based on limited descriptions – no resource estimates available

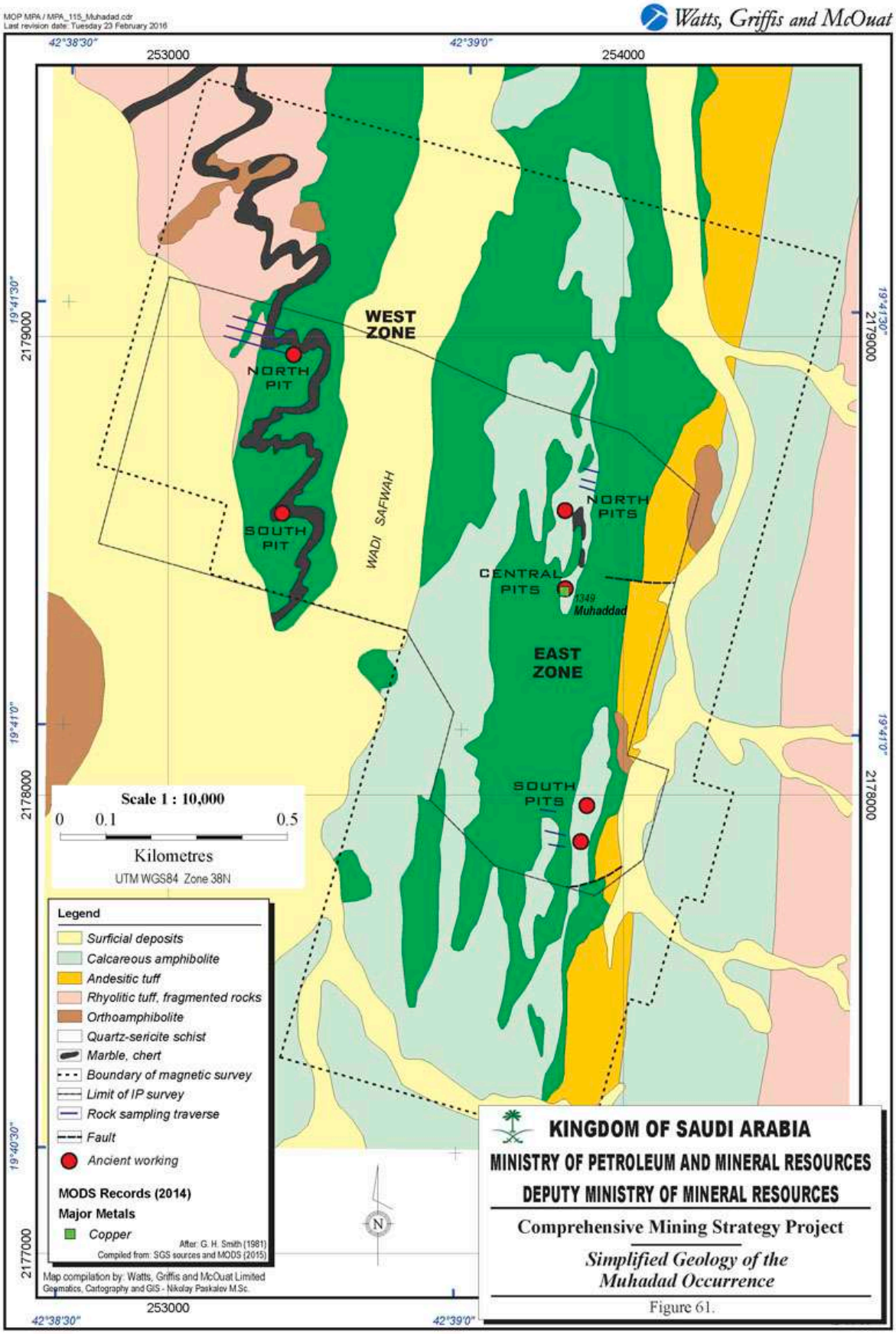
Most of the work in the belt has focused on the Muhadad prospect. Regional studies in the early 1980s included geological mapping of the region at 1:10,000 scale and detailed mapping of the ancient workings at 1:200 and 1:1,000 scales. Extensive chip sampling traverses and some grab sampling were completed during this program, including 203 samples from the north, south and central pits of the east zone, and 158 samples from the west zone. Forty-nine grab samples were also taken of quartz veins. The sampling revealed significant low-grade enrichment in base and precious metals around the ancient workings. Significant chip sampling results from the east zone included maximum values of 0.56% Cu and 0.10% Pb over 3 m and 0.86% Zn over 6 m from the south pits; 0.55% Cu, 1.0% Pb and 9.5% Zn over 1 metre from the central pits; and 0.15% Cu and 8.6% Zn over 1 metre from the north pits. Grab samples contained up to 20,000 ppm Cu, 2,750 ppm Pb, 38,500 ppm (3.85%) Zn, 3.4 g Au/t and 48 g Ag/t. The west zone contained up to 3,940 ppm Cu, 7,367 ppm Pb and 10,867 ppm (1.09%) Zn over 6 m. Grab samples contained up to 18,000 ppm (1.8%) Pb, 22,500 ppm (2.25%) Zn, 1.2 g Au/t and 62 g Ag/t. At the same time as the sampling was completed, geophysical surveys were carried out consisting of a 46 line-kilometre magnetometer survey, 9.3 line-kilometres of IP surveying and an SP test survey of 690 m. Following the work, it was concluded that there was no potential for stratabound or stockwork mineralization despite the commercially interesting analytical results (Smith G.H., 1981). During 1991, the BRGM sampled the Muhadad occurrence as part of an evaluation of the mineral occurrences of the Bishah region. Preliminary results showed that most samples contained gold values of 0.15-0.77 g/t however three samples of "brecciated facies" returned 1.49-3.49 g/t.

The most recent work at Muhadad was carried out by the BRGM during 1996. This exploration comprised the creation of a topographic grid over a 1.25 km^2 area, the collection of 146 chip samples and 8 wadi sediment samples, an IP-resistivity survey, the completion of 10 angled diamond drill holes (585 core samples were analysed) and petrographic studies on 40 selected samples. The first three drill holes (C001-03) were drilled on the eastern polarizing anomaly (structure) intersected meta-andesite and biotite schist with up to 12% pyrite. Holes C004 and C005 drilled in the central quartz-scree area intersected metarhyolite

locally containing dense milky-quartz (barren) stockwork veining. The 6th hole in the same area intersected the main contact zone between felsic and mafic volcanic units. Holes C007 to C009, drilled in the Southern and Central Pits areas intersected isolated thin sheets of laminated submassive sulphide composed of dominant sphalerite and pyrite, "possible major galena" and minor chalcopyrite. The grades in drill core samples were as high as 20% Zn, but did not exceed 1.5% Pb, 1% Cu, 1 g Au/t and 75 g Ag/t (Jaques and Saleh, 2000). In the near-surface oxidized zone, hole C007 intersected a siliceous gossan and associated massive meta-chert, both heavily stained by malachite and chrysocolla as well as and plumbo-jarosite. They are characterized by a Cu-Pb-(Zn-Au-Ag-Ba) signature. The grades were as high as 18% Cu, and 4% Pb, but did not exceed 1.20% Zn, 1 g Au/t and 100 g Ag/t. The best intersections are summarized as:

DDH	From	To	Width	Cu	Pb	Zn	Au	Ag
C007	**31.40**	**35.60**	**4.20**	**7.4**	**2.4**	**0.6**	**0.6**	**39.5**
	56.85	**57.85**	**1.00**	**1.5**	**0.0**	**1.0**	**1.7**	**60.5**
C008	**28.00**	**31.30**	**3.30**	**0.1**	**0.0**	**1.1**	**0.9**	**6.0**
	78.90	**80.20**	**1.90**	**0.6**	**0.6**	**5.6**	**0.5**	**39.0**
C009	**68.30**	**70.05**	**1.75**	**0.2**	**0.0**	**2.0**	**0.2**	**20.9**
C010	**44.00**	**47.95**	**3.95**	**0.5**	**0.0**	**1.8**	**0.1**	**12.2**

The reconnaissance core-drilling campaign in Muhadad confirmed that the mineralization is characterized by clusters of strongly sheared stratabound base-metal rich bodies related to island-arc bimodal volcanism. The BRGM interpreted the mineralization to be an exhalative, Kuroko-type VMS system. The nature and composition of the sulphides and the lack of a strong copper-bearing stockwork zone suggest to WGM that the mineralization discovered to date is distal from the vent. The BRGM stated that the "sporadically exposed gossan pods of Muhadad do not correspond to minor subsurface satellite expressions of a major, hidden, deep-rooted, polymetallic deposit". The BRGM concluded that the drilling intersected sparse and small-sized lenses of submassive sulfide mineralization with no economic potential due to the limited size even through the base-metal grades were quite high. The BRGM estimated the resources to be 120,000 t averaging 3% Zn, 2% Cu and 1% Pb which was below its threshold of interest of 300,000 t with similar grades. The BRGM stated that "the Muhadad prospect has no economic potential under present-day conditions and no further work is warranted". No work has been carried out since that time.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Last revision date: Tuesday 23 February 2016
Watts, Griffis and McOuat
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253000
42°39'0"
254000
19°41'30"
2179000
19°41'0"
2178000
19°40'30"
2177000
WEST ZONE
NORTH PIT
SOUTH PIT
WADI SAFWAH
NORTH PITS
CENTRAL PITS
1349
Muhaddad
EAST ZONE
SOUTH PITS
Scale 1 : 10,000
0 0.1 0.5
Kilometres
UTM WGS84 Zone 38N
Legend
Surficial deposits
Calcareous amphibolite
Andesitic tuff
Rhyolitic tuff, fragmented rocks
Orthoamphibolite
Quartz-sericite schist
Marble, chert
Boundary of magnetic survey
Limit of IP survey
Rock sampling traverse
Fault
Ancient working
MODS Records (2014)
Major Metals
Copper
After: G. H. Smith (1981)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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Comprehensive Mining Strategy Project
Simplified Geology of the Muhadad Occurrence
Figure 61.

Geology

The Muhadad prospect is the most prospective in this mineral belt. The base and precious-metals occurrence (MODS 1349) is located about 40 km south of Bishah. It consists of sheared and gossanous zones within an assemblage of metavolcanic and metasedimentary rocks. There are two zones about 600 m apart. The East Zone extends over a strike length of 900 m and is hosted by calcareous amphibolite cut by metamorphosed quartz porphyry (quartz-sericite schist). Copper mineralization, marked by ancient workings on malachite-stained gossan, occurs in quartz-sericite schist, magnetite-bearing metaquartzite-chert horizons and locally sheared quartz veins. The workings and pits have maximum dimensions of 30 m x 2 m (Smith, 1981). Two pits 350 m apart are sited on the west zone. Mineralization consists of malachite staining on quartz-sericite schist, marble, and quartzite-chert. The geological setting of the two workings is thought to lie on fold hinges of the same marble-quartzite unit.

Recommendations

The recommendations in WGM CR-11-13 for the Muhadad prospect and the other suspected VMS occurrences in this mineral belt are still valid. WGM strongly disagrees with the conclusions of the BRGM on this prospect. The drilling carried out was the very first testing of the geophysical anomalies and the geological model. As an early stage exploration program, the BRGM has not appreciated the fact that this exploration program was a great success. Given that the drilling was shallow – none of the intersections were below 75 m from surface, the BRGM has given no thought to the development of this deposit in 3D space. A re-examination of the geophysical data from the previous work on the Muhadad prospect is recommended to delineate any subtle anomalies that may been overlooked during the first evaluation, and repeated IP surveying with a wider ‘a’ spacing is needed to investigate deeper. The results of this work should be compiled with the results of other geophysical and geochemical work in an attempt to define priority drill targets.

An airborne EM-Mag survey for this belt and the projected northern extensions under Harrat al Buqum is certainly recommended.

3.2.3.7 Wadi Bidah VMS Belt

Location, History and Status

The Wadi Bidah VMS belt is located in the Asir Terrane and it is comprised of Bidah Belt layered rocks (855-815 Ma) and covering an area of 2,014 km^2 (Figure 62). The VMS deposits and prospects in this belt, listed in Table 43, are confined to the Hawiyah Formation (Johnson 1999b). This formation consists of a series of bimodal mafic to felsic volcanic and volcaniclastic rocks including quartz porphyries and minor sediments. Many of the rocks in this belt have a very strong penetrative foliation that obscures many textural

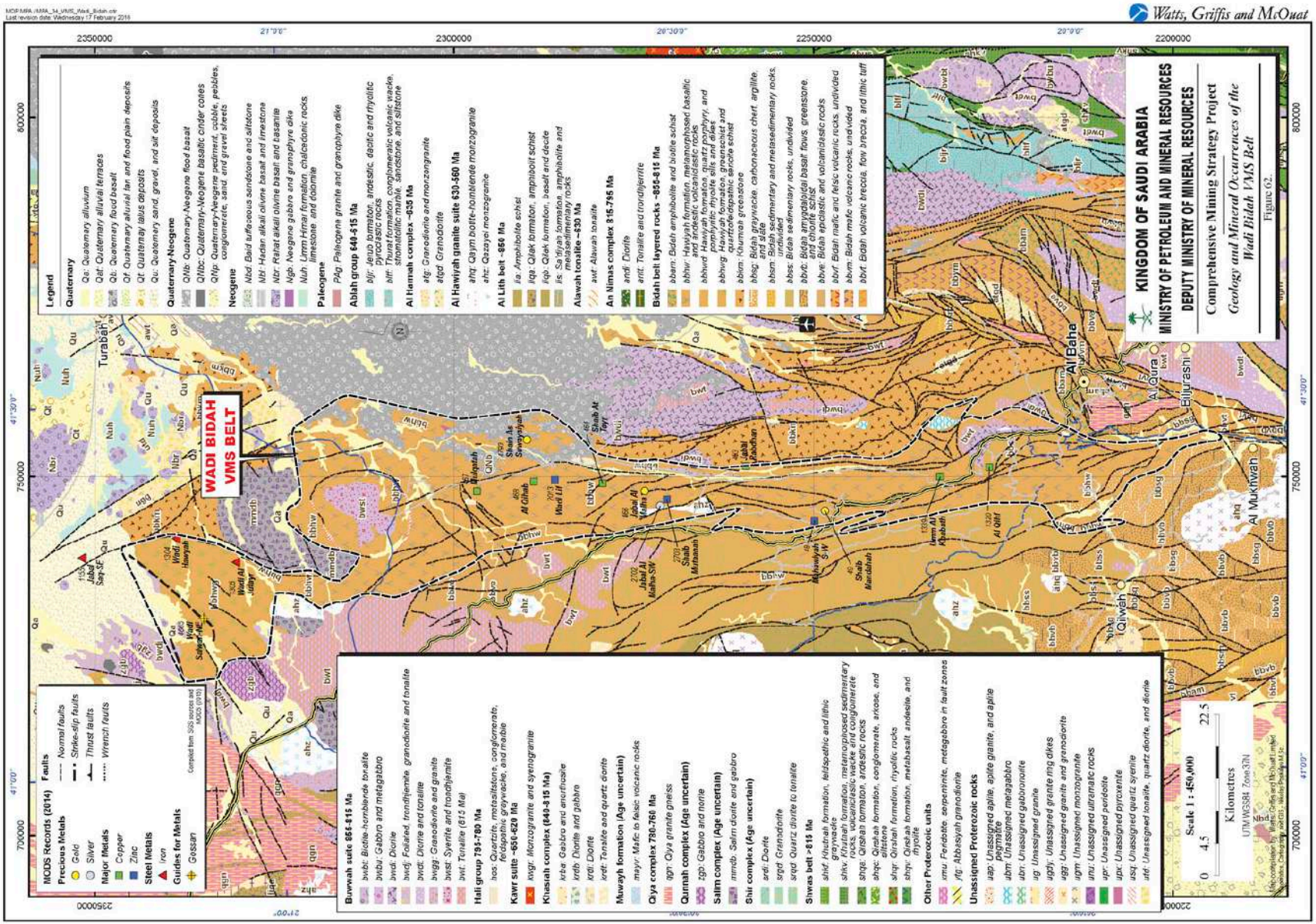
features. A number of VMS deposits both proximal and distal are scattered along the belt in the Hawiyah Formation at approximately the same stratigraphic horizon (Beziat and Donzeau, 1989). The geological control of the massive sulphide deposits in the Wadi Bidah belt has been further described by Volesky et al (2002).

Table 43
Summary of Mineral Occurrences in the Wadi Bidah VMS Belt

MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0463	Rabathan	Rabathan	Cu	41.4095830	20.4163890	Al 'Aqiq	Medium	dd, lenses, v
0464	Shaib At Tayr	Shaib at Tare	Cu	41.3894440	20.5966670	Al 'Aqiq	Medium	Lenses
0466	Jabal Al Malha	Mulhal	Au	41.3784720	20.5439720	Al Qura	Undefined	V
0467	Mulgatah	Mulgatah	Cu	41.3814440	20.7544440	Turubah	Medium	dd
0468	Al Qihab	Gehab	Cu	41.3928890	20.6827500	Turubah	Low	Lenses
2013	Wadi Lif	Wadi Leif	Zn	41.3949440	20.6568610	Turubah	Medium	dd, stratiform
0048	Mahawiyah SW	*Mahawiyah						Undetermined
0049	Shaib Mandahah	Wadi Mandahah	Au	41.3486110	20.3180560	Al Qura	Medium	V
4793	Jibal Al Hajar NW7	*Abu Sulal	Cu	41.4490000	20.6907780	Turubah	Very low	Undetermined
1339	Umm Al Kabath	*Umm al Khabath	Cu	41.3922220	20.1730560	Al Qura	Medium	Lenses, veins
1320	Al Qihf	*Arqub Al Hazim	Cu	41.4036110	20.1111110	Al Mandaq	Very low	Undetermined
2702	Jabal Al Malha SW	Mulhal No. 2	Ag	41.3583330	20.5250000	Al Qura	Undefined	V
1305	Wadi Al Jufayr	*Al Jaufir	Fe	41.2912500	21.0571940	At Ta'if	Medium	Lenses
1155	Jabal Saq SE	*Umm Hijlan	Fe	41.2998330	21.2507500	Turubah	Medium	Lenses
2703	Shaib Mutaanah	*Bilajimah	Zn	41.3666670	20.5166670	Al Qura	Medium	dd,banded v
4665	Wadi Salwan NE	*Al Godayir	G	41.2166670	21.1000000	At Ta'if	Very low	Stratiform
1304	Hawwiyah	*Hawwiyah	Fe	41.3237220	21.1320560	At Ta'if	Medium	Massive

NOTES: 1) ranking according to MODS 2) V=veins, dd = disseminated
* classified as VMS based on limited descriptions – no resource estimates available

Several deposits in this belt have a calculated reserve/resource attached to them, however the Rabathan prospect is the largest and most significant in the Wadi Bidah VMS Belt. During the mid-1960s, a mineral reconnaissance mapping program was carried out in the Wadi Bidah district. Reconnaissance mapping was performed in the region and prospect-scale sampling was completed at the Rabathan prospect (Smith and Kouther, 1967). Subsequently, Earhart and Mawad (1970) mapped the Wadi Bidah district at 1:50,000 scale, and the Rabathan prospect was mapped at 1:1,000 scale. As part of this exploration program, eight diamond drill holes (R1-R8) totalling 959.5 m were completed to test gossans in the Rabathan area. Jackaman (1972) mapped the Wadi Bidah district, including the Rabathan prospect, and proposed a revised interpretation of the stratigraphy of the area. Greenwood (1975c) mapped the geology of the Jabal Ibrahim quadrangle, which contains the Rabathan prospect, at a scale of 1:100,000. Kiilsgaard and others (1978) re-examined the known sulfide deposits in the Wadi Bidah area, and remapped the Rabathan prospect at 1:500 scale, and magnetic and gravity surveys were completed over portions of the prospect. Six additional closely spaced holes (RB9-RB14) totalling 1,273 m were diamond drilled to test the extent of mineralization intersected by previous drilling at Rabathan in the vicinity of hole R4. All holes except R14 encountered sulfide mineralization and the best intersection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Geology and Mineral Occurrences of the Wadi Bidah VMS Belt
Figure 62.
Watts, Griffis and McOuat
WADI BIDAH VMS BELT
Legend
Quaternary
Neogene
Paleogene
Ablah group 640-615 Ma
Al Hannah complex ~635 Ma
Al Hawiyah granite suite 630-560 Ma
Al Lith belt ~650 Ma
An Nimas complex 815-795 Ma
Alawah tonalite ~630 Ma
Bidah belt layered rocks ~855-815 Ma
Buwwah suite 855-815 Ma
Kawr suite ~650-620 Ma
Khasiah complex (640-615 Ma)
Muwayh formation (Age uncertain)
Qya complex 780-760 Ma
Qirnah complex (Age uncertain)
Salm complex (Age uncertain)
Shir complex (Age uncertain)
Siwas belt >615 Ma
Other Proterozoic units
Unassigned Proterozoic rocks
MODS Records (2014)
Faults
Precious Metals
Major Metals
Steel Metals
Guides for Metals
Scale 1 : 450,000
Kilometres
UTM WGS84 Zone 37N
Comprehensive Mining Strategy Project
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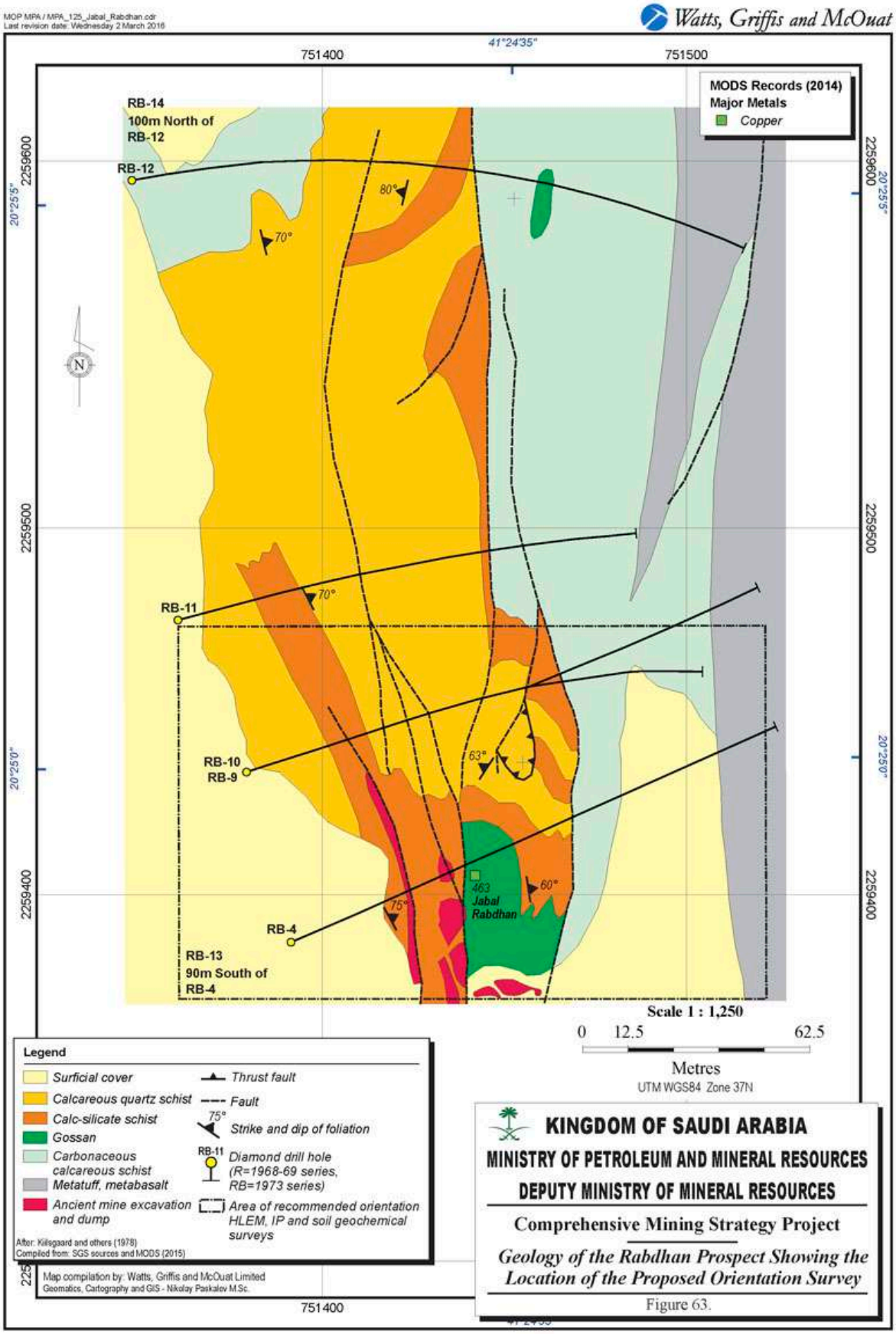
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Last revision date: Wednesday 2 March 2016
Watts, Griffis and McOuat
41°24'35"
751400
751500
2259600
2259500
2259400
20°25'5"
20°25'0"
MODS Records (2014)
Major Metals
Copper
RB-14
100m North of
RB-12
RB-12
RB-11
RB-10
RB-9
RB-4
RB-13
90m South of
RB-4
80°
70°
70°
63°
60°
75°
463
Jabal
Rabdhan
N
Scale 1 : 1,250
0 12.5 62.5
Metres
UTM WGS84 Zone 37N
Legend
Surficial cover
Calcareous quartz schist
Calc-silicate schist
Gossan
Carbonaceous calcareous schist
Metatuff, metabasalt
Ancient mine excavation and dump
Thrust fault
Fault
75° Strike and dip of foliation
RB-11 Diamond drill hole (R=1968-69 series, RB=1973 series)
Area of recommended orientation HLEM, IP and soil geochemical surveys
After: Kiilsgaard and others (1978)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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Geology of the Rabdhan Prospect Showing the Location of the Proposed Orientation Survey
Figure 63.

averaged 5.56% Cu over 5.1 m in hole R9. Geoterrex carried out an airborne EM and magnetic survey over the Wadi Bidah area in 1977, which outlined an anomaly coincident with the Rabathan prospect. Riofinex (1979a) re-evaluated the geology of the Wadi Bidah district, remapping and resampling the Rabathan prospect and re-calculating the potential resources. Smith and others (1983) carried out rock-chip geochemical surveying of the Rabathan prospect.

Geology

The Rabathan prospect, shown in Figure 63, is the largest and most significant prospect in the belt - gossanous occurrences crop out intermittently over a strike length of approximately 17 km. The gossans are hosted by north-trending chlorite schists and calcareous carbonaceous schists of the Baish Group. These rocks are highly sheared and contorted in places, but for the most part they form a steep easterly-dipping sequence that is locally overturned. The mineralized host rocks are interlayered with mafic to intermediate lavas, pyroclastic rocks and iron formation. There is a small 10 m x 60 m ancient working adjacent to the main gossan in the R4 area.

Recommendations

This belt is a typical VMS mineral belt containing several deposits and occurrences. Massive sulphide mineralization has been proven by drilling at the Rabathan prospect and additional exploration is justified at the prospect and in its geological setting. The mineralized occurrences all lie in or near one single stratigraphic unit within the volcanic pile and much can be learned from good quality geological mapping. In particular, the prospective marble/alteration area at Rabathan and throughout the area requires follow up mapping and sampling. Orientation-type (test) HLEM, spectral IP and soil geochemical surveys (25 x 25 m grid) are recommended for the area shown on Figure 63. The objective of this work is to determine if the response of the sulfides can be differentiated from that of the enclosing graphite schist. If this proves successful, then geophysical and/or geochemical surveying should be expanded to cover the area between holes R2 and RB13, and any anomalous areas defined by the geological or lithogeochemical surveys. Additional drilling is warranted along profiles spaced 25 m apart to trace the extent of the massive sulphides intersected in holes R2, R4 and RB9-RB13 as well as to evaluate the significance of any geophysical anomalies. In carrying out the foregoing recommendations, cultural considerations may limit the amount and type of work that can be completed in parts of the area. Many other base metal sulphide occurrences along the belt require similar work but are not as advanced or as well known due to a lower level of historical exploration work.

3.2.3.8 Wadi Shwas VMS Belt

Location, History and Status

The Wadi Shwas VMS belt lies east of and mostly parallel to the adjacent WBMB and it occupies an area of about 3893 sq. km in the Asir Terrane (Figure 64). It is underlain by Shwas belt sedimentary rocks (>815 Ma) and volcanics belonging to the Khutnah and Qirshah Formations respectively that have been metamorphosed to the greenschist facies. The Quishah Formation is made up of mafic to intermediate volcanic and volcaniclastic rocks and it hosts most of the known VMS deposits.

The Wadi Shwas belt contains two main VMS deposits (Al Hajar and Jadmah) with an attached reserve/resource and a host of lesser prospects (Table 44).

Table 44
Summary of Occurrences in the Wadi Shwas VMS Belt

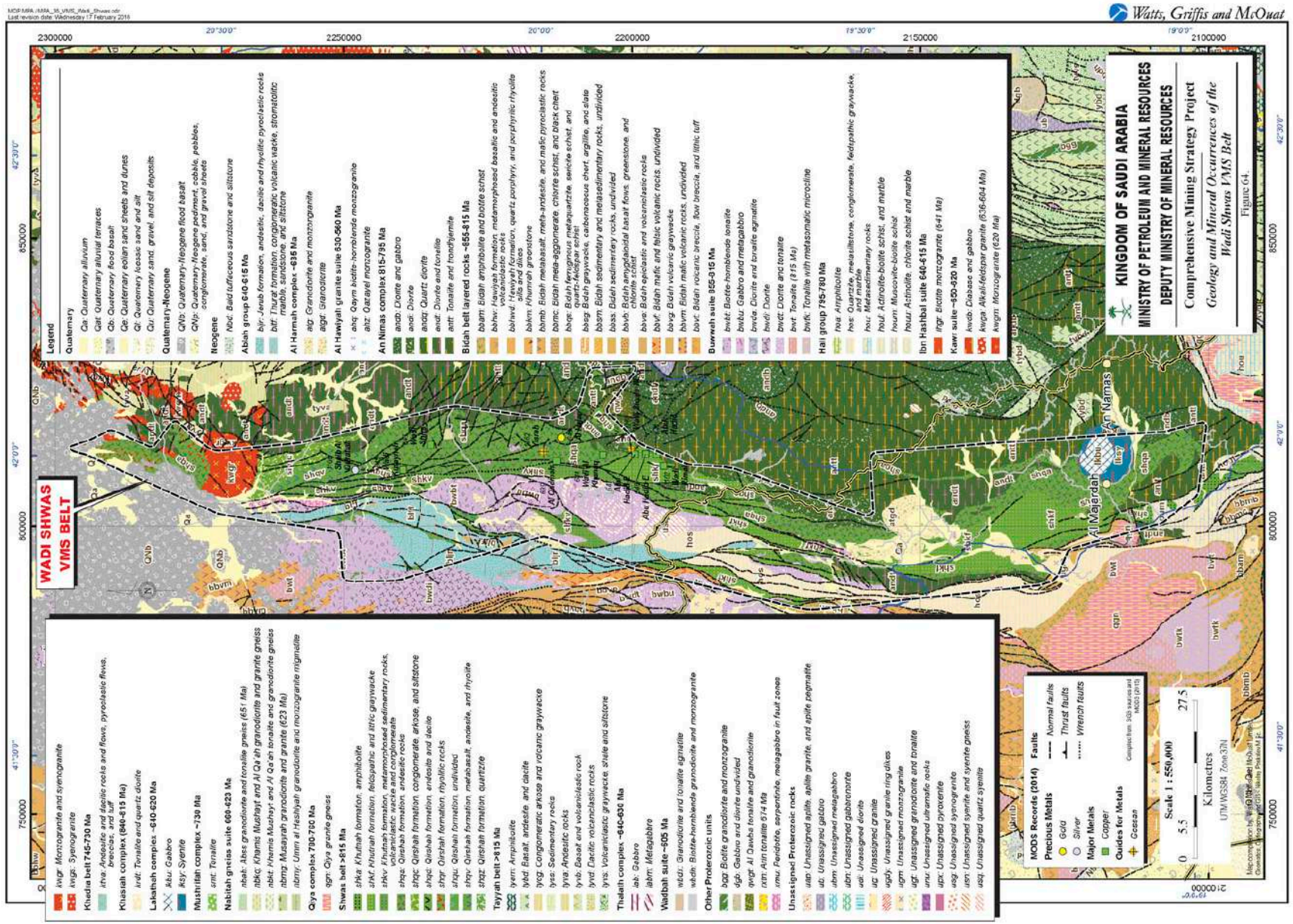
MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0639	Al Qadmah	Jadmah	Cu	41.9754720	19.9888890	Balqarn	Very high	sm / ms, lenses, stringers
0641	Wadi Shirs	Shmaytah	Cu	42.0055560	20.1861110	Bishah	Low	dd, v
0644	Wadi Al Khanaq	Al Wakaban	Cu	41.9833330	19.9166670	Balqarn	Very low	dd
0645	Wadi Kutaynah	Iktinah	Cu	41.9650560	20.2300560	Bishah	Medium	dd, sm / ms
0646	Abu Hadid	Abu Hadid	Cu	41.9833330	19.8333330	Balqarn	Medium	dd, stratiform
0647	Abu Hadid-E	Siqam As Sawan	Cu	41.9833330	19.8666670	Balqarn	Medium	dd, stratiform
0648	Abu Hadid-E	Shabat As Suqah	Cu	41.9833330	19.8500000	Balqarn	Medium	dd, stratiform
1102	Wadi Rimah	Al Mahtriq	Cu	41.9638890	19.8222220	Balqarn	Medium	dd, stratiform
0649	Al Hajar	Al Hajar	Au	42.0136110	19.9810560	Balqarn	Very high	dd, sm / ms, stockwork v
1262	Yisrah	Ysrah	G	41.9902780	20.0094440	Balqarn	Undefined	undetermined
1263	Wadi Siqam-NE	Al Hashiyah	G	41.9930560	19.8725000	Balqarn	Very low	veins
1106	Shaib Al Qurahah	Abu Sydra	Ag	41.9656110	20.3048610	Al 'Aqiq	Low	undetermined
No Index	?	*Iktinah 13	Gossan	uncertain		-----	-----	-----
No Index	?	*Gossan GO 14	Gossan	uncertain		-----	-----	-----

NOTES: 1) ranking according to MODS 2) v=veins, dd = disseminated; sm = sub-massive; ms = massive
* classified as VMS based on limited descriptions – no resource estimates available

It is possible that the first visit of the ancient workings at Al Hajar occurred during 1965 by the USGS when an attempt was made to find the sources of airborne EM conductors on the ground (Trent, 1965). In 1973, the first systematic exploration by the DGMR consisted of a 20 m x 40 m SP survey and a small amount of Turam (EM) surveying. A long SP anomaly was found to be coincident with the gossans. IP and/or more Turam-EM were recommended in advance of drill-testing the conductors (Gazzaz, 1974). The maps of these surveys were unavailable. The Japanese Geological Mission ("**JGM**") carried out 1:2,000-scale geological mapping using aerial photographs for control purposes. The gossans were extensively sampled, and three diamond drill holes totalling 562 m were completed. The logs and sections of drill holes HAJ-1 to HAJ-3 are missing from the Fujii and others (1978) report. The log of HAJ-3, revised sections of all drill

holes, and selected analytical data are reproduced in Cheeseman and Poloni (1980). The work by the JGM defined several types of gossan, including an opaline variety, in four zones. Fifty-three samples contained between 0.01% and 1.33% Cu, nil to 1.25% Pb, and 0.01% to 0.27% Zn. The JGM reported that 19 of the samples contained between 0.12 to 7.70 ppm Au and 0.8 to 19.5 ppm Ag, the first report of gold at the site. Drill hole HAJ-1 intersected copper mineralization grading 3.01% Cu over 1.2 m, and 2.07% Cu over 3.1 m due to supergene enrichment (chrysocolla and native copper). Elsewhere, only disseminated pyrite and minor chalcopyrite were intersected (Fujii and others). Further sampling of the gossans by the JGM totalling 13 one-metre samples returned 210 to 5,470 ppm Cu and 140 to 1,450 ppm Zn. There was no attempt to determine gold or silver contents.

During 1975-1976, the DGMR undertook geophysical surveys on a 20 m x 40 m and 20 m x 80 m grid for a total of 8 line-kilometers of surveying, including a magnetic survey (352 stations), gradient array IP survey (286 measurements), three-array IP survey on four lines, and a dipole-dipole IP survey on one line (ARGAS, 1978). The work outlined a N-striking, 400-500 m long anomaly comprising a weak SP response, high chargeability and low resistivity (Gazzaz, 1974). The IP response is characteristic of a weathering or oxidized horizon near surface and may reflect the base of the oxidized zone. A second anomaly to the north was associated with an area of gossan and underlying disseminated sulfide mineralization tested by drill holes HAJ-1 and HAJ-2 (Cheeseman and Poloni). During 1975-1980, the DGMR remapped the prospect and undertook a small drainage geochemical program, with a sampling program to test gossan and other bedrock types. Drill hole HAJ-3 was deepened and drill hole HAJ-4 was drilled for a total of 406.35 m. Other work included petrographic studies of drill core and gossans. Seventeen chip samples were taken from or across the base of the weathered profile in gossan zones. Samples averaged 0.82 g Au/t, but one 5.5 m interval gave average gold values of 3.9 g/t and 51 g Ag/t. Mineralization in the extension of drill hole HAJ-3 consisted of 1-3% pyrite to a depth of 320 m, with minor base-metal concentrations (1.98% Cu, 0.14% Zn and 12.1 g Ag/t over 1.5 m). Zones up to 56 m in width of chloritized rhyolite in hole HAJ-4 contained 2-5% pyrite but only minor base-metal concentrations. The best assays were obtained from two 1.5 m intervals containing 1.58% and 0.08% Cu, and 0.07% and 1.71% Zn. The DGMR felt that the sulfide mineralization of drill holes HAJ-3 and HAJ-4 and the overlying gossans explained the principal geophysical anomaly. Cheeseman and Poloni recommended no further exploration for base metals at Al Hajar, but felt that there should be additional sampling of the weathered rocks for precious metals. Initial geochemical studies at Al Hajar by BRGM in 1979 and 1980 showed that the chlorite-rich, chalcopyrite-bearing rocks are the product of magnesian alteration of felsic tuffs, and thus represent alteration pipes up to 100 m thick. Barbier and others (1983) noted that drill holes HAJ-1 and HAJ-2 were sited outside surface areas of high copper content and that the grades encountered may therefore be relatively low.


WADI SHWAS VMS BELT
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Geology and Mineral Occurrences of the Wadi Shwas VMS Belt
Figure 64.
Watts, Griffis and McOuat
Legend
Quaternary
Neogene
Quaternary-Neogene
Ablah group 640-615 Ma
Al Hawiyah granite suite 630-560 Ma
An Nimas complex 815-795 Ma
Al Harmah complex ~835 Ma
Bidah belt layered rocks ~655-615 Ma
Duwweh suite 955-915 Ma
Ibn Hashbal suite 640-615 Ma
Hali group 795-780 Ma
Kawi suite ~650-620 Ma
Khadiat belt 745-730 Ma
Khasiah complex (840-815 Ma)
Lakathieh complex ~640-620 Ma
Mushrifah complex ~730 Ma
Nabitah gneiss suite 660-623 Ma
Shwas belt >815 Ma
Tayyah belt >815 Ma
Thalath complex ~640-630 Ma
Wadbah suite ~605 Ma
Other Proterozoic units
Unassigned Proterozoic rocks
MODS Records (2014)
Faults
Normal faults
Thrust faults
Wrench faults
Precious Metals
Gold
Silver
Major Metals
Copper
Guides for Metals
Gossan
Scale 1 : 550,000
Kilometres
UTM WGS84 Zone 37N
Al Majardah
An Nimas

Between 1987 and 1989, BRGM undertook a major exploration program to evaluate the gold potential of the near-surface oxidized zone at Al Hajar. Surface work included 1:500-scale geological mapping, "reconnaissance" rock chip sampling (900 samples), sampling in forty 25-m spaced trenches (4,637 samples) and geophysical surveying (SP, mise-a-la-masse, magnetic, resistivity and IP). Both gossans had been adequately diamond drilled with 44 holes totalling 3,850 m at a 25 m x 25 m spacing at Al Hajar North *a*nd 37 holes totalling 2,308 m on a 50 m x 50 m grid a Al Hajar South. About 6,000 drill core samples were analyzed. Other work included petrographic studies, density measurements, more than 1,000 spot cyanidation tests on drill core and trench samples, bottle and column cyanidation tests (mostly on samples from Al Hajar North) and an in-situ heap-leaching test of 1,500 t of material from Al Hajar North which yielded 6,224.48 g gold and 2,634.5 g silver. A water availability study involving a VLF-EM survey was completed and nine additional holes totalling 447 m were drilled for pumping tests. A feasibility study was also completed at that time by the BRGM. The Al Hajar North deposit was demonstrated to be shaped like a 300 m x 130 m ellipse, with an average depth of 45 m. Its total geological reserves were estimated to be 2.37 Mt grading 2.5 g Au/t, with estimated recoverable reserves of 1.54 Mt grading 3.45 g Au/t using a 1 g/t cut-off. It was estimated that 80-92% of the gold would be recoverable. The Al Hajar South deposit is also an elliptical zone 410 m long and 220 m wide, with an average thickness of 37 m. It was estimated to contain total geological reserves of 5.73 Mt grading 1.44 g Au/t and estimated recoverable reserves of 2.69 Mt grading 2.6 g Au/t with 70-85% of the gold recoverable. The BRGM's preliminary feasibility study was favorable at a throughput of 400,000 t per year grading 2.88 g Au/t and 500,000 t per year at 2.53 g Au/t. The BRGM envisaged additional drilling at both deposits (3,500 m), further metallurgical work, completion of the hydrogeological studies, and a final feasibility study (BRGM, 1989). A resource of 300,000 t grading 6.82% Cu was estimated for sulfate-enriched rock at the base of the gold-rich gossan. Below this, a resource of primary (hypogene) massive sulphides for Al Hajar North and South was estimated to total 1.85 Mt grading 2.13% Zn in primary massive sulfides and 904,500 t grading 1.30% Cu in vein stockwork sulfides (BRGM, 1989). WGM understands that Ma'aden has mined out the leached gossan cap on the deposit, but no details of this work are available, nor is any information available concerning a mine plan for the primary sulphide mineralization.

Geology

The Al Hajar Au-Ag-Cu-Zn deposit (MODS 0649), is the most advanced and prospective prospect in the Wadi Shwas VMS belt. It is hosted by steeply dipping, moderately folded volcanic rocks of the Qirshah Formation, including dacitic to rhyodacitic pyroclastic rocks and flows, rhyolite, and mafic flows and dikes (Fujii and others, 1978). Disseminated, veinlet and massive sulfide mineralization is mainly hosted within chloritized (hydrothermally altered) rhyodacite. At Al Hajar North, a massive sulfide body, 160 m long and 40 to 90 m thick occurs within a talcose and chloritic zone. The massive body as well as the altered rocks enclosing it are cut by a stockwork sulfide zone. Massive sulfides at Al Hajar South are less well defined. Pyrite and pyrrhotite predominate with minor chalcopyrite, sphalerite, arsenopyrite and magnetite, as well as a number of minor sulfide minerals and sulphosalts. The Al Hajar deposit is also part of the Wadi Shwas Gold Belt and a figure showing the geological setting is presented in that section of this report.

Recommendations

Between the USGS and the BRGM, the Al Hajar sites and the immediately surrounding areas have been mapped and extensively sampled. Nevertheless, when the geological maps are reviewed, critical structural information such as bedding orientations, facings and fold axes is missing. This information is vital to understanding the geology and designing an exploration program focused on the stratabound massive sulfide mineralization. In order to provide a suitable geological base, detailed (1:5,000 scale) mapping is recommended for all of the stratigraphic units known to host mineralization in this belt as well as the flanking formations overlying and underlying the mineralized horizons. Concurrent with this work, lithogeochemical sampling is recommended to outline the petrochemical compositions and affinity of the volcanic units and to detect the various alteration facies associated with the mineralizing process that created the volcanogenic massive sulfide deposits. Orientation HLEM, IP (dipole-dipole) and DEEPEM (deep penetrating time-domain EM) surveys are recommended for the Al Hajar area to determine the response of the mineralization to the various survey methods. These surveys should be carried out over a 50 x 25 m grid. The geophysical method(s) showing the best response should be selected to accompany a magnetometer survey (100 x 25 m grid) over the Al Hajar deposit area.

The Wadi Shwas mineral belt is an excellent VMS belt with considerable potential for additional discoveries. We understand that the weathered zone at Al Hajar and possibly Jadmah has been mined, but the unoxidized sulphides have not. Details of any recent work in this area are unavailable so our recommendations are made without recourse to this work. A modern airborne EM-Mag survey is recommended for the belt combined with appropriate follow up of attendant anomalies. Follow-up ground surveys should employ the best techniques available based on the responses achieved from the detailed surveying at Al Hajar and applying this knowledge to surveying extensions along strike of the host formations within the VMS belt using an appropriate profile spacing depending on the presence or absence of a geophysical anomaly.

3.2.3.9 Jabal Sayid VMS Belt

Location, History and Status

The Jabal Sayid mineral belt is located in the northern sector of the Jiddah Terrane and it comprises a bimodal sequence of mafic to felsic volcanics, volcaniclastics and sediments (including black shales) belonging to the Mahd Group (~775 Ma) plus mafic to felsic volcanics of the Arj Group (~785 Ma). This belt is bounded on the west and southeast by Quaternary Harrats Rahat and Kishib respectively and on the north, east and south by older intrusive rocks belonging to the Dhukhr complex (816-803 Ma). It covers an

area of approximately 9,579 sq. km. and its extent is shown on Figure 65. The main deposits and prospects in the belt are tabulated in Table 45.

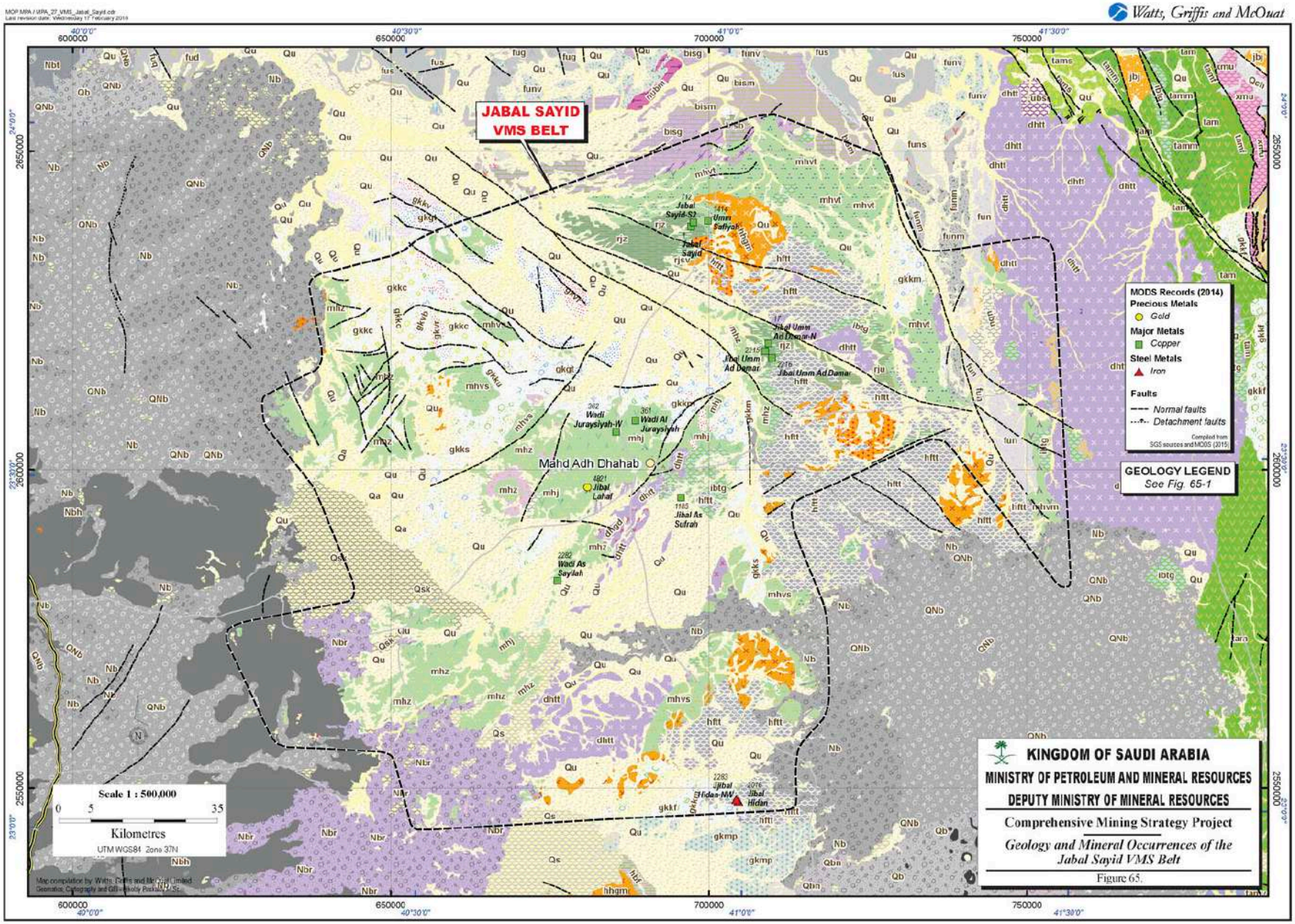
Table 45
Summary of Occurrences in the Jabal Sayid VMS Belt

MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0001	Jabal Sayid	Jabal Sayid	Cu	40.9361670	23.8426110	Al Mahd	Very high	bx, ms
0017	Jibal Umm Ad Damar-N	Umm Ad Damar-N	Cu	41.0532780	23.6752500	Al Mahd	Medium	lenses
0361	Wadi Al Juraysiyah	Wadi Jurayssiyah-E	Cu	40.8467220	23.5686110	Al Mahd	Low	dd
0362	Wadi Juraysiyah-W	Wadi Juraysiyah-W	Cu	40.8166670	23.5527780	Al Mahd	Very low	dd
0712	Jabal Sayid-S2	Jabal Sayid-S2	Cu	40.9401110	23.8487780	Al Mahd	High	stratiform, stockwork v
1185	Jibal As Sufrah	Jabel As Sofra	Cu	40.9151110	23.4590000	Al Mahd	Medium	dd
1414	Umm Safiyah	Umm Safiyah	Cu	40.9625830	23.8509170	Al Mahd	Medium	dd
2215	Jibal Umm Ad Damar	Umm Ad Damar-SE	Cu	41.0481110	23.6647500	Al Mahd	Medium	dd, lenses, stratiform
2216	Jibal Umm Ad Damar	Umm Ad Damar-SE	Cu	41.0581940	23.6550560	Al Mahd	Medium	dd, stratiform
2282	Wadi As Sayilah	Jabal Ad Daba	Cu	40.7235830	23.3430830	Al Mahd	Low	dd
4821	Jibal Lahaf	Lahuf prospect	Au	40.7710830	23.4752500	Al Mahd	Medium	veins
2016	Jibal Hidan	Jabal Hadhn-E	Fe	40.9967220	23.0249440	Al Mahd	Undefined	lenses
2283	Jjibal Hidan-NW	Jabal Ihdan-E	Fe	40.9935560	23.0277500	Al Mahd		undefined

NOTES: 1) ranking according to MODS 2) v=veins, dd = disseminated; bx = breccia; ms = massive
* classified as VMS based on limited descriptions – no resource estimates available

The Jabal Sayid belt contains two known VMS deposits of which the Jabal Sayid Mine is developed on a large world class deposit that is currently in production, and the Umm ad Damar deposit that is not yet being exploited at this time. In addition the belt contains nine other occurrences that do not have a resource figure attached to them.

The earliest work in the Jabal Sayid belt was in 1954 when samples from waste dumps at the ancient mine sites were analyzed, and an estimated 108,000 short tons of slag were found to contain 0.85% Cu, 17.14 g Ag/t and trace amounts of gold (Goudarzi, 1954). Test pits in ancient dumps averaged 1.87% to 2.10% Cu and 96 stope samples averaged 0.72% Cu (Schaffner, 1954a). In 1959, a reconnaissance survey of the ancient workings was completed, a magnetometer survey was carried out and 1:100 scale sketches of the workings were created (MacLean, 1959).


Watts, Griffis and McOuat
JABAL SAYID
VMS BELT
Mahd Adh Dhahab
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
Steel Metals
Iron
Faults
Normal faults
Detachment faults
GEOLOGY LEGEND
See Fig. 65-1
Scale 1 : 500,000
0 5 35
Kilometres
UTM WGS84 Zone 37N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology and Mineral Occurrences of the Jabal Sayid VMS Belt
Figure 65.

The Jabal Sayid prospect has had a very long exploration history which in most respects parallels that of some other prospects in the Kingdom. Many workers, including the BRGM, came to negative conclusions regarding the project, including Ma'aden which held the exploration licence for many years before relinquishing it only to see the licence immediately acquired by a junior exploration company, Citadel Resources Group Ltd. of Melbourne, Australia. After several drilling programs, Citadel was acquired by Equinox Minerals Ltd. which was then acquired by Barrick Gold. In 2014, Barrick formed a 50:50 joint venture with Ma'aden, for the latter bringing the project full-circle. The decision to bring the deposit into production was based on the February, 2009 resource estimate by Citadel as follows:

Resource Classification	Type	Tonnes (millions)	Copper (%)	Tonnes Copper (x1,000)	Zinc (%)	Tonnes Zinc (x1,000)
Indicated	Massive Sulphide	6.4	1.21	77	1.67	106
	Stockwork	24.8	1.62	403	0.17	42
	Oxide	0	n/a	0		0
	All	**31.2**	**1.54**	**480**	**0.47**	**148**
Inferred	Massive Sulphide	15	0.8	114	1.9	279
	Stockwork	52	1.2	613	0.3	144
	Oxide	.5	1.6	7	0.3	1
	All	**67**	**1/1**	**735**	**0.6**	**425**
Total	Massive Sulphide	21	0.9	192	1.8	385
	Stockwork	77	1.3	1,016	0.2	186
	Oxide	.5	1.6	7	0.3	1
Grand Total		**99**	**1.2**	**1,215**	**0.6**	**572**

Of the total estimated resources of 99 Mt averaging 1.2% Cu at a 0.2% Cu cut-off grade, the mine plan involves the mining of 32.2 Mt using a 1% copper grade as the cut-off for copper ore blocks. The underground and open cut mining of the deposit has been extensively studied, and the mine plan involved staged development as follows:

Ore Body 1 — Open-cut mining was carried out on a resource of 1.35 Mt grading 1.3 g Au/t in oxidized gold mineralisation out-cropping at surface together with approximately 0.5 Mt of copper ore averaging 1.6% Cu.

Ore Body 2 and 4 — The existing decline for underground access was enlarged to handle larger underground haul trucks that can haul up to 100 t for production. Conventional large scale open stopes were planned for extraction of ore, with selective stope development to optimise grade over the life of the project. A transition to shaft hoisting in later years was also planned.

The ore to be mined from Lode 2 and 4 underground and delivered to the concentrator over the 11-year life of mine will total 30.4 Mt with an average copper grade of 2.26% and average gold and silver grades of 0.14 g/t and 8.11 g/t, respectively, however it is expected that overall precious metal grades will increase. The production rate is expected to average 2.8 Mt per year.

The Umm ad Damar area was over-flown in 1962 as part of a regional (3,930 km2) magnetometer-scintillometer survey conducted by Hunting Survey Corporation. Ground surveys comprising Turam, SP, magnetic, IP-resistivity, gravity and mise-a-la-masse were subsequently completed (ARGAS, 1975). Turam anomalies reflected zones of faulted and weathered bedrock. SP anomalies indicated a series of conductors which were confirmed by the IP survey. Graphitic shale resulted in local gravity lows. In early 1963, additional airborne magnetic surveys were carried out in addition to 26.3 line-kilometres of ground magnetometer, EM, resistivity and seismic surveys. Copper mineralization was found to occur on the flanks of isolated magnetic anomalies and to be marked by EM anomalies and zones of low resistivity (Agocs, 1963a). Other magnetic and EM anomalies occur away from known mineralization. Additional EM conductors up to 2,133 m long and 2-3 times stronger than anomalies affiliated with the main areas of mineralization were detected (Agocs, 1963b). On the basis of these results, further ground magnetometer surveying and 1,661 m of drilling were recommended. In 1964, three diamond drill holes (DDH 1, 2 and 3) totalling 259 m were completed on the south prospect (Bhutta, 1966). Two of these holes intersected chalcopyrite stringers and broader zones of intense pyritization. The best intersection, obtained in hole DDH-3, assayed 4.8% Cu, 1.2% Zn and 57.2 g Au/t over 1.52 m (Bhutta). Two gold-bearing sections grading 6.9 g/t over 0.30 m and 2.4 g/t over 0.46 m were detected. Drill core recoveries were poor, generally ranging from 10% to 50%. Four additional diamond drill holes numbered DDH-4 to DDH-7 totalling 982 m were completed on the north prospect. Hole DDH-4 intersected a 10.7 m thick section averaging 0.8% Cu, 0.72% Zn, 9.2 g Ag/t and traces of gold.

Over the next few years, the BRGM carried out additional geophysical surveys and in 1968 completed three diamond drill holes (DA1, DA2, DDH3a) totalling 456.4 m on the south workings (Ransom, 1982). Drill hole DDH-3A, sited 70 m to the northeast of known sulphide mineralization, did not intersect economically significant mineralization. Between then and 1984, successive exploration programs of mapping, geophysical surveying and diamond drilling (12 holes totalling 2554.65 m) the discovery of new gossans, intersections ranged from 1 to 5 m assaying 1.03 to 2.04% Cu. Interestingly, the drilling carried out by Serem-US Steel was all down-dip. One hole intersected a 9 m section grading 2.3% Cu and 27.5 g Ag/t. Serem-U.S. Steel estimated that mineralization at Umm ad Damar South totalled approximately 1 Mt grading 2% Cu and 1.0% to 2.5% Zn with a small precious-metal content (Ransom, 1984).

Riofinex began an evaluation of the Umm ad Damar prospect in 1979 commencing with detailed mapping as well as ground magnetometer and IP surveying. The 4/6 Gossan about 1.2 km northwest of the south workings, was discovered during the 1982-83 field season. Follow-up work included detailed mapping trenching, IP surveying and percussion drilling. Riofinex extended the area of exploration west and southeast of the ancient workings, and alluvium in the new areas were geochemically sampled from a depth of 2-3 m by augering, but results were compromised by local supergene mineralization within calcrete at

approximately 2.5 m depth. The IP surveys on 100 m lines indicated that mineralized zones, extended westerly for 200 m beyond previously defined limits. Anomalies in the Southeast extension area were drill-tested and found to contain no mineralization. Riofinex collected weathered bedrock samples from 448 auger holes at stations 10 to 20 m apart, along survey lines spaced at 50 to 100 m over the 4/6 Gossan and approximately 5.8 line-kilometres of IP surveying was carried out. A strong chargeability anomaly was detected, and 14 trenches totalling 644 m were excavated across this anomaly. Channel samples assayed across lenticular bodies of hydrothermal alteration in pyritic rhyodacite contained as much as 3.2% Cu and 6.5% Zn over unspecified distances. Two percussion holes, UAD-13 and UAD-14 totalling 137 m were completed. In the first hole, a 9 m section graded 0.88% Cu, 1.95% Zn, 0.5 g Au/t and 7.2 g Ag/t. A 4.2 m intersection in the second hole averaged 1.15% Cu, 0.25% Zn, 1.02% Pb, 16.1 g Au/t and 449.8 g Ag/t. A single follow-up hole was recommended to undercut hole UAD-14. Riofinex concluded that mineralization in the South and Southeast Zones was stratabound, but that the exact geological relationship of mineralized areas or zones was unclear. Strike extensions were limited or interrupted by faults and intrusive rocks, and further work was recommended. Riofinex considered the presence of a large tonnage copper deposit to be remote, and suggested a maximum deposit size of 1 Mt grading 2% Cu, 2% Zn, and 30 g Ag/t to a depth of 200 m. Additional detailed geological mapping and IP surveying was recommended. During 1984, Ransom's re-evaluation of the drilling led to the conclusions that the drill holes on the North Prospect did not adequately test the known mineralized zones and IP conductors. Two additional diamond/percussion holes (UAD-11, UAD-12) were drilled and hole UAD-11, drilled to a depth of 150 m of which the upper 40 m was percussion drilled, intersected a 16 m thick (true) zone averaging 0.66% Cu, 0.12% Zn and 12.9 g Ag/t within which a 2.7 m section assayed 1.87% Cu (Howes, 1984).

Following this further geophysical surveying was recommended in the form of a blanket IP survey across all zones to unify the model and to fill gaps in the knowledge base. During 1986, the BRGM undertook an evaluation of the Jabal Sayid - Umm ad Damar - Mahd adh Dhahab region, and concluded that Umm ad Damar was unlikely to contain massive sulfide mineralization of the Jabal Sayid type. Nevertheless, the BRGM remapped and resampled the ancient workings and the Riofinex trenches, unfortunately using the MIBK analytical extraction method for gold and silver which mostly failed to detect significant precious metal values. During 1988, the DGMR carried out detailed mapping and the collection of 245 bedrock samples for geochemical analysis. No statistically significant enrichment was found in areas of sodic or potassic alteration. Since that time, the Umm ad Damar prospect has been located on an exploration licence owned by Ma'aden and no further reports on exploration activities have been made available. This also applies to other deposits in the Jabal Sayid belt such as the Jibal Lahaf (Lahuf) prospect.

Geology

The gold, silver and base-metal mineralised gossans that occur in the Jabal Sayid area have been mined since pre-historic times. Jabal Sayid is a copper-rich, volcanic-hosted sulphide deposit, hosted by felsic volcanic rocks that include extrusive, intrusive and fragmental rhyolites. The host rocks are NE-trending and dip almost vertically. They have been interpreted as forming the northern limb of a localised anticline

that is formed around a core of intrusive rhyolite, associated with parallel NW-trending axial plane shears

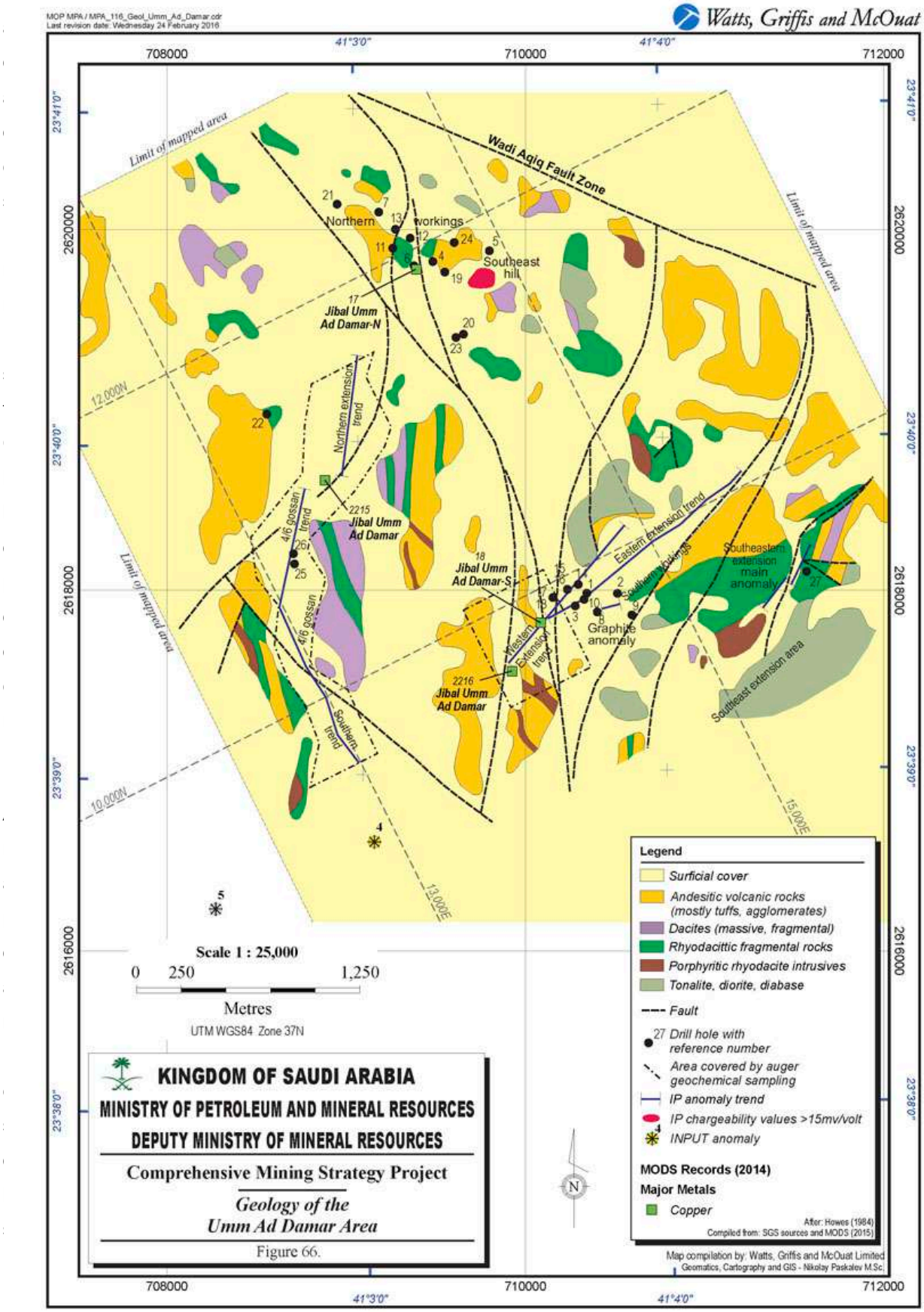


Figure 66: Geology of the Umm Ad Damar Area

fragmental unit and is spatially associated with sheared sericite-chlorite schist and chlorite-amphibole rock. Sulphide is commonly laminated within a schistose chloritic groundmass. Anastamosing pyrite veinlets are common along the margins of the zone and define a banding thought to be a result of deformation. The host sequence may be a large, deformed breccia zone (Ransom, 1982).

Recommendations

The Jabal Sayid mineral belt hosts the largest known VMS deposit in Saudi Arabia. It ranks as a large deposit even by worldwide standards. An airborne EM and Mag (and possibly gravity) survey is recommended for this belt using modern equipment. Any resulting anomalies should be followed up by a combination of prospecting, sampling and drilling. The use of down-hole EM is recommended for the Jabal Sayid deposit and the potential to expand the presently known resource is considered to be excellent.

There is no reason to repeat previous exploration surveys at Umm ad Damar, however there is good reason to compile the work done to date and to determine to what extent anomalies have been adequately tested. Exploration is more than a simple task of drilling anomalies as shallowly as possible. Our ability to use geophysical surveying to detect mineralization at depth is limited. Combined with a desire to constrain exploration costs, this tends to limit how deeply we test favourable geological environments. Even when our metallogenic model remains valid to significantly greater depths, prospects and targets have been denied and downgraded based only on shallow drill holes. When exploration models remain open and untested at depth, we must account for the potential for a deposit to be deeper than we have explored. The top of the No. 3 Orebody at Jabal Sayid occurs at a depth of 200 m. How can Umm ad Damar be dismissed as uneconomic when most of the drilling has tested zones above 150 m. The exploration to data has focused on testing anomalies without a clear appreciation of the overall geological environment. Following a thorough compilation of the exploration data, a 3D model should be constructed of the paleo-geological volcanic environment and the associated seafloor terrain to identify possible locations of mineralization based on conventional metallogenic models. Within this context, and while recognizing the need for deeper, systematic drilling, further exploration is recommended to test several airborne geophysical anomalies which may be indicative of stratabound volcanogenic Cu-Zn-Ag mineralization within felsic volcanic rocks southwest of Umm ad Damar. Work initiated by Riofinex on the south and southeast zones should be continued to the south and west along the felsic volcanic units. The airborne INPUT map of the area shows two untested anomalies within this sector (anomalies 4 and 5) and thematic anomaly maps of the area have detected a gossan near the contact with the Mahd Formation (Bobillier, 1979). The anomalies should be located on the ground by approximately 20 km of HLEM and ground magnetic surveys. Resultant ground electromagnetic anomalies should be tested by trenching or diamond drilling keeping in mind the physical size of a significant orebody, and the need to space drill holes according – that is, open up the grid and increase the horizontal and vertical spacing of drill holes.

An airborne EM and Mag (and possibly gravity) survey is recommended for the entire mineral belt using modern equipment and all anomalies should be followed up by prospecting, sampling and drilling.

3.2.3.10 Al Ays VMS Belt

Location, History and Status

The Al Ays mineral Belt is located in the Hijaz Terrane covering an area of about 15,033 sq. km. It comprises rocks of the Al Ays Group (<745->700 Ma), a bimodal volcanic assemblage accompanied by volcaniclastic and sedimentary members (Figure 67). Along its north edge the belt disappears under Paleozoic sedimentary rocks, and to the east and southeast it is covered by basalts of Harrat Khaybar. The Dabah Fault Zone forms the southwestern boundary. It should be noted that the Al Ays Group rocks cross the Dabah Fault extending to the south all the way to Madinah. However this extension has not been included in the mineral belt boundaries because it lacks any mineral occurrences. This suggests that the environment in this section (lithological facies) was not conducive to the formation of VMS deposits. The belt is remarkably deficient in VMS prospects hosting only three that fall into this class. A listing of the occurrences assigned to the VMS classification is presented in Table 46.

Table 46
Summary of Occurrences in the Al Ays VMS Belt

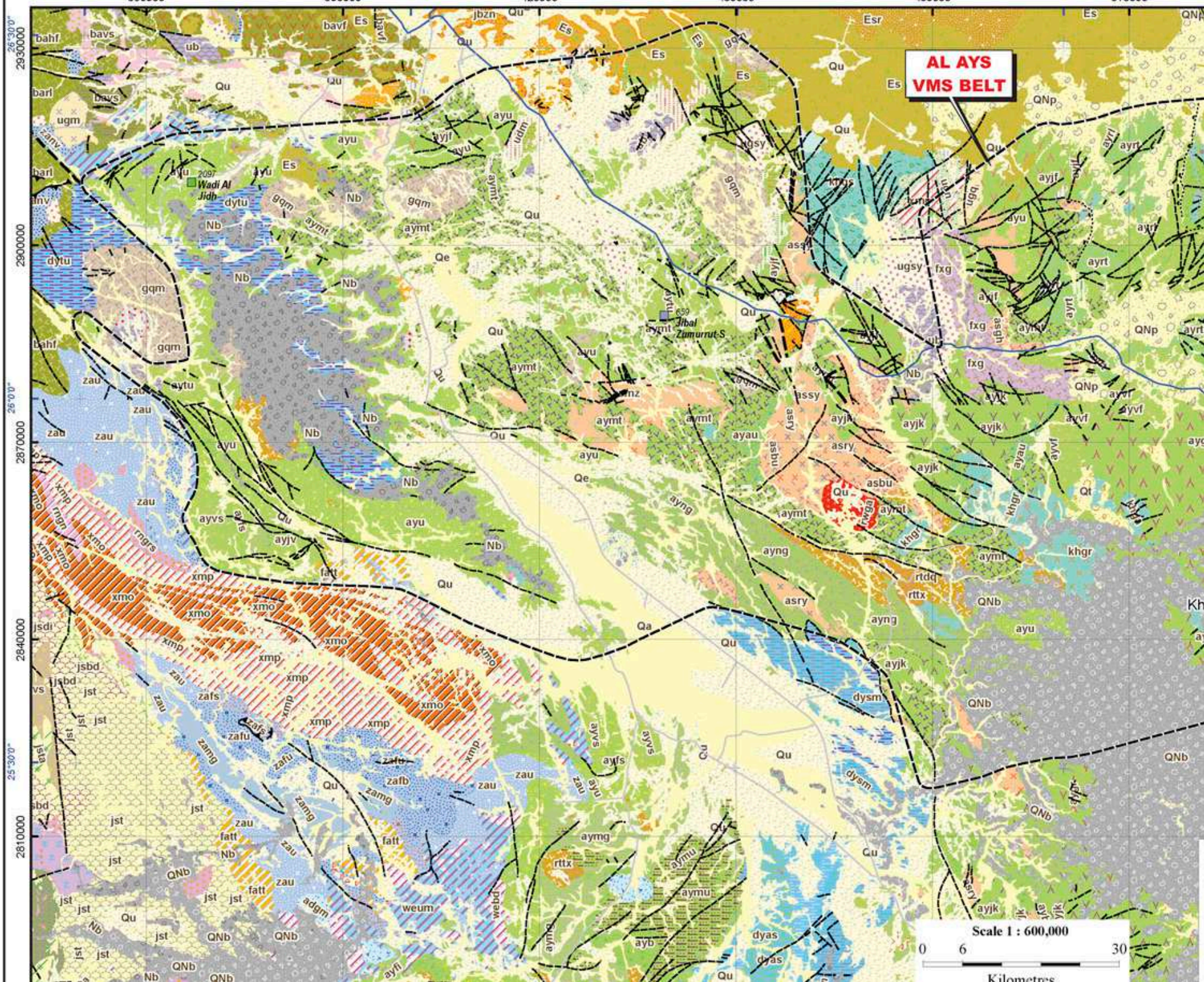
MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
2097	Wadi Al Jidh	Wadi Jad'He	Cu	37.6666670	26.3000000	Al Ula	Low	stockwork, dd
0659, 0659	Jibal Zumurrut-S	Qal'At Zumurrud-SE	Pb	38.3902780	26.1219440	Al Ula	Medium	dd, v

NOTES: 1) ranking according to MODS 2) v=veins, dd = disseminated; bx = breccia; ms = massive
* classified as VMS based on limited descriptions – no resource estimates available

During regional geologic mapping by Hadley (1973), no significant metallic minerals were observed although one of six samples contained 110 g Au/t. No further work was recommended, and none is known to have been subsequently done.

Geology

There are only two occurrences in this belt with possible VMS affinities and the most prospective is the cluster of ancient mine workings and occurrences at Qalat Zummurrud (Figure 68). The ancient workings of Qalat Zumurrud North (MODS 0658, 0659) consist of trenches, shafts and pits in several different zones over an area of about 1 km^2 on two sides of a wadi. Limonitic quartz and calcite veinlets occur in andesitic volcaniclastic rocks adjacent to a small quartz diorite intrusion (Hadley, 1973, 1987).


AL AYS
VMS BELT
Wadi Al Jidh
Jibal Zumurrut-S
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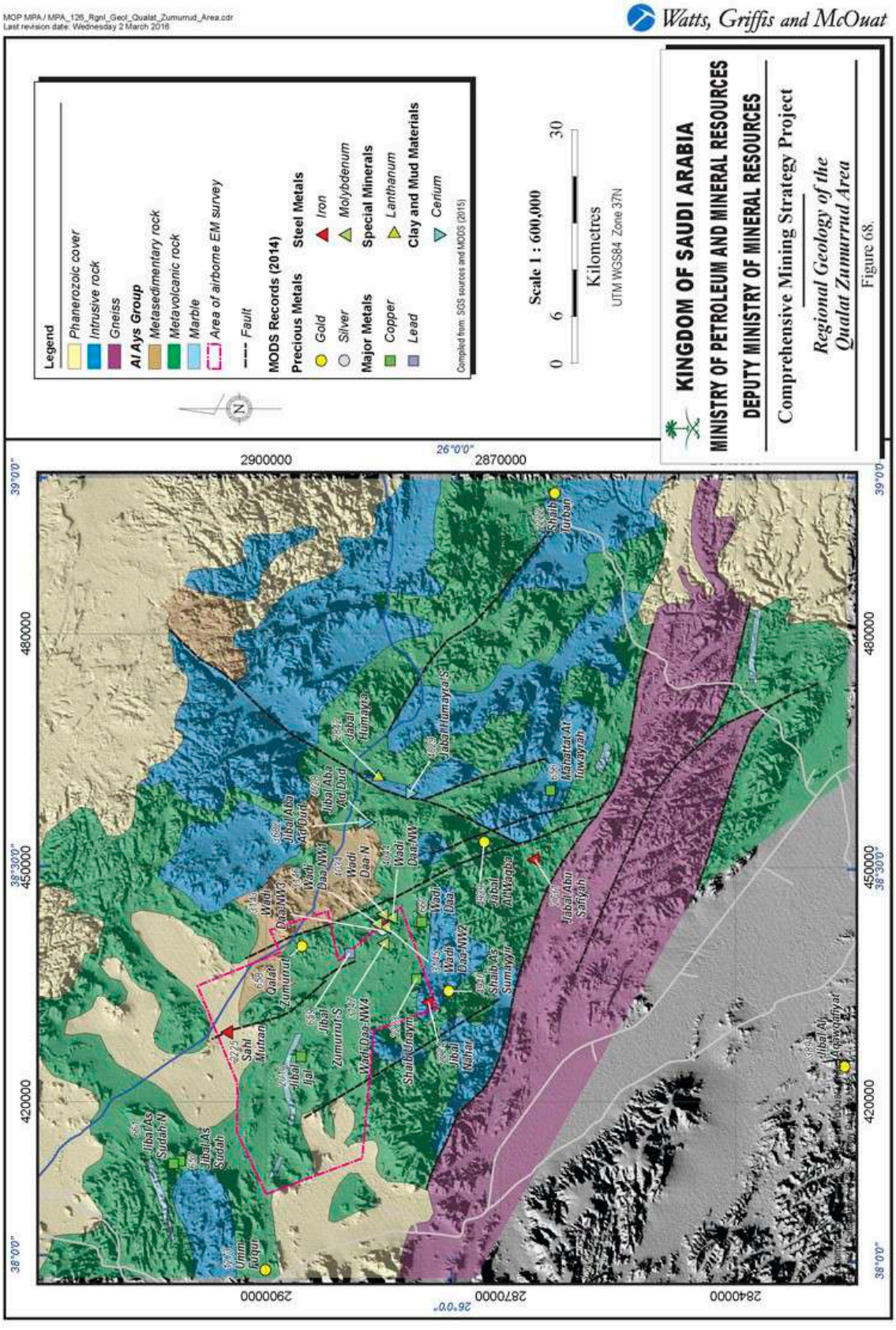
0 6 30
Kilometres


MOP MPA / MPA_126_Rgnl_Geol_Qualat_Zumurrud_Area.cdr
Last revision date: Wednesday 2 March 2016
Watts, Griffis and McOuat
Legend
Phanerozoic cover
Intrusive rock
Gneiss
Al Ays Group
Metasedimentary rock
Metavolcanic rock
Marble
Area of airborne EM survey
Fault
MODS Records (2014)
Precious Metals
Steel Metals
Gold
Iron
Silver
Molybdenum
Major Metals
Special Minerals
Copper
Lanthanum
Lead
Cerium
Clay and Mud Materials
Compiled from: SGS sources and MODS (2015)
Scale 1 : 600,000
0 6 30
Kilometres
UTM WGS84 Zone 37N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Regional Geology of the Qualat Zumurrud Area
Figure 68.
2900000
2870000
2840000
480000
450000
420000
39°0'0"
38°30'0"
38°0'0"
26°0'0"
Jabal Humayra
Jabal Humayra S
Mahattat Al Inwayah
Jabal Abu Ad Dud
Wadi Daa NW3
Wadi Daa-N
Wadi Daa-NW
Wadi Daa
Wadi Daa NW2
Jabal Al Waqba
Jabal Abar Sanyan
Shaib As Sumaygir
Qalat Zumurrud
Jabal Zumurrud S
Wadi Daa NW4
Shaib Unaym
Jabal Nehar
Sahl Muthan
Jabal Ijal
Jabal As Sudah
Jabal As Sudah N
Umm Fuqur
Shaib Turban
Jabal Al Aqawiriyat

Recommendations

This mineral belt contains only two possible VMS occurrences therefore the potential of the area is not considered to be great. The work recommended by WGM in CR-11-10 is still valid for this area.

WGM recommends that 1:2,000 scale geological mapping and additional systematic (channel) sampling of ancient workings be carried out at Qalat Zumurrud. Trenching might be facilitated with the assistance of a backhoe or excavator. The sampling of the mineralized zone should be systematic with no sample longer than one metre, and all sampled intervals to be broken at major lithological contacts. GPS instrumentation must be used for spatial control for trench locations, samples and geological formations and structures.

3.2.3.11 Nuqrah VMS Belt

Location, History and Status

This mineral belt lies in the western portion of the Afif Terrane covering an area of 7,671 sq. km (Figure 69). It is composed of rocks belonging to the Isamah Formation (~840 Ma) that form an assemblage of greenschist facies mafic to felsic volcanic rocks with minor sediments. The belt is bounded on the north and south sides by the Halaban-Zarghat and the Sukhaybarah Fault Zones respectively, which comprise part of the Nabitah Fault swarm. The eastern side of the Nuqrah Belt abuts the younger Jiddah series granites, while the west side of the belt is in contact with the Hulayfah volcanic belt.

The main VMS deposits in the Nuqrah Mineral belt are the Nuqrah North and South deposits and the An Nimarah deposit. The An Nimahr area is located 40 km west of Nuqrah. Ancient workings with copper and lead mineralization lie in a steeply dipping belt of SSW-striking Halaban rocks. The ancient workings are located within a pyroclastic sequence that is similar to that found at Nuqrah and at Jabal Sayid. The Nimarah mineralization consists of sphalerite, chalcopyrite and pyrite with subordinate alabandite, galena, pyrrhotite and traces of molybdenite. Based on two drill holes, only one of which intersected mineralization, the BRGM estimated that the prospect contains a resource of approximately 200,000 tonnes (Delfour, 1975). The drill hole intersection was 7 m in length with an average grade of 0.6% Cu, 0.35% Pb, 3.63% Zn, 1 g Au/t and 36 g Ag/t. The belt also contains a substantial number of copper occurrences, most of which do not have VMS affinities. Table 47 summarizes the known and assumed VMS deposits/occurrences in the belt.

The Nuqrah North and South prospects are the most significant in the Nuqrah mineral belt. The Nuqrah North (MODS 0014) and South (0013) Zn-Cu-Pb-Au-Ag deposits are the most intensively explored deposits

in the belt. The ancient workings of North Nuqrah comprise a series of aligned trenches over a distance of 200 m.

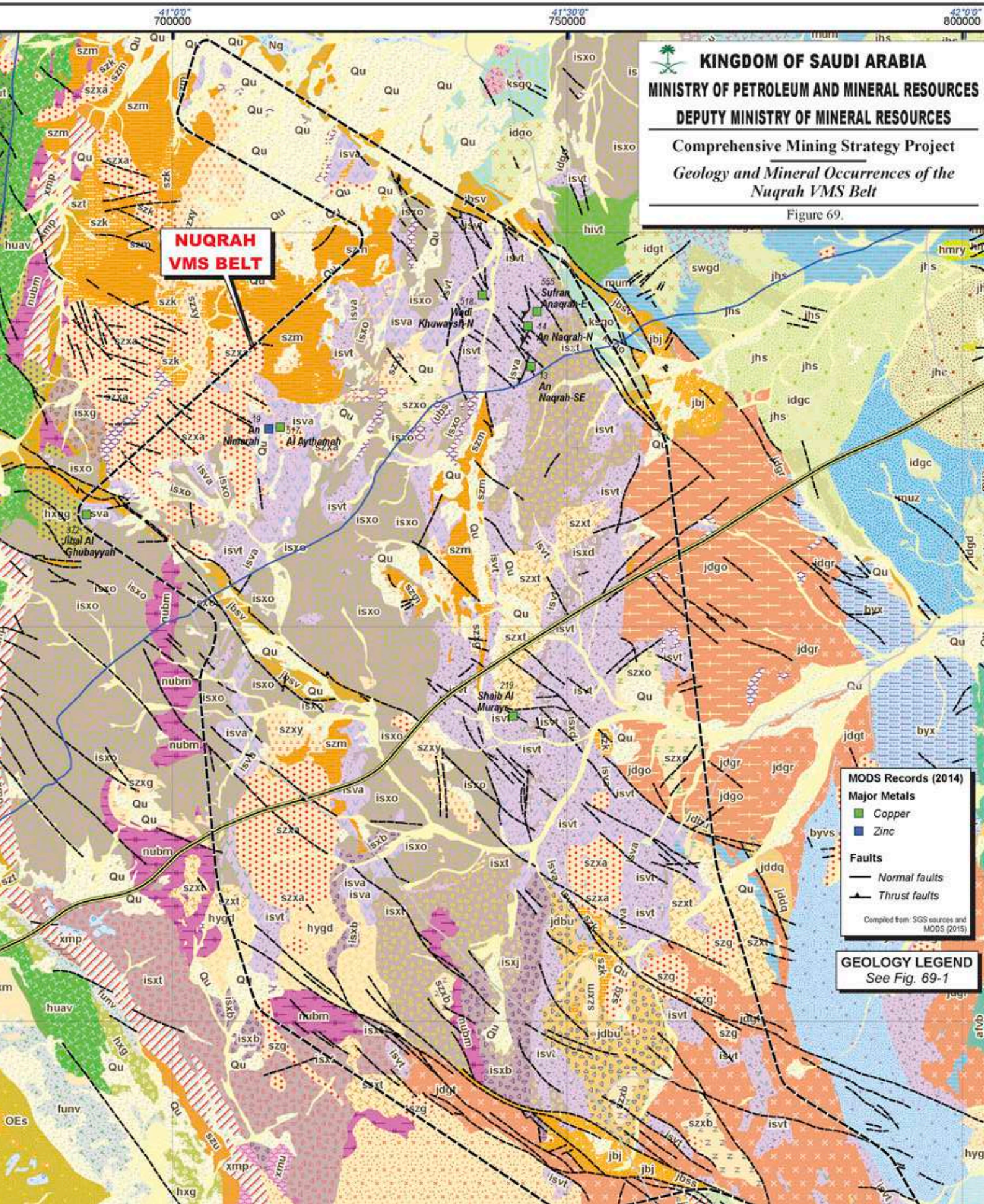
Table 47
Summary of Occurrences in the Nuqrah VMS Belt

MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0002	Jibal As Sufrah-N2	As Safra	Cu	41.8973610	24.2221670	Al Mahd	Medium	dd, stockwork v
0013	An Naqrah-SE	Nuqrah-SE	Cu	41.4430280	25.5943890	Riyad al Khabra	Medium	lenses
0014	An Naqrah-N	An Naqrah-N	Cu	41.4403890	25.6408060	Riyad al Khabra	Medium	lenses, bedded
0219	Shaib Al Murayr	Jabal Subhah	Cu	41.4127500	25.1946390	Riyad al Khabra	Low	v
0372	Jibal Al Ghubayyah	Jabal At Tuwalah	Cu	40.8807220	25.4330560	Riyad al Khabra	Low	stockwork v
0517	Al Aythamah	Al Aythamah	Cu	41.1263890	25.5298890	Riyad al Khabra	Medium	stratiform
0518	Wadi Khuwaysh-N	Wadi Al Abub	Cu	41.3837500	25.6771940	Al Hinakiyah	Medium	dd, v
0555	Sufran Anaqrah-E	Nuqrah	Cu	41.4518890	25.6568330	Al Hinakiyah	Low	undetermined
0019	An Nimarah	An Nimmar	Zn	41.1117780	25.5280830	Al Ghazalah	Medium	dd, lenses

NOTES: 1) ranking according to MODS 2) v=veins, dd = disseminated; bx = breccia; ms = massive
* classified as VMS based on limited descriptions – no resource estimates available

From 1967 to 1969, regional geophysical surveys (airborne electromagnetic, magnetic and scintillometer) were flown over the Nuqrah area and the mineralized belt was mapped at a scale of 1:100,000 with limited wadi and alluvial geochemical sampling. Follow-up ground geophysical surveys (IP, Turam, SP, and magnetic) were completed over the Nuqrah North and South deposits. A total of 17,292 m of drilling was carried out in the Nuqrah North and South deposits by the various exploration agencies. Resource estimates were made by several parties at different times but some of the most recent estimates were by Holzem (1976a). He calculated resources at Nuqrah South as 811,000 t grading 1.14% Cu, 3.01% Pb, and 7.46% Zn with 5.64 g Au/t and 199.5 g Ag/t. At Nuqrah North, the resources were estimated at 275,000 t grading 0.88% Cu, 1.99% Pb and 6.39% Zn together with 1.78 g Au/t and 173.3 g Ag/t. Petromin/Granges received an exploration licence for the area in 1978 and carried out a program of geophysical surveying and 4,000 m of diamond drilling which then supported a feasibility study in 1980. Using the information gained from their drilling program at Nuqrah South, the resources at this deposit were recalculated as 610,000 t ("drill-indicated plus inferred") grading 1.5% Cu, 4.8% Pb and 11.0% Zn with 8.7 g Au/t and 347 g Ag/t. Due to the lack of work at Nuqrah North, Petromin/Granges accepted Holzem's (1976a) resource estimate.

The An Nimahr area of ancient mine workings is located about 40 km west of Nuqrah. The early exploration of this area was carried out as part of the programs covering Nuqrah. This work was done by the DMMR, the BRGM, Nippon Mining Co. and Granges International Mining. In 1967, ARGAS completed an airborne magnetometer and scintillometer survey over the Nuqrah and An Nimabr areas.


41°0'0"
700000
41°30'0"
750000
42°0'0"
800000
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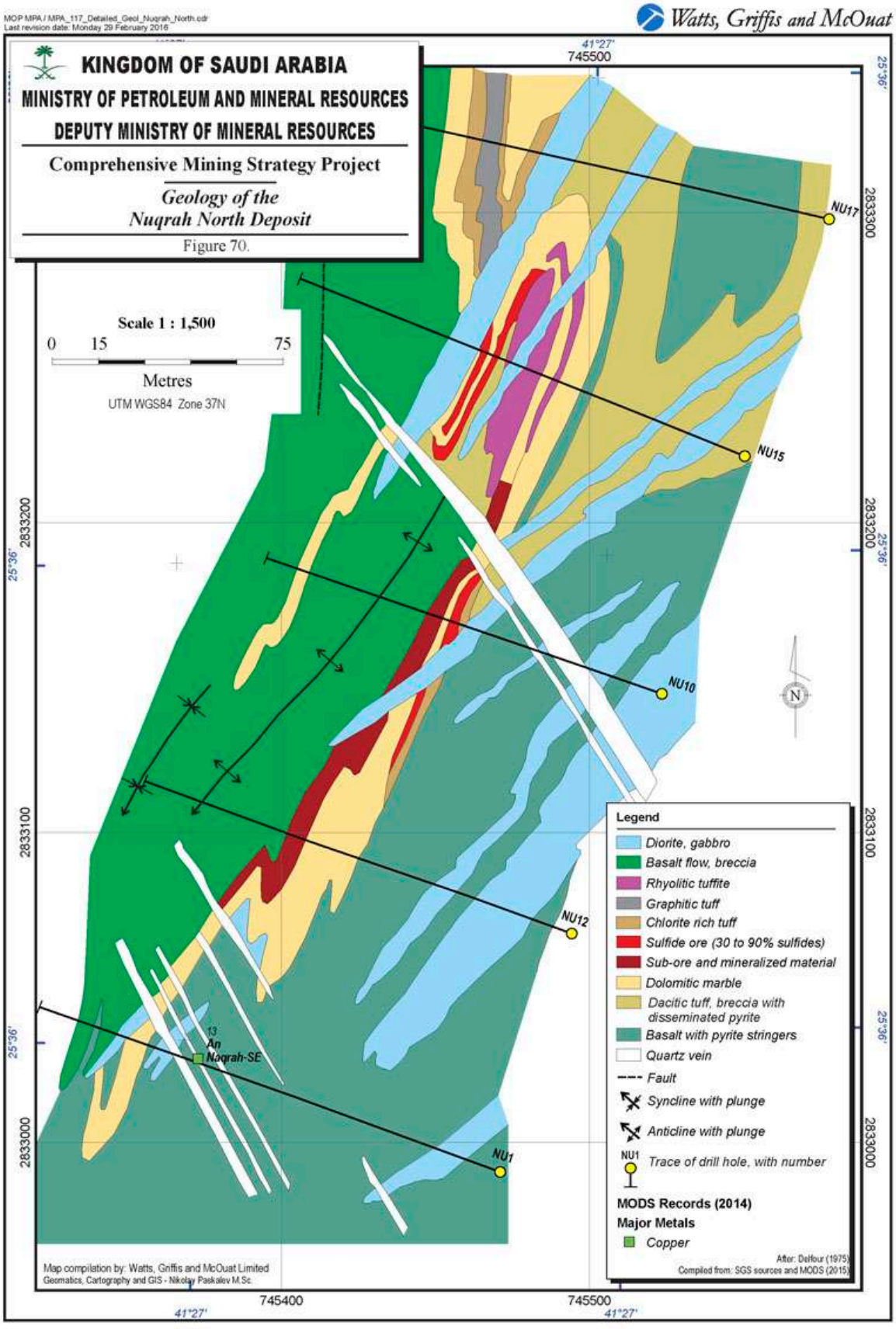
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology and Mineral Occurrences of the Nuqrah VMS Belt
Figure 69.
NUQRAH VMS BELT
Sufran Anaqrah-E
Wadi Khuwaysh N
An Naqrah-N
An Naqrah-SE
An Nimrah
Al Aythamah
Jibal Al Ghubayyah
Shaib Al Murays
MODS Records (2014)
Major Metals
Copper
Zinc
Faults
Normal faults
Thrust faults
Compiled from: SGS sources and MODS (2015)
GEOLOGY LEGEND
See Fig. 69-1

This was followed by an INPUT surveys in the An Nirnahr area in 1969. During this early period, the Nuqrah-An Nimahr area was geologically mapped at 1:100,000 scale concurrently with wadi sediment and alluvial geochemical sampling. These surveys were the basis for a series of exploration programs carried out between 1969 and 1980 that were directed at follow-up of airborne geophysical anomalies and with intensive investigations of the An Nimahr deposit. During 1970, the BRGM completed 4 drill holes totalling 1,247 m in the An Nirnahr area. This was followed by 3 drill holes (767 m) completed in 1975 by Nippon Mining in the An Nimahr area. The drilling intersected semi-massive base metal sulfides hosted by altered tuff and marble. The best intersection was 10.9 m grading 0.93% Cu. 0.15% Pb. 3.90% Zn, 0.85 g Au/t and 23 g Ag/t (Duhamel, 1975). Several narrow intersections had significantly higher copper values, for example, 0.40 m assaying 5.38% Cu, 0.17% Pb, 1.25% Zn and 31 g Ag/t (Clegg, 1985). The SGS report an initial resource estimate of approximately 200,000 tonnes grading 0.7% Cu, 0.4% Pb, 4.0% Zn and 30 g Ag/t. WGM did not have the in-puts for this model at the time of this review, but it is doubtful that the stated resources would meet current best practices standards in the minerals sector. It is uncertain what work has been done at An Nimahr since this time as the area is on a Ma'aden licence.

Geology

At Nuqrah North, mineralization is hosted by dacitic to rhyolitic tuffs and basaltic flows with minor intercalated marble and graphitic rocks (Figure 70). The mineralization consists of SE-dipping massive to semi-massive sulphide lenses approximately 3-15 m thick composed of pyrite, sphalerite and galena. These are intercalated with a carbonate/graphite/chert unit and underlain by highly altered (chlorite, talc, carbonate) rhyolitic tuffs. The sulphides are generally overlain stratigraphically by massive andesite flows. The sequence at North Nuqrah appears to be overturned. The ancient workings at South Nuqrah are more extensive than those at North Nuqrah, and consist of a discontinuous, 200 m long trench and a large pit roughly 30 m in diameter and 12 m deep. The geology of the deposit is very similar to that of North Nuqrah and the stratigraphic sequence consists of a lower, 1,000 m thick unit of rhyolitic crystal and lapilli tuff composed of flow-structured rhyolite, pumiceous rhyolite and some andesitic pumice. This is a very homogenous and compact unit with minor andesitic flows and andesitic tuff. The uppermost part is strongly altered with sericite and chlorite, and carries up to 20% pyrite. This unit is overlain by alternating lenses of calcareous to dolomitic marble and brecciated marble, gray fine-grained or crystal rhyolitic tuff, graphitic crystal tuff, graphite and/or chlorite schist, and localized black jasper. In the upper part, sulphide mineralization is associated with graphitic and chloritic material. This unit is overlain by a single slightly porphyritic amygdaloidal andesite flow which in turn is overlain by alternating reworked fine-grained or crystal rhyolitic tuff, sometimes graphitic and chloritic, and gray flow-banded rhyolite (soda rhyolite or quartz keratophyre). The sulfides at Nuqrah South (Figure 71) are conformable with the host rocks striking NNE and dipping 55°-70° W. They comprise a lens about 300 m long and 5-6 m thick composed of variable amounts of pyrite, chalcopyrite, galena, sphalerite, hessite and altaite.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Last revision date: Monday 29 February 2016
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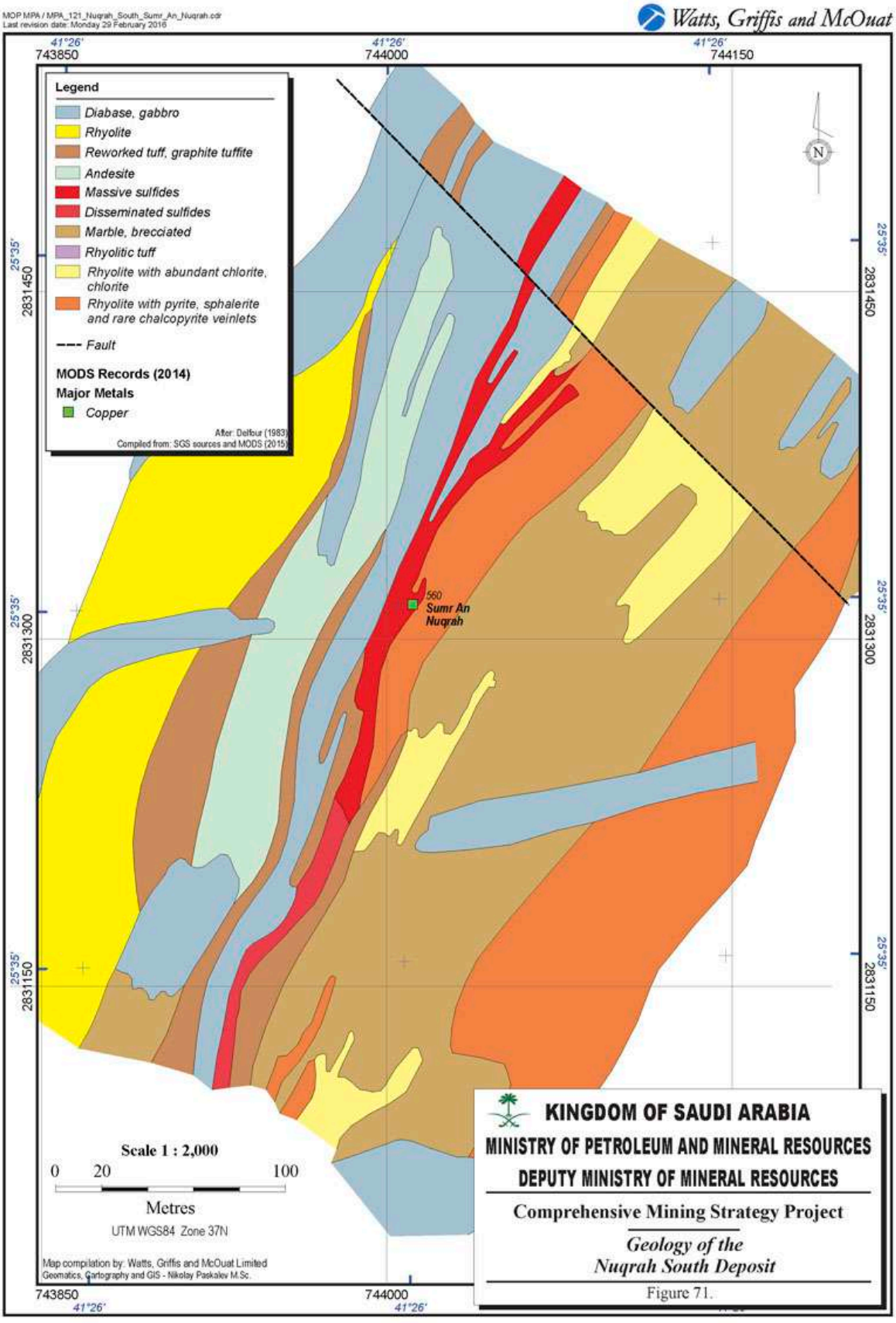
Geology of the
Nuqrah North Deposit
Figure 70.
Scale 1 : 1,500
0 15 75
Metres
UTM WGS84 Zone 37N
41°27'
745500
25°36'
2833300
2833200
2833100
2833000
NU17
NU15
NU10
NU12
NU1
13
An
Nuqrah-SE
N
Legend
Diorite, gabbro
Basalt flow, breccia
Rhyolitic tuffite
Graphitic tuff
Chlorite rich tuff
Sulfide ore (30 to 90% sulfides)
Sub-ore and mineralized material
Dolomitic marble
Dacitic tuff, breccia with disseminated pyrite
Basalt with pyrite stringers
Quartz vein
Fault
Syncline with plunge
Anticline with plunge
NU1
Trace of drill hole, with number
MODS Records (2014)
Major Metals
Copper
After: Delfour (1975)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
745400
745500
41°27'


MOP MPA / MPA_121_Nuqrah_South_Sumr_An_Nuqrah.cdr
Last revision date: Monday 29 February 2016
Watts, Griffis and McOuat
41°26'
743850
744000
744150
25°35'
2831450
2831300
2831150
Legend
Diabase, gabbro
Rhyolite
Reworked tuff, graphite tuffite
Andesite
Massive sulfides
Disseminated sulfides
Marble, brecciated
Rhyolitic tuff
Rhyolite with abundant chlorite, chlorite
Rhyolite with pyrite, sphalerite and rare chalcopyrite veinlets
Fault
MODS Records (2014)
Major Metals
Copper
After: Delfour (1983)
Compiled from: SGS sources and MODS (2015)
560
Sumr An Nuqrah
N
Scale 1 : 2,000
0 20 100
Metres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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Geology of the
Nuqrah South Deposit
Figure 71.

The An Nimahr deposit is hosted in steeply dipping, NNE-striking Halaban Group volcanic and volcaniclastic rocks. The current structural hanging wall of the deposit is meta-andesite which overlies a sequence of felsic meta-pyroclastic rocks containing carbonate (talcose dolomitic marble) horizons. The sequence is NE-dipping but probably over-turned. Ancient workings are focused mostly on the marble horizons. The mineralization is composed of sphalerite, chalcopyrite and pyrite, with subordinate alabanite, galena and pyrrhotite with traces of molybdenite. The geological setting is very similar to that at Nuqrah. As mentioned in the history section for this VMS belt, WGM does not consider the previously reported mineral resources of 200,000 tonnes to be credible.

Recommendations

The recommendations proposed by WGM in CR-11-12 are still valid including the regional airborne geophysical surveys. Deep penetrating ground EM surveying such as the TITAN system is warranted in the immediate vicinity of the Nuqrah North and South deposits.

Given the long history of work at Nuqrah, all available data should be compiled onto a set of plans, cross-sections and longitudinal sections, probably at 1:1,000 scale. These will permit an evaluation of the entire database and should improve the definition of the geometry of the sulphide lenses. Given the length of time since any of the work was completed, the central area should be subjected to detailed GPS-controlled mapping at 1:5,000 scale. Lithogeochemical sampling on a 200 x 100 m grid is also justified using both bedrock and alluvium as sample media. A selective leach geochemical technique should be used for alluvium to test its ability to trace buried mineralization. Geophysical equipment has evolved substantially in the three decades since most of the geophysical survey work was completed. Modern EM and magnetometer surveys are warranted, especially deep penetrating time domain EM surveying such as PEM or UTEM or the TITAN system is recommended, particularly for the geologically favorable area immediately surrounding and between the two deposits.

WGM also recommend that the Nuqrah North and South sulphide lenses be diamond drill tested to their outer limits at no greater than 50 m intervals along strike and down dip. This is estimated to require approximately 23,000 m of drilling. In addition to assaying mineralized intercepts, the core should be sampled at about 25 m intervals and analyzed for major oxides to characterize the alteration types and intensities associated with the deposit. Drill holes below depths of 200 m should be surveyed with down hole time or frequency domain electromagnetic equipment to seek additional "hidden" (off-hole) sulphide lenses.

Although the BRGM resource estimate of 200,000 tonnes is not credible, the 7-metre intersection averaging 3.63% Zn, 0.6% Cu, 0.35% Pb, 0.1 g Au/t and 36 g Ag/t is very interesting from an exploration perspective. The An Nimahr deposit is certainly under-explored and warrants additional exploration. The drilling completed thus far has been successful in confirming the presence of economically interesting VMS-type

mineralization and the work to date represents a good first step. The prospect requires follow-up deep IP surveying to locate targets for drilling. The deposit should be modelled in 3D and additional staged drilling of IP targets should be based on this model.

3.2.3.12 Shaib Lamisah VMS Belt

Location, History and Status

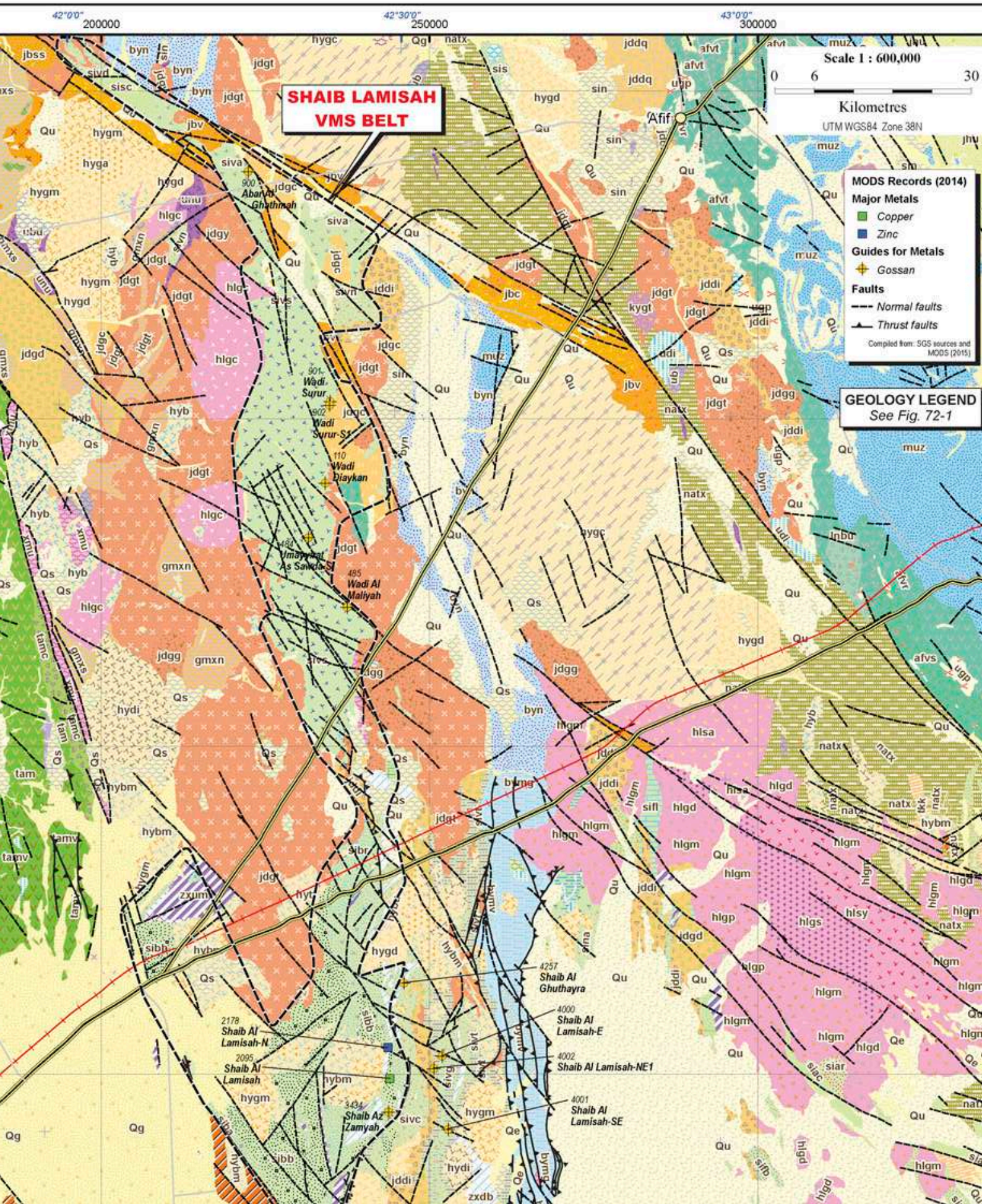
The Shaib Lamisah Belt is located in the western Afif Terrane and it encompasses an area of about 3,362 sq. km. as shown in Figure 72. This mineral belt contains rocks belonging to the As Siham Group (<750->695 Ma), and principally those lithologies comprising the Bahjah and Tandub Formations. These rocks form an assemblage of intermediate to felsic volcanics and sedimentary strata metamorphosed to the greenschist facies. The belt is terminated on the north and on the south by the Haliban-Zarghat and Sukhaybarah Faults, respectively, which are part of the Nabitah system.

The Shaib Lamisah deposit is the only VMS prospect in this belt that has a reserve/resource attributed to it. A listing of the VMS occurrences in this belt is presented in Table 48.

Table 48
Summary of Occurrences in the Shaib Lamisah VMS Belt

MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
2095	Shaib Al Lamisah	Sha'ib Lamisah	Cu	42.5097780	22.5816110	At Ta'if	Medium	dd, lenses
0110	Wadi Diaykan	Wadi Ablah-NE	Gossan	42.3980830	23.3991940	'Afif	Low	Lenses
0484	Umayyirat As Sawda-S	Jabal As Sihan	Gossan	42.3746110	23.3236940	At Ta'if	Low	Lenses
0485	Wadi Al Maliyah	Wadi Al Maliyah	Gossan	42.4342780	23.2287780	'Afif	Medium	Lenses
0900	Abar Al Ghathmah	Wadi Jarir-W	Gossan	42.2745280	23.8265560	'Afif	Very low	Lenses
0901	Wadi Surur	Al Hazarah-SE	Gossan	42.4033890	23.5117500	'Afif	Very low	Lenses
0902	Wadi Surur-S1	Al Hazarah-SE	Gossan	42.4023890	23.5065280	'Afif	Very low	Lenses
3434	Shaib Az Zamyah	Wadi Dhamiah Gossan	Gossan	42.5086110	22.5354170	At Ta'if	Very low	Undetermined
4000	Shaib Al Lamisah-E	Shaib Lamisah	Gossan	42.5741390	22.5962500	At Ta'if	Medium	Lenses
4001	Shaib Al Lamisah-SE	Shaib Lamisah	Gossan	42.5968890	22.5126110	At Ta'if	Medium	Lenses
4002	Shaib Al Lamisah-NE1	Shaib Lamisah	Gossan	42.5860560	22.6135000	At Ta'if	Medium	Lenses
4257	Shaib Al Ghuthayra	Jabal Abalgah	Gossan	42.5274170	22.7137780	At Ta'if	Very low	dd, lenses
2178	Shaib Al Lamisah-N	Sha'ib Lamisah-N Gossan	Zn	42.5065830	22.6243060	At Ta'if	Medium	dd, lenses

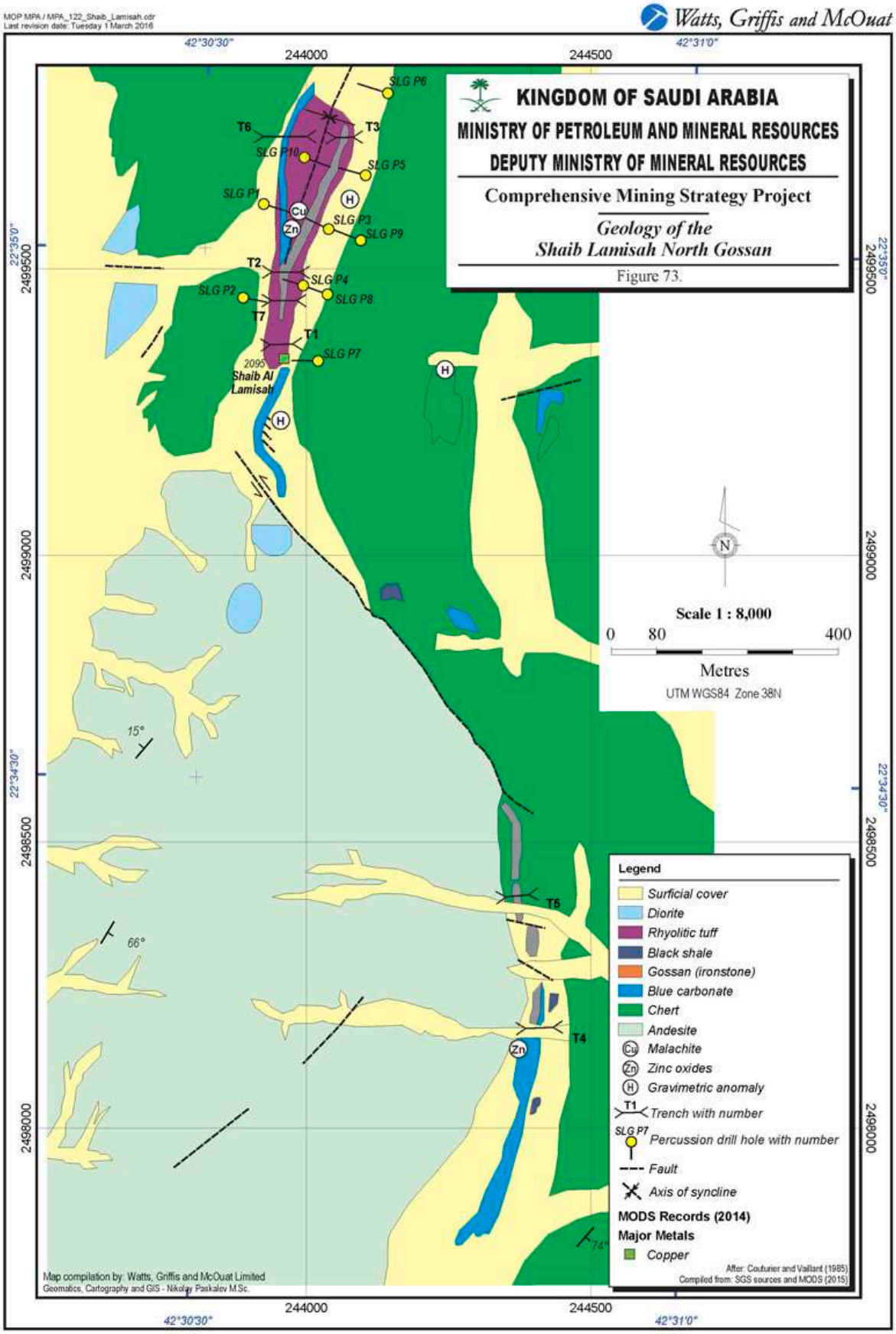
NOTES: 1) ranking according to MODS 2) v=veins, dd = disseminated; bx = breccia; ms = massive
* many are classified as VMS based on limited descriptions – no resource estimates available


42°0'0"
200000
42°30'0"
250000
43°0'0"
300000
SHAIB LAMISAH
VMS BELT
Scale 1 : 600,000
0 6 30
Kilometres
UTM WGS84 Zone 38N
Afif
MODS Records (2014)
Major Metals
Copper
Zinc
Guides for Metals
Gossan
Faults
Normal faults
Thrust faults
Compiled from: SGS sources and MODS (2015)
GEOLOGY LEGEND
See Fig. 72-1
900 Abar Al Ghuthmah
901 Wadi Surur
902 Wadi Surur-S1
110 Wadi Diaykan
484 Umayyat As Sawda-S1
485 Wadi Al Maliyah
4257 Shaib Al Ghuthayra
4000 Shaib Al Lamisah-E
4002 Shaib Al Lamisah-NE1
4001 Shaib Al Lamisah-SE
2178 Shaib Al Lamisah-N
2095 Shaib Al Lamisah
3434 Shaib Az Zamyah

Centered 30 km east and south of Zalim, the Shaib Lamisah Cu-Zn-Ag prospects (MODS 2095 and 2178) consist a series of ancient workings on pyrite-chalcopyrite-sphalerite lenses within felsic volcanic rocks at the main prospect (2095). These were first explored in modern times by the BRGM following their rediscovery in 1980, and the prospect was sampled and tested with a limited geophysical survey including ground magnetic, Max-Min and IP profiles. An airborne INPUT survey was also completed. The Max-Min survey identified parallel conductors on strike from the ancient workings. Five diamond drill holes totalling 777 m were drilled to test the down-dip extension of the gossan exposed in the ancient workings and a related Max-Min anomaly. The initial results could not be interpreted as wide sections of black shale contained no distinctive stratigraphic markers. During 1980, the area of geological mapping and ground geophysical surveying was extended and an anomaly east of the main workings was detected. During 1980-81, 17 percussion drill holes totalling 1,550 m tested conductors and explored along strike from the main prospect and proved that the sulphide zone dipped to the west. Subsequently, 3 diamond drill holes totalling 927 m were drilled to test the down-dip extension of the zone after a gravity anomaly was identified west of the main gossan outcrops. The diamond drill holes were interpreted as indicating that the sulphide horizon was narrowing with depth, but no reasonable explanation was given for the gravity anomaly.

In 1982, exploration work focused on the Shaib Lamisah North Gossan airborne INPUT conductors (MODS 2178), and on gossans within the felsic units to the east of the main zone. A wadi-sediment and soil geochemical survey was carried out along strike and down section from the main sulphide zone in a 340 km^2 area. The results were used to assess gossan zones and INPUT anomalies. Soil sampling on an 80 x 80 m grid was then carried out over the North Gossan zone and outcrops in the immediate area were grid-sampled. Ground magnetic, EM, IP and limited gravity surveys were carried out to define the airborne conductors and gossan zones. As a result, six INPUT anomalies were selected for follow-up by trenching and percussion drilling, and 18 holes were subsequently drilled totalling 1,505 m. All conductors were found to be related to graphite accompanied in most cases by disseminated pyrite and pyrrhotite. Base-metal and gold values were of geochemical interest only, with the exception of Anomaly 6 (L12) which gave geochemically anomalous gold values of 0.03-0.05 ppm in pyritic graphite. No diamond drilling was recommended.

In 1982, seven trenches totalling approximately 320 m were excavated across the Shaib Lamisah North prospect in order to sample the gossan, and 10 percussion holes (SLG PI-PI0) totalling 1,188 m were drilled to test the down-dip extension of the mineralization. The trenching was of a superficial nature because the gossan was too hard for the capability of the mechanical shovel. A further three percussion holes (P2-P4) intersected disseminated sulfide with no significant zinc values. This contrasts with enriched metal values in the surface gossan. The drilling revealed a complicated structure and that the stratigraphic position of the gossan at surface was not corroborated by the mineralized intersections in the drill holes. Four additional percussion holes were drilled to check three gravity anomalies in the North Gossan area. The anomalies were shown to be due to carbonate units and andesite, and that associated conductive anomalies could be explained by the presence of pyritic black shales. During 1983, the BRGM


MOP MPA / MPA_122_Shaib_Lamisah.cdr
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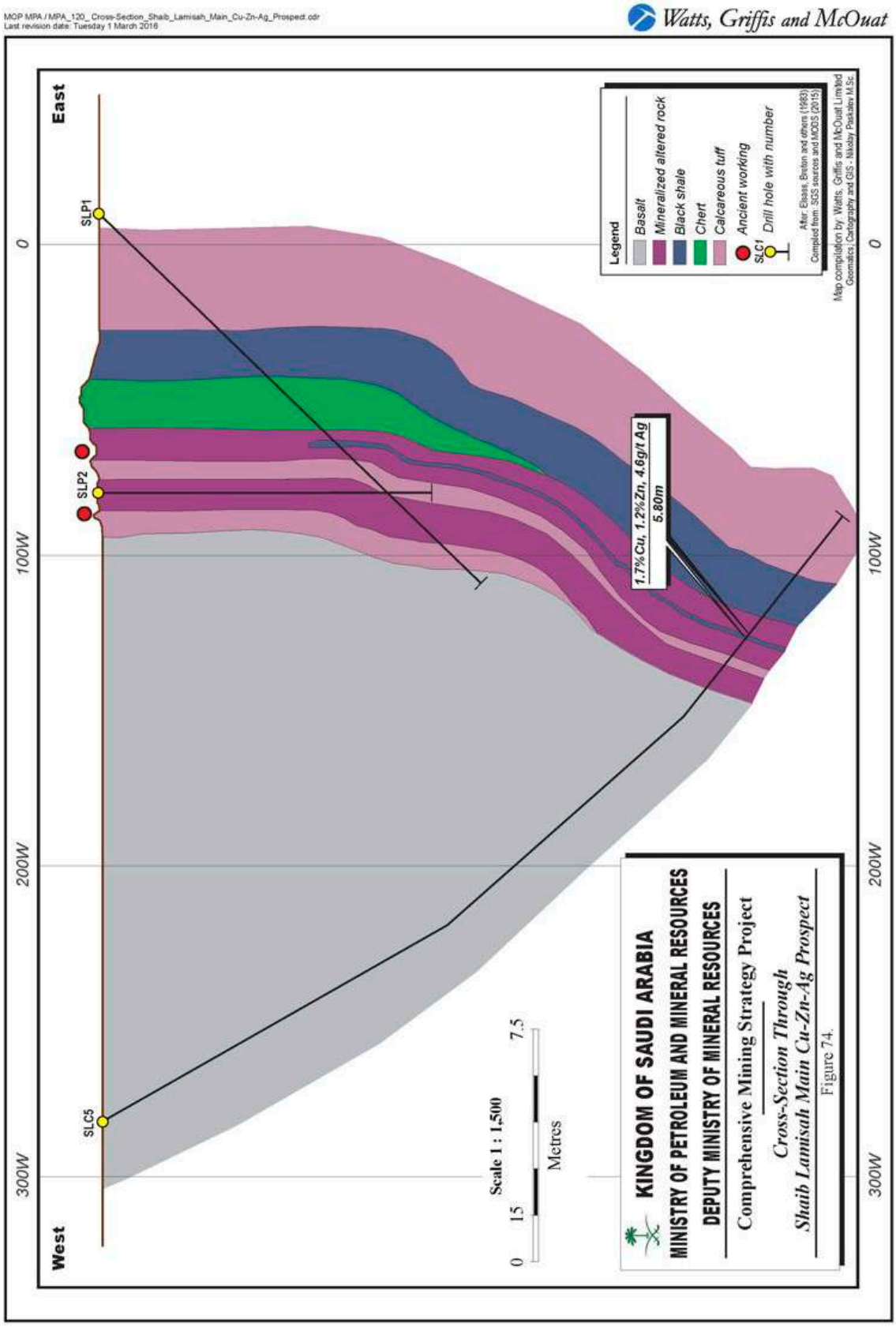
Geology of the
Shaib Lamisah North Gossan
Figure 73.
42°30'30"
42°31'0"
244000
244500
22°35'0"
22°34'30"
2499500
2499000
2498500
2498000
SLG P6
T6
T3
SLG P10
SLG P5
SLG P1
SLG P3
SLG P9
T2
SLG P4
SLG P2
SLG P8
T7
T1
SLG P7
2095
Shaib Al Lamisah
T5
T4
15°
66°
74°
N
Scale 1 : 8,000
0 80 400
Metres
UTM WGS84 Zone 38N
Legend
Surficial cover
Diorite
Rhyolitic tuff
Black shale
Gossan (ironstone)
Blue carbonate
Chert
Andesite
Malachite
Zinc oxides
Gravimetric anomaly
Trench with number
Percussion drill hole with number
Fault
Axis of syncline
MODS Records (2014)
Major Metals
Copper
After: Couturier and Vaillant (1985)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.


MOP MPA / MPA_120_ Cross-Section_Shaib_Lamisah_Main_Cu-Zn-Ag_Prospect.cdr
Last revision date: Tuesday 1 March 2016
Watts, Griffis and McOuat
East
West
SLP1
SLP2
SLC5
0
100W
200W
300W
1.7% Cu, 1.2% Zn, 4.6g/t Ag
5.80m
Legend
Basalt
Mineralized altered rock
Black shale
Chert
Calcareous tuff
Ancient working
SLC1
Drill hole with number
After: Elass, Breton and others (1983)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pavkalev M.Sc
Scale 1 : 1,500
0 15 7.5
Metres
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Cross-Section Through
Shaib Lamisah Main Cu-Zn-Ag Prospect
Figure 74.

used 17 of its percussion holes and eight of its diamond drill holes to estimate the mineral resources at Shaib Lamisah to total 1.40 Mt at an average grade of 1.70% Cu, 1.90% Zn and 9.0 g Ag/t (Elsass, Breton and others, 1983). Since that time, it is uncertain what additional exploration may have been carried out at Shaib Lamisah.

Geology

The Shaib Lamisah prospect consists of banded pyrite-chalcopyrite-sphalerite lenses within felsic volcanic and black shale units at the eastern margin of a pyritized diorite pluton (Figure 73). The North Gossan area contains two north-trending gossans (north portion and south portion) with an aggregate total strike length of about 850 m. The southern portion of the gossan appears to be the faulted strike extension of the northern portion. The host formations are described as west-dipping however the stratigraphic sequence may be overturned (Figure 74). If so, the mineralization would be underlain by metabasalt and overlain by a sequence of black shales which give way upwards to chert. This sequence suggests a geological setting not unlike that for Besshi-type VMS deposits.

Recommendations

The recommendations proposed by WGM in WGM-CR-11-12 for the Shaib Lamisah main and north areas are still considered to be valid. Geological mapping should concentrate on identifying and tracing out any stratigraphic marker horizons for the area. The other less certain occurrences in this mineral belt should be mapped and sampled to determine their metallogenesis and stratigraphic relationships. An airborne survey has been proposed for the area and this recommendation is still valid.

The gravity anomaly associated with the main prospect is unexplained by drilling in the vicinity, and it requires additional surveying to confirm its presence and if confirmed, drilling specifically designed to test it. Further diamond drilling is warranted in this sector of the prospect in order to determine the distribution of sulfides and alteration patterns within the zone. The main and north prospects require systematic diamond drilling to a depth of 250 m from surface in order to determine metal distribution and alteration patterns. The drill hole spacing along strike and down dip at the Shaib Lamisah prospects should be no greater than 100 m. Closer drill hole spacings may be required in complex areas where mineralization is encountered. An estimated total of 18,000 m of core drilling will be required to define the potential of the main prospect and to evaluate the source of untested geophysical anomalies. Holes should be drilled from west to east. All mineralized sections should be sampled and analysed for base metals, silver and gold, the latter being by the fire assay method. The representative sample of core should be taken at about 25 m intervals for major oxide analysis to characterize alteration patterns. WGM recommends that the total strike length of the north and southern portions of the gossan be core drill tested at 50 m intervals. This would require an estimated 6,800 m of drilling. Lithogeochemical sampling of the core should be included with standard sampling and assaying of mineralized sections during the drilling program. The trace of the

mineralized unit will be affected by the structural deformation in the area, and so we recommend that this aspect of the geology of the prospect be investigated in detail by mapping at 1:5,000 scale of the north gossan area. Any evidence indicating stratigraphic topping directions should be carefully documented. The other possible VMS occurrences in this mineral belt should be mapped and sampled to determine their genesis. An airborne survey was proposed for the entire mineral belt however it is uncertain whether this survey was ever completed.

3.2.3.13 Kutam – Al Masane VMS Belt

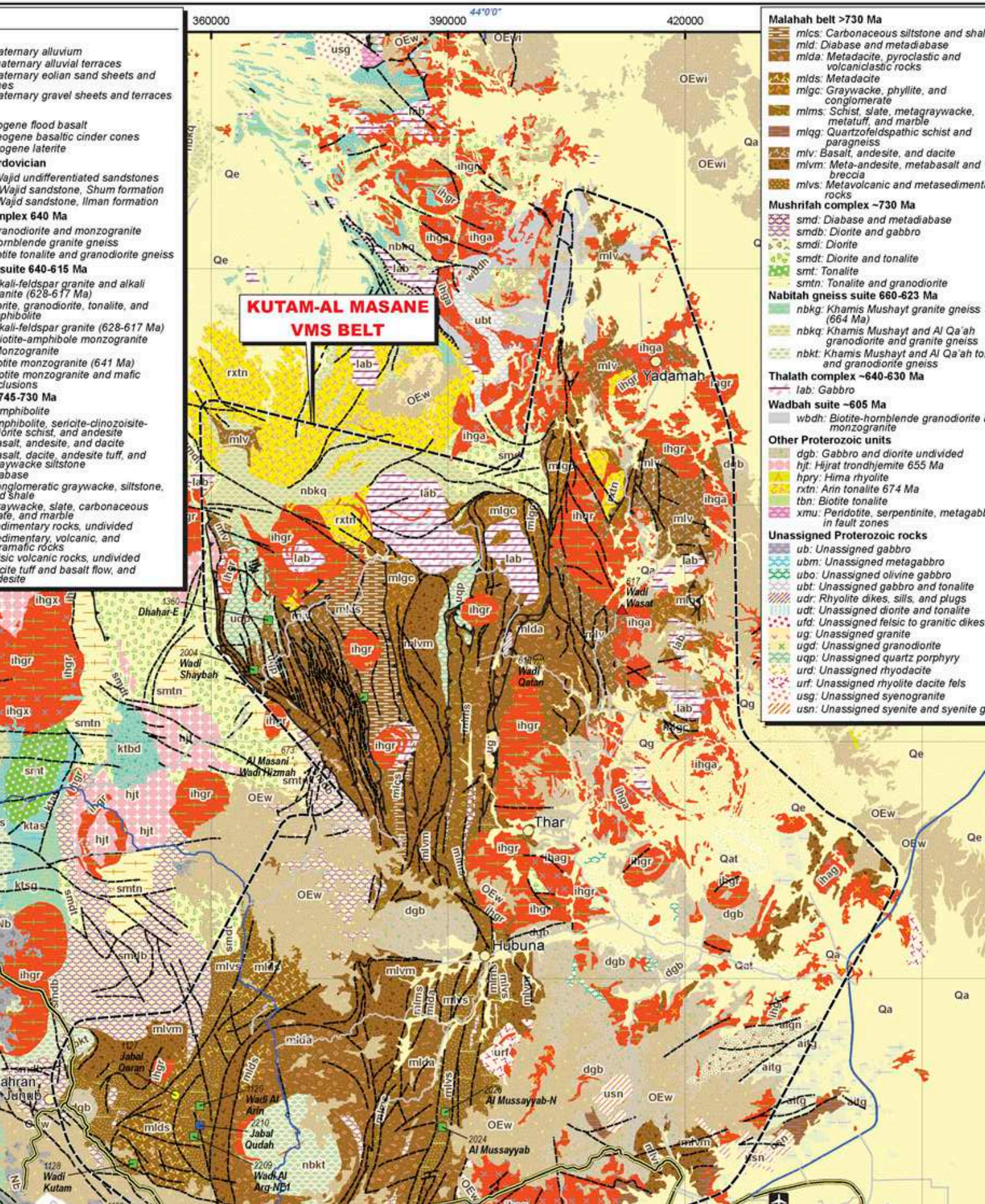
This mineral belt is located in the southern portion of the Asir Terrane, covering an area of about 8,791 km^2 (Figure 75). The western side of the belt is delineated by the Asharah Fault zone while on the south it continues to the Yemen border. The eastern margin is covered by Quaternary sand and alluvium. It is comprised mainly of rocks of the Malahah belt (>730 Ma), an assemblage of mafic to felsic volcanic and volcaniclastic rocks and sediments, all metamorphosed to the greenschist-amphibolite facies.

The principal VMS type deposits in this mineral belt are Al Masane and Kutam plus a number of smaller occurrences. All deposits classified as having VMS affinities are listed in Table 49. The two main VMS deposits in this mineral belt, Kutam and Al Masane, have been the subject of a large amount of work over the years. While the Kutam deposit awaits a production decision which may require the benefits of time and some enlargement of the mineral resource base, the Al Masane Mine commenced underground production in late 2012 at a mining rate of 2,000 t/day. AMAK, the owner of Al Masane, continues its exploration to maintain its resource base.

Table 49
Summary of Occurrences in the Kutam-Al Masane VMS Belt

MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0673	Al Masani	Al-Masane	Cu	43.8591670	18.1363890	Badr Al Janub	High	dd, lenses, stratiform
1128	Wadi Kutam	Kutam	Cu	43.5878610	17.5998060	Zahran Al Janub	Medium	dd, v
1129	Wadi Al Arin	Hemair	Cu	43.6666670	17.6666670	Badr Al Janub	Low	sb lenses, ms, stwk v
1360	Dhahar-E	Dhahar-E	Cu	43.7444440	18.2236110	Ahad Rufaydah	Very low	dd, lenses, stockwork veins
2004	Wadi Shaybah	Al Hajirah	Cu	43.7277780	18.1666670	Ahad Rufaydah	Medium	dd, stwk v
2024	Al Mussayyab	Al Mussayyab	Cu	43.9561110	17.6444440	Emarah center	Low	v
2026	Al Mussayyab-N	Al Mussayyab-N	Cu	43.9597220	17.6611110	Emarah center	Very low	v
2209	Wadi Al Arg-NE1	Hemair-SE	Cu	43.6597220	17.6319440	Zahran Al Janub	Low	dd, v
1127	Jabal Qaran	Farah Garan	Au	43.6375000	17.6788890	Zahran Al Janub	Medium	dd, lenses, massive, stwk v
0617	Wadi Wasat	Wasat Gossan	Fe	44.1675000	18.2372780	Thar	Medium	dd, lenses, stratiform
0618	Wadi Qatan	An Nugger	pyrite	44.0683890	18.1830830	Thar	Medium	dd, shear zone
1132	Ship Duwayin	Al Ashyab	Zn	43.6197220	17.5036110	Zahran Al Janub	Medium	dd
2210	Jabal Qudah	Hemair Gossan	Zn	43.6666670	17.6444400	Badr Al Janub	Very low	dd, bx elements, v

NOTES: 1) ranking according to MODS 2) v=veins, stwk = stockwork; dd = disseminated; bx = breccia; ms = massive; sb = stratabound
* many are classified as VMS based on limited descriptions – no resource estimates are available.


360000
390000
420000
44°0'0"
KUTAM-AL MASANE
VMS BELT
Yadamah
Thar
Hubuna
Dhahar-E
Wadi Shaybah
Al Masani
Wadi Hizmah
Wadi Wasat
Wadi Qatan
Jabal Qaran
Wadi Al Arin
Jabal Qudah
Al Mussayyab-N
Al Mussayyab
Wadi Kutam
Wadi Al Arg-NB1
Malahah belt >730 Ma
mlcs: Carbonaceous siltstone and shal
mld: Diabase and metadiabase
mlda: Metadacite, pyroclastic and volcaniclastic rocks
mlds: Metadacite
mlgc: Graywacke, phyllite, and conglomerate
mlms: Schist, slate, metagraywacke, metatuff, and marble
mlqg: Quartzofeldspathic schist and paragneiss
mlv: Basalt, andesite, and dacite
mlvm: Meta-andesite, metabasalt and breccia
mlvs: Metavolcanic and metasediment rocks
Mushrifah complex ~730 Ma
smd: Diabase and metadiabase
smdb: Diorite and gabbro
smdi: Diorite
smdt: Diorite and tonalite
smt: Tonalite
smtn: Tonalite and granodiorite
Nabitah gneiss suite 660-623 Ma
nbkg: Khamis Mushayt granite gneiss (664 Ma)
nbkq: Khamis Mushayt and Al Qa'ah granodiorite and granite gneiss
nbkt: Khamis Mushayt and Al Qa'ah to and granodiorite gneiss
Thalath complex ~640-630 Ma
lab: Gabbro
Wadbah suite ~605 Ma
wbdh: Biotite-hornblende granodiorite monzogranite
Other Proterozoic units
dgb: Gabbro and diorite undivided
hjt: Hijrat trondhjemite 655 Ma
hpry: Hima rhyolite
rxtn: Arin tonalite 674 Ma
tbn: Biotite tonalite
xmu: Peridotite, serpentinite, metagabb in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
ubo: Unassigned olivine gabbro
ubt: Unassigned gabbro and tonalite
udr: Rhyolite dikes, sills, and plugs
udt: Unassigned diorite and tonalite
ufd: Unassigned felsic to granitic dikes
ug: Unassigned granite
ugd: Unassigned granodiorite
uqp: Unassigned quartz porphyry
urd: Unassigned rhyodacite
urf: Unassigned rhyolite dacite fels
usg: Unassigned syenogranite
usn: Unassigned syenite and syenite g
aternary alluvium
aternary alluvial terraces
aternary eolian sand sheets and es
aternary gravel sheets and terraces
ogene flood basalt
eogene basaltic cinder cones
ogene laterite
rdovician
Wajid undifferentiated sandstones
Wajid sandstone, Shum formation
Wajid sandstone, Ilman formation
nplex 640 Ma
ranodiorite and monzogranite
ornblende granite gneiss
otite tonalite and granodiorite gneiss
suite 640-615 Ma
kali-feldspar granite and alkali anite (628-617 Ma)
orite, granodiorite, tonalite, and phibolite
kali-feldspar granite (628-617 Ma)
iotite-amphibole monzogranite
lonzogranite
otite monzogranite (641 Ma)
otite monzogranite and mafic clusions
745-730 Ma
mphibolite
nphibolite, sericite-clinozoisite-lorite schist, and andesite
asalt, andesite, and dacite
asalt, dacite, andesite tuff, and aywacke siltstone
abase
nglomeratic graywacke, siltstone, d shale
aywacke, slate, carbonaceous ate, and marble
dimentary rocks, undivided
dimentary, volcanic, and ramafic rocks
sic volcanic rocks, undivided
cite tuff and basalt flow, and desite

The United States Geological Survey ("**USGS**") mission has carried out various regional investigations of the Al Masane area. The first systematic mapping (1:500,000 scale) was by Brown and Jackson who published the Geologic Map of the Asir Quadrangle in 1959. Mr. Hatem El-Khalidi rediscovered the gossans and ancient workings at Al Masane in 1967 while flying aerial reconnaissance traverses. In 1971, an exploration licence was granted to Arabian Shield Development Co. ("**ASDC**") and National Mining Co. ("**NMC**"), and exploration programs including geological mapping, geochemical sampling, geophysical surveys and drilling were initiated. Mr. El-Khalidi provided the first modern description of the Al Masane deposit based on geological mapping shortly after its discovery, which was described at that time as mineralized shear zones. Two geologists from the Directorate General of Mineral Resources ("**DGMR**") of the Ministry of Petroleum and Mineral Resources of the Kingdom of Saudi Arabia visited the prospect shortly after the discovery and also described it as mineralized shear zones.

By 1975, after drilling three holes and intercepting sulphides, the similarity of Al Masane with Canadian massive sulphide deposits began to become apparent. Robertson Research International ("**RRI**") was contracted to work on the deposits in 1975 and 1976 and its work consisted of core logging, mineralogical studies, 1:1,000 scale mapping of the gossans and a regional air photo interpretation. The RRI geologists concluded that the mineralization was largely structurally controlled. However, in RRI's second report, it shifted to a stratabound hypothesis (Fernette and Neczkar, 1981). On a more regional scale, Greenwood (1980) carried out reconnaissance (1:100,000 scale) mapping in 1974 of the Wadi Malahah quadrangle, which includes Al Masane. Greenwood's mapping included a brief visit to the Saadah gossan and some sampling. Greenwood's work laid the foundation for the present understanding of the regional geology of the area. In 1977, the USGS spent 43 days mapping Al Masane and the surrounding area at 1:20,000 scale. This study was directed largely at the volcanic stratigraphy, structure and rock geochemical sampling. A Pangea Resources geologist, Douglas Martin, spent three months at Al Masane in 1977. Martin logged holes WS-1 to 12, and AH-1 to 10, and mapped the Saadah zone at 1:1,000 scale. He emphasized the stratabound volcanogenic character of the deposits. Wandke (1977) who produced the first estimate of possible ore reserves amplified Martin's conclusions. The Riofinex Geological Mission conducted a regional geologic review and Wadi sediment sampling program in the Wadi Wassatt-Kutam region (in 1977 and 1978; Riofinex, 1978), which included two to three days at Al Masane. Riofinex's conclusions about the regional geology and the setting of the Al Masane deposits differed considerably from that of the USGS geologists.

During 1977, WGM of Toronto, Canada were retained by ASDC to study the deposits, and an underground development program was recommended to define the tonnage and grade of the deposit. Fernette and Neczkar of WGM compiled a regional geologic map of the ASDC exploration license areas to aid in continued exploration. By September 1980, a permanent exploration camp including water supply and power plant had been established and a program of 3,700 m of underground access and development using trackless mining equipment and 20,000 m of underground diamond drilling were completed by WGM. The results from this underground program were incorporated into a positive feasibility study issued by WGM in 1982, which recommended the development of the resource. Continued surface prospecting in the immediate area by WGM led to the discovery of the Moyeath zone in late 1980. Although the surface expression of the gossan was small, preliminary diamond drilling indicated a significant massive sulphide deposit at depth. In the course of the underground program several geologists from the BRGM visited Al Masane and conducted geological and mineralogical studies (Sabir, 1981; Hottin, 1981; P. Elsass and G. Pouit, 1982). WGM supervised the collection of bulk metallurgical samples in 1981 from underground and pilot plant test work was done at the Colorado School of Mines Research Institute ("**CSMRI**") in the United States to confirm the laboratory test work completed previously by Lakefield Research of Canada Limited ("**Lakefield**") in Canada on the drill core. During the period from 1982 to 1987, in-fill diamond drilling was carried out on the Al Houra and Moyeath deposits by WGM, and the ore reserves were expanded. Following this, ASDC applied for a mining licence which, for unknown reasons was not granted until the mid 2000s. During this hiatus, no additional diamond drilling was been carried out on the property and the minesite was placed on a care and maintenance basis. As of 2009, the drilling on the deposits totalled 331 holes (47,278 m), approximately half of which (168 or 20,968 m) were drilled from underground. Of these, 264 holes or 80% of the total contributed to the resource estimate. Table 50 provides a recent estimate of the Al Masane resources as of 2012. The mine was inaugurated in October, 2012.

Table 50
Mineral Resources for the Al Masane Deposit, 2012

Classification	Tonnes (t x 000's)	Zn (%)	Cu (%)	Au (g/t)	Ag (g/t)
Measured	535	4.0	1.5	0.83	23
Indicated	5,279	3.8	1.3	0.84	25
Inferred	108	4.0	1.1	1.13	30

These estimates do not account for recent mining activities.

The mine has been operating at a production rate of 2,000 t of ore per day, however production has recently been suspended due to low commodity prices. The current statement of resources lists Measured and Indicated Resources as 9.4 Mt grading 4.23% Zn, 1.21% Cu, 0.97 g Au/t and 31 g Ag/t. In addition to this, the total Inferred Resources are 0.6 Mt grading at 7.42% Zn, 1.00% Cu, 1.18 g Au/t and 13g Ag/t. The increase in resources comes from on-going exploration drilling in the mine area.

The Kutam deposit is the largest in the entire belt and it has significant potential for expansion. This deposit (MODS 1128) is located within the southern Asir mountains. The ancient workings marking the deposit were discovered by the USGS in 1973 during a regional mapping program covering the half-degree Mayza Quadrangle (17/43B). The USGS subsequently carried out geological, geochemical and geophysical surveys as well as drilling eight diamond drill holes totalling 1,929 m (Smith and others, 1977). Noranda obtained an exploration license for the area in 1976 and carried out more detailed geological mapping and geophysical surveying (ground and airborne INPUT), followed by the drilling of 15 cored holes (3,495 m). After Noranda completed its program, Riofinex carried out an economic assessment of the deposit and concluded that it was not viable if it was assumed that no additional tonnage or higher grade mineralization would be discovered (Riofinex;1978a). The metal zoning at Kutam was studied and Riofinex postulated that a high-grade copper stringer zone may exist at depth. A resource was estimated for the prospect that totalled 16.43 Mt grading 1.03% Cu, 0.51% Zn and 0.1 g Au/t (Lawson Gold independent Technical Report, 2012). Coffee considered the resource estimate to have deficiencies however they recommended that the resource be considered as Inferred Resources. The resources were open to depth and Coffey recommended additional drilling at depth down plunge to potentially increase the resource base.

Geology

On a regional scale, the Al Masane deposit is the most significant deposit found to date and it is located in a major volcanic belt which has been previously referred to as the Malahah belt. Three separate massive sulphide orebodies are currently recognized: Saadah, Moyeath and Al Houra. In a regional sense, the extension of this belt to the north is offset several time by Najd faults presenting a discontinuous geometry that may not truly reflect its true continuity. Examples of volcanogenic massive sulphide mineralization within similar rocks can be found along its entire strike length from Nuqrah in the north to Najran in the south. The stratigraphy was first studied in the Wadi Wassatt-Qatan areas where the island arc affinities of the rocks were first recognized by the USGS which established a regional stratigraphic framework during reconnaissance geologic mapping (Greenwood, 1980a and b). Riofinex challenged this framework, favouring a structural control on mineralization, but was ultimately proven to be wrong. In general terms the layered rocks of the Al Masane region consist of a volcanic assemblage and a metasedimentary assemblage. These outcrop in a series of north trending belts. The USGS recognized two formations in the region: the Wassatt Formation composed of volcanic rocks and the younger, predominantly sedimentary, Qatan Formation. Fernette and Neczkar (1981) largely followed the USGS interpretation in their compilation of the regional geology because their work more accurately reflected the stratigraphic and structural picture understood at the time. Five lithological units of layered rocks were outlined originally but these were subdivided and expanded on as a result of the detailed work by WGM as follows:

Andesitic Tuff and Agglomerate (Mv1) Mafic pyroclastic rocks make up the western part of the Al Masane section and occur locally within the section. The rocks are referred to as andesite, but are probably basaltic and mafic tuff is the most common lithology, locally containing fusiform bombs up to 10-20 cm long. The unit contains thin lenses, up to 6 m thick locally, of coarse felsic agglomerate and scattered thin interbeds of black shale.

Rhyolite Porphyry (Fv1) this unit is comprised of gray to dark green-gray, massive, quartz ± plagioclase porphyry, with coarse quartz and plagioclase phenocrysts and a cherty, massive groundmass. The phenocrysts are generally fresh and unbroken although some plagioclase may be sericitized. The groundmass is homogeneous and composed of fine-grained quartz, and albite with fine epidote, carbonate, and minor chlorite and sericite. The groundmass texture is often microlitic and spherulitic. Based on the massive texture and relations with other units the rocks were interpreted as felsic flows.

Felsic Tuff and Crystal Tuff (Fv2) felsic tuff and crystal tuff comprise the bulk of the eastern part of the felsic section at Al Masane. These rocks have a layered, a coarser "clastic" groundmass texture and interbeds of sedimentary rocks particularly black shale.

Laminated Cherty Rhyolite (Fv3) This is a very distinctive rock characterized by prominent primary lamination and a cherty texture. Compositionally the rock is a soda-rhyolite or quartz keratophyre (commonly silicified) which occurs as domes and as interbeds in the felsic section.

Micaceous Felsic Tuff (Fv4) Silver-gray schist which is weakly pyritic with muscovite folia separating thin cherty or granoblastic layers. Quartz eyes are usually absent. These rocks are closely associated with the mineralization, overlying the mineralized exhalative-sedimentary rocks in the Al Houra zone and forming the hanging wall to the sulphides in the Saadah zone. In addition a thin but laterally persistent bed of micaceous tuff often precious metal rich underlies the N. Houra sulphides. Portions of the micaceous tuff flanking the felsic dome at N. Houra are conglomeratic and grade downward (west) into andesitic agglomerate. The micaceous tuffs overlying the Saadah zone are very siliceous within 1-2 m of the sulphides. Fernette and Neczkar (1981) interpreted these rocks to be water laid felsic tuffs with the possibility that they may be in part epiclastic tuffaceous sediments.

Lapilli Tuff (Fv5) Lapilli and lapilli quartz crystal tuff contain mainly flattened pumice platelets and minor fragments of felsic tuff and black shale in a micaceous and carbonaceous matrix composed of fine quartz, feldspar, sericite and chlorite.

Bedded Feldspathic Chert (Fv6) Thin bedded and cherty with either muscovite folia or thin interbeds of chloritite (black chlorite) and carbonatized albite crystals and abundant sericite alteration. The rocks are closely associated with the mineralization and the felsic domes and are interpreted to be exhalites.

Talc (t) Generally nearly pure talc, but may contain interbeds of dolomite or disseminated dolomite and quartz, almost invariably containing pyrite and less commonly sphalerite or chalcopyrite. This was interpreted as a sedimentary (exhalative) horizon by WGM based on bedding structures, an association with black shale, a stratiform geometry and sharp contacts with dolomite. Parallels were drawn with the Mattagami massive sulphide deposits in Quebec, Canada.

Chloritite (CH) Principally a black to greenish-black, well foliated chlorite rock similar to that which is associated with massive sulphide mineralization at Nuqrah. It contains variable amounts of quartz, dolomite and 1-5% disseminated pyrite (locally as much as 40%) in addition to the black chlorite. It is locally interlayered with feldspathic chert (Fv6) and was deposited with chert near the crest and flanks of the felsic domes.

Dolomite (d) Lenses and thin beds of carbonate rocks, mostly dolomitic, occur in the felsic portion of the Masane volcanic pile. Some are closely associated with the sulphide mineralization. The carbonate sediments are volumetrically a minor constituent of the Masane section but are important because of their close spatial and probably genetic relationship to the mineralization.

Shale (SH) Thin beds of black shale occur at various places through the volcanic section, and are also associated with the sulphide mineralization. The shales are black, siliceous and usually weakly pyritic. **Sandstone (ss)** Gray to dark gray, feldspathic to lithic arenite occur several places in the section as thin lenses usually associated with black shale. Texturally these rocks are similar to the granulose clastic tuffs of the micaceous tuff (Fv4) unit but lack the schistosity.

Diabase Sills (Db) Diabase sills ranging from 0.5 to 30 m thick extensively intrude the Al Houra zone largely along the sulphide horizon. Sills also occur in a few scattered places in other parts of the section.

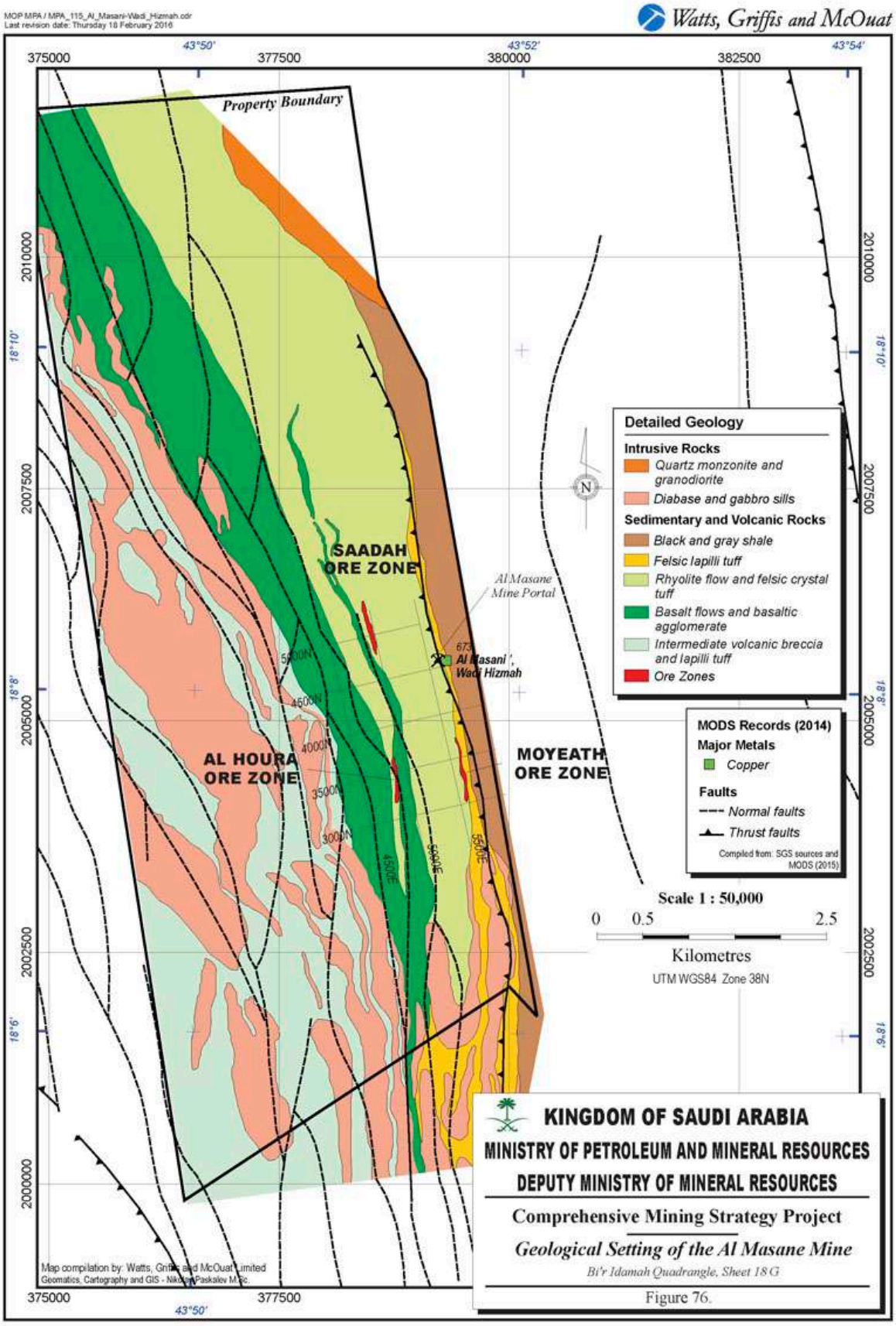
Porphyry Dikes (pd) Tan to white quartz feldspar porphyry dikes and sills intrude the section east of Al Houra zone. The feldspar phenocrysts are sericitized and the groundmass silicified. The rocks usually intrude along shale horizons in the felsic tuffs.

Basalt Dikes (b) Basalt dikes are the youngest intrusions in the area. They are dark gray to black, aphanitic, usually have prominent chilled margins and locally sheared contacts. Two sets of basalt dikes are present. The earliest are thin basalt sills and dikes concentrated in swarms in the black shale overlying the lapilli tuff at the eastern edge of the volcanic pile.

Gossan (G) Well developed gossans are exposed over both the Al Houra and Saadah zones.

The Saadah, Moyeath and Al Houra orebodies occur at separate stratigraphic positions within the same sequence of rocks (Figure 76). The gossans which mark them are composed of hematite, goethite, talc and quartz, with lesser gypsum and jarosite and minor sericite, chlorite, bassanite, kaolinite and calcite. Smithsonite and hemimorphite are common as accretionary to massive veins and surface coatings. Malachite is present locally as are spherical aggregates of chalcopyrite. Often the copper-bearing mineral in the gossans is not evident, consequently some copper may be contained in goethite. The Al Houra gossans are partly destroyed by ancient mining activity. The exposures are small outcrops near and in the mine pits and of 1 to 2 m wide beds of in-situ gossan. The Saadah gossan consists of an excellent outcrop of in-situ gossan in a tributary to Wadi Saadah and large outcrop of solution deposited gossan (ferricrete) cementing gravels on the Wadi bank. The in-situ gossan exhibit excellent ex-sulphide textures including bedding and brecciation. Limonite boxworks after pyrite are common. Often the pyrite pseudomorphs show relict embayments (carries texture) where the pyrite was partially replaced by sphalerite. Identifiable ex-sphalerite or ex-chalcopyrite textures are not common. The transition from gossan to fresh sulphide takes place over a 0.3 m interval in the Wadi Saadah orebody.

The depth of weathering below outcrops on the valley sides and in Sheb Al Houra is not known. Porous weakly weathered zones were seen as much as 150 m below the surface. While some supergene copper and zinc minerals are present, e.g. chalcocite, smithsonite and hemimorphite, there is no significant amount of supergene enrichment. Comparison of gossan analyses with the average ore grade indicates 60-70% leaching of copper and zinc. Gold is stable and shows local enrichment in the weathered zone by a factor of 30%. Silver appears to be stable to slightly leached overall but locally enriched. Lead is generally 40 to 50% leached, however some lead enrichment occurs locally.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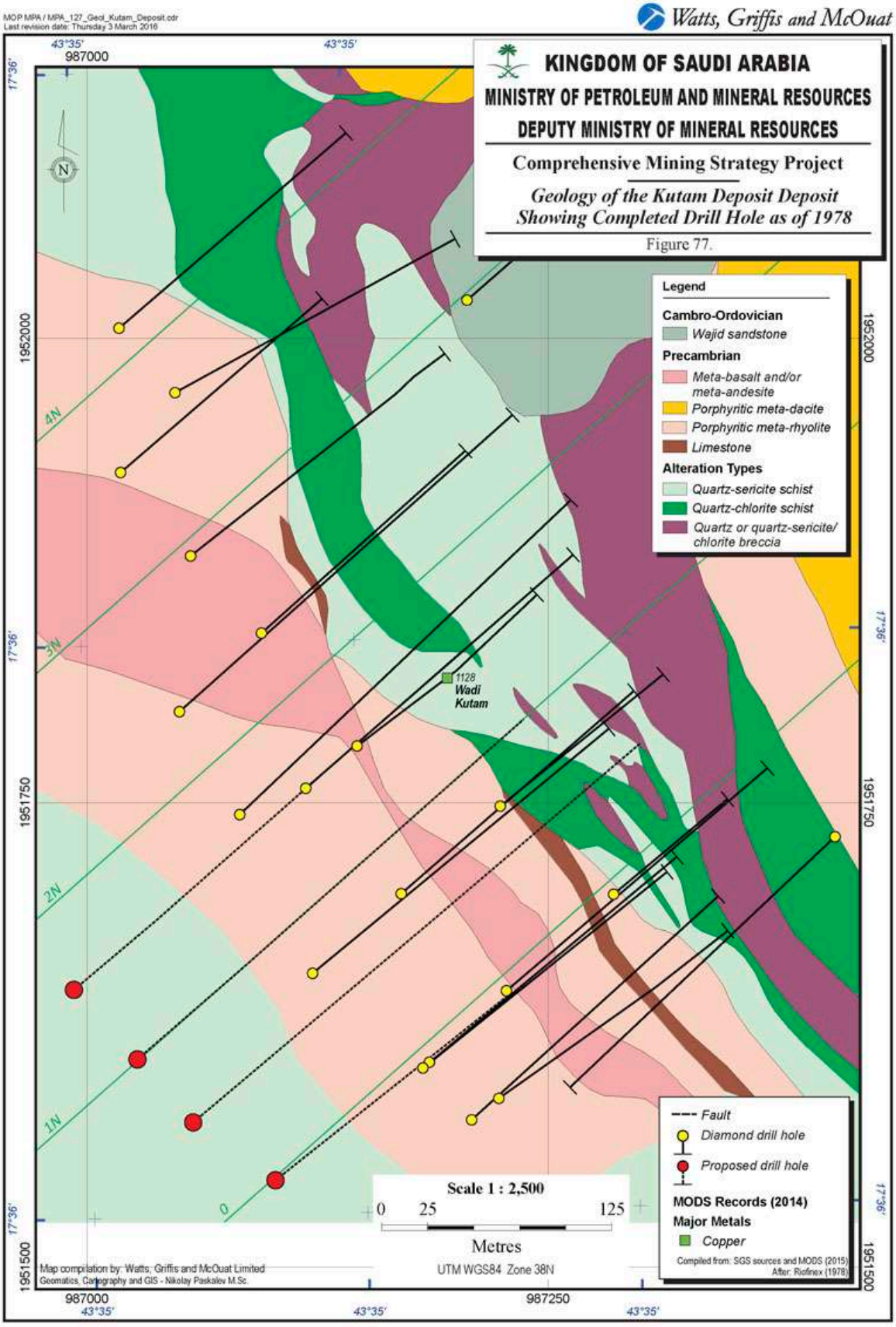
Last revision date: Thursday 18 February 2016
Watts, Griffis and McOuat
43°50'
43°52'
43°54'
375000
377500
380000
382500
2010000
2007500
2005000
2002500
2000000
18°10'
18°8'
18°6'
Property Boundary
SAADAH ORE ZONE
AL HOURA ORE ZONE
MOYEATH ORE ZONE
Al Masane Mine Portal
Al Masani ', Wadi Hizmah
5000N
4500N
4000N
3500N
3000N
4500E
5000E
5500E
N
Detailed Geology
Intrusive Rocks
Quartz monzonite and granodiorite
Diabase and gabbro sills
Sedimentary and Volcanic Rocks
Black and gray shale
Felsic lapilli tuff
Rhyolite flow and felsic crystal tuff
Basalt flows and basaltic agglomerate
Intermediate volcanic breccia and lapilli tuff
Ore Zones
MODS Records (2014)
Major Metals
Copper
Faults
Normal faults
Thrust faults
Compiled from: SGS sources and MODS (2015)
Scale 1 : 50,000
0 0.5 2.5
Kilometres
UTM WGS84 Zone 38N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Setting of the Al Masane Mine
Bi'r Idamah Quadrangle, Sheet 18 G
Figure 76.

The mineralization has been subdivided by WGM in the 80s into five types on the historical drill plans and cross sections. These types are thin bedded zinc-rich massive sulphides (ms1), copper-rich massive sulphides (ms2), sulphide breccia (ms3) and massive pyrite as well as disseminated or interbedded sulphides:

- A zinc content of greater than 3.5% is the primary characteristic used to define the ms1 ore type. These are in general thin bedded to laminated massive sulphides with calcareous of siliceous, rarely talcose, gangue. They are typically gold-silver-rich;
- The ms2 sulphide type consists of fine- to medium-grained massive to bedded sulphides with a zinc grade of less than 3.5%. These ores tend to have somewhat higher copper values than the ms1 type and generally low precious metals. Talc is the most common gangue;
- The sulphide breccia (ms3) is a variant on the ms2 ore type that is composed of fragments of massive pyrite in a matrix of massive to heavily disseminated pyrite, chalcopyrite and local sphalerite. The fragments range from 1 to 10 cm in diameter and are matrix supported. Talc is the principal gangue mineral;
- Massive pyrite occurs in several places It is generally massive, medium- or fine-grained with a talc-dolomite or silica gangue; and
- Disseminated or interbedded sulphides are sufficiently high grade to be of economic interest in several places. In addition, thin sulphide beds or disseminations occur in various parts of the mineralized section. Overall, however, disseminated sulphides do not constitute a volumetrically important type of mineralization at Al Masane.

In contrast with many volcanogenic massive sulphide deposits, Al Masane does not appear to have an underlying zone of stringer mineralization.

At Kutam, the mineralization consists of disseminated and stringer chalcopyrite and sphalerite in quartz-sericite and quartz-chlorite schists near the contact with a large intrusion of felsic quartz-feldspar porphyry through to be a rhyolite dome. Some metal zonation is apparent within the mineralized zone, but lateral continuity of high-grade mineralized sections is poor, although the whole mineralized zone has been traced by drilling over a strike length of approximately 400 m and a width of about 100 m. Indicated Mineral Resources of 4.028 Mt grading 2.04% Cu and 0.99% Zn were calculated by Riofinex in the late 1970s, however a more recent estimate places the resources, classified as “Indicated”, at 16.43 Mt grading 1.03% Cu, 0.51% Zn and 0.1 g Au/t (Lawson Gold, 2012). The resources are considered to be open to depth. A simplified geological map is presented as Figure 77.


MOP MPA / MPA_127_Geol_Kutam_Deposit.cdr
Last revision date: Thursday 3 March 2016
Watts, Griffis and McOuat
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Kutam Deposit Deposit Showing Completed Drill Hole as of 1978
Figure 77.
Legend
Cambro-Ordovician
Wajid sandstone
Precambrian
Meta-basalt and/or meta-andesite
Porphyritic meta-dacite
Porphyritic meta-rhyolite
Limestone
Alteration Types
Quartz-sericite schist
Quartz-chlorite schist
Quartz or quartz-sericite/ chlorite breccia
1128
Wadi Kutam
Fault
Diamond drill hole
Proposed drill hole
MODS Records (2014)
Major Metals
Copper
Compiled from: SGS sources and MODS (2015)
After: Riofinex (1978)
Scale 1 : 2,500
0 25 125
Metres
UTM WGS84 Zone 38N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
43°35'
987000
987250
17°36'
1952000
1951750
1951500
4N
3N
2N
1N
0
N

Recommendations

The substantial number of VMS occurrences in this mineral belt attest to its potential to host additional economically significant deposits. The prospect-scale work recommended in WGM-CR-11-14 is valid. An airborne EM-Mag survey is recommended for the entire mineral belt. The survey should also cover the projected extension of the permissive lithologies to the east under alluvium and Paleozoic cover rocks.

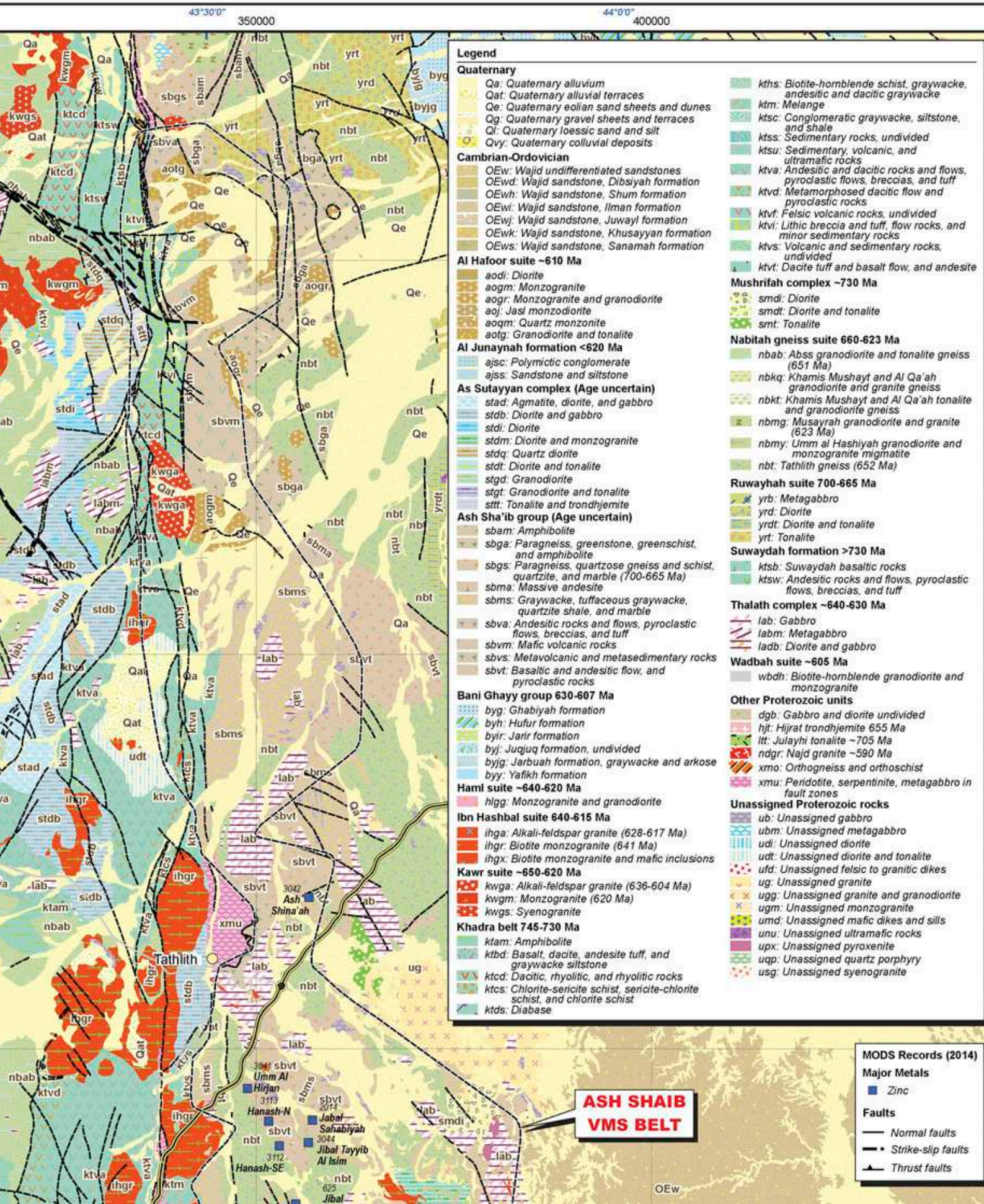
The success of on-going exploration drilling at Al Masane indicates the immense importance of a sustained search for mineralization. This less applies not only in mining but in basic exploration as well. Al Masane underwent a 30-year history of exploration activity prior to mining, and yet additional economically viable mineralization is still being found. Translated into an exploration-stage project, this simply means that initial failures must be carefully weighted in the light of all possibilities, and pushed aside if the exploration model has not been thoroughly tested. Too many prospects in the Kingdom have been walked away from on the basis of very superficial exploration and results that are not conclusive.

The two main VMS deposits (Kutam and Al Masane) in this mineral belt have been the subject of a large amount of work over the years and they have reached an advanced stage of exploration. While Al Masane is in production, the Kutam deposit probably awaits a time when its resource base is sufficiently large to justify development. Being somewhat lower in grade than Al Masane, it may also wait for the discovery of a higher-grading zone or more favourable base metals prices. Until that time, the Kutam deposit should be explored to test the model proposed by Legg (1983). Four holes of about 400 m each should be drilled on sections 0, 0+50N, 1+00N and 1+50N and each should also be geophysically surveyed using the down-hole electromagnetic technique to explore for massive sulphides in the vicinity of each hole. The untested ground geophysical (EM) anomalies detected by Noranda in the vicinity of the Kutam deposit also require drill testing. Compilation followed by mapping at a scale of 1:1,000 is also recommended for the Kutam deposit.

3.2.3.14 Ash Shaib VMS Belt

Location, History and Status

The Ash Shaib VMS belt is located in the Asir Terrane and it covers an area of approximately 3,585 sq. km. The belt encompasses rocks belonging to the Ash Shaib Group that are of uncertain age (Figure 78). They may be coeval with the Malahah Belt assemblage to the south, however the age relationship is uncertain and consequently they have been assigned to a separate mineral belt. The Ash Shaib Group is composed of mafic to intermediate volcanic rocks with some volcaniclastics and sedimentary rocks.


43°30'0"
350000
44°0'0"
400000
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Ql: Quaternary loessic sand and silt
Qvy: Quaternary colluvial deposits
Cambrian-Ordovician
OEw: Wajid undifferentiated sandstones
OEwd: Wajid sandstone, Dibsiyah formation
OEwh: Wajid sandstone, Shum formation
OEwl: Wajid sandstone, Ilman formation
OEwj: Wajid sandstone, Juwayl formation
OEwk: Wajid sandstone, Khusayyan formation
OEws: Wajid sandstone, Sanamah formation
Al Hafoor suite ~610 Ma
aodi: Diorite
aogm: Monzogranite
aogr: Monzogranite and granodiorite
aoj: Jasl monzodiorite
aoqm: Quartz monzonite
aotg: Granodiorite and tonalite
Al Junaynah formation <620 Ma
ajsc: Polymictic conglomerate
ajss: Sandstone and siltstone
As Sutayyan complex (Age uncertain)
stad: Agmatite, diorite, and gabbro
stdb: Diorite and gabbro
stdi: Diorite
stdm: Diorite and monzogranite
stdq: Quartz diorite
stdt: Diorite and tonalite
stgd: Granodiorite
stgt: Granodiorite and tonalite
sttt: Tonalite and trondhjemite
Ash Sha'ib group (Age uncertain)
sbam: Amphibolite
sbga: Paragneiss, greenstone, greenschist, and amphibolite
sbgs: Paragneiss, quartzose gneiss and schist, quartzite, and marble (700-665 Ma)
sbma: Massive andesite
sbms: Graywacke, tuffaceous graywacke, quartzite shale, and marble
sbva: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
sbvm: Mafic volcanic rocks
sbvs: Metavolcanic and metasedimentary rocks
sbvt: Basaltic and andesitic flow, and pyroclastic rocks
Bani Ghayy group 630-607 Ma
byg: Ghabiyah formation
byh: Hufur formation
byir: Jarir formation
byj: Juqjuq formation, undivided
byjg: Jarbuah formation, graywacke and arkose
byy: Yafikh formation
Haml suite ~640-620 Ma
hlgg: Monzogranite and granodiorite
Ibn Hashbal suite 640-615 Ma
ihga: Alkali-feldspar granite (628-617 Ma)
ihgr: Biotite monzogranite (641 Ma)
ihgx: Biotite monzogranite and mafic inclusions
Kawr suite ~650-620 Ma
kwga: Alkali-feldspar granite (636-604 Ma)
kwgm: Monzogranite (620 Ma)
kwgs: Syenogranite
Khadra belt 745-730 Ma
ktam: Amphibolite
ktbd: Basalt, dacite, andesite tuff, and graywacke siltstone
ktcd: Dacitic, rhyolitic, and rhyolitic rocks
ktcs: Chlorite-sericite schist, sericite-chlorite schist, and chlorite schist
ktds: Diabase
kths: Biotite-hornblende schist, graywacke, andesitic and dacitic graywacke
ktm: Melange
ktsc: Conglomeratic graywacke, siltstone, and shale
ktss: Sedimentary rocks, undivided
ktsu: Sedimentary, volcanic, and ultramafic rocks
ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
ktvd: Metamorphosed dacitic flow and pyroclastic rocks
ktvf: Felsic volcanic rocks, undivided
ktvi: Lithic breccia and tuff, flow rocks, and minor sedimentary rocks
ktvs: Volcanic and sedimentary rocks, undivided
ktvt: Dacite tuff and basalt flow, and andesite
Mushrifah complex ~730 Ma
smdi: Diorite
smdt: Diorite and tonalite
smt: Tonalite
Nabitah gneiss suite 660-623 Ma
nbab: Abss granodiorite and tonalite gneiss (651 Ma)
nbkq: Khamis Mushayt and Al Qa'ah granodiorite and granite gneiss
nbkt: Khamis Mushayt and Al Qa'ah tonalite and granodiorite gneiss
nbmg: Musayrah granodiorite and granite (623 Ma)
nbmy: Umm al Hashiyah granodiorite and monzogranite migmatite
nbt: Tathlith gneiss (652 Ma)
Ruwayhah suite 700-665 Ma
yrb: Metagabbro
yrd: Diorite
yrdt: Diorite and tonalite
yrt: Tonalite
Suwaydah formation >730 Ma
ktsb: Suwaydah basaltic rocks
ktsw: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
Thalath complex ~640-630 Ma
lab: Gabbro
labm: Metagabbro
ladb: Diorite and gabbro
Wadbah suite ~605 Ma
wbdh: Biotite-hornblende granodiorite and monzogranite
Other Proterozoic units
dgb: Gabbro and diorite undivided
hjt: Hijrat trondhjemite 655 Ma
ltt: Julaylhi tonalite ~705 Ma
ndgr: Najd granite ~590 Ma
xmo: Orthogneiss and orthoschist
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubm: Unassigned metagabbro
udi: Unassigned diorite
udt: Unassigned diorite and tonalite
ufd: Unassigned felsic to granitic dikes
ug: Unassigned granite
ugg: Unassigned granite and granodiorite
ugm: Unassigned monzogranite
umd: Unassigned mafic dikes and sills
unu: Unassigned ultramafic rocks
upx: Unassigned pyroxenite
uqp: Unassigned quartz porphyry
usg: Unassigned syenogranite
Tathlith
Ash Shina'ah
Umm Al Hirjan
Hanash-N
Hanash-SE
Jabal Sahabiyah
Jibal Tayyib Al Isim
Jibal
ASH SHAIB VMS BELT
MODS Records (2014)
Major Metals
Zinc
Faults
Normal faults
Strike-slip faults
Thrust faults

Deposits and occurrences in the Ash Shaib mineral belt assigned to the VMS category are listed in Table 51.

Table 51
Summary of Occurrences in the Ash Shaib VMS Belt

MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0625	Jibal Shiqayb	Ash Sha'lb	Zn	43.6640000	19.2430000	Tathlith	Medium	stratiform
2014	Jabal Sahabiyah	Muwayqirah,	Zn	43.6397220	19.3575000	Tathlith	Medium	stratiform
3041	Umm Al Hirjan	Harjan	Zn	43.5611110	19.3930560	Tathlith	Medium	dd, stratiform
3042	Ash Shina'ah	Ash Shina'ah	Zn	43.6334720	19.6130280	Tathlith	Very low	boxworks, stratiform
3044	Jibal Tayyib Al Isim	Ash Shajjah	Zn	43.6348330	19.3318610	Tathlith	Very low	v
3110	Jibal Ummahat Az Zuhur	Umm Ad Duhur	Zn	43.6555560	19.1750000	Tathlith	Medium	stratiform
3111	Ghurran Al Hashim	Ghoran Al Hashim	Zn	43.6200000	19.2611110	Tathlith	Medium	stratiform
3112	Hanash-SE	Hanash-SE	Zn	43.6000000	19.3277780	Tathlith	Medium	stratiform
3113	Hanash-N	Hanash-N	Zn	43.5869440	19.3559720	Tathlith	Medium	stratiform

NOTES: 1) ranking according to MODS 2) v=veins, stwk = stockwork; dd = disseminated; bx = breccia; ms = massive; sb = stratabound
* many are classified as VMS based on limited descriptions – no resource estimates available

The Ash Shaib deposit is the only VMS-type prospect in the entire belt for which a mineral resource is estimated, and so it is considered to be the most significant VMS occurrence. The Ash Shaib zinc deposit (MODS 0625) is located approximately 45 km south of Tathlith. In 1965 the USGS rediscovered the ancient workings and subsequently completed a program of geophysical surveying (ground EM, SP, resistivity and magnetometer) and drilling. In 1967, the DGMR completed a Turam survey over the prospect, and an INPUT survey was flown over an area which contained the deposit. In 1968 Sander Geophysics carried out a helicopter-borne EM and magnetometer survey over the area and six holes totalling 1,331.5 m were diamond drilled in 1968. During 1977, Riofinex completed a ground follow-up program of geophysical surveying, geochemical sampling, and in 1978 four holes totalling 900.05 m were diamond drilled to test targets identified by the geophysical surveys. A resource of 1.7 Mt grading 6.0% Zn and 0.3% Cu has been estimated for the deposit. In 1978 Riofinex and Barringer Research carried out geochemical (wadi-sediment) orientation studies over the deposit, and concluded that the +10 # and -10/+25 # fractions provided the greatest anomaly contrast. Little if any exploration work has been done since that time.

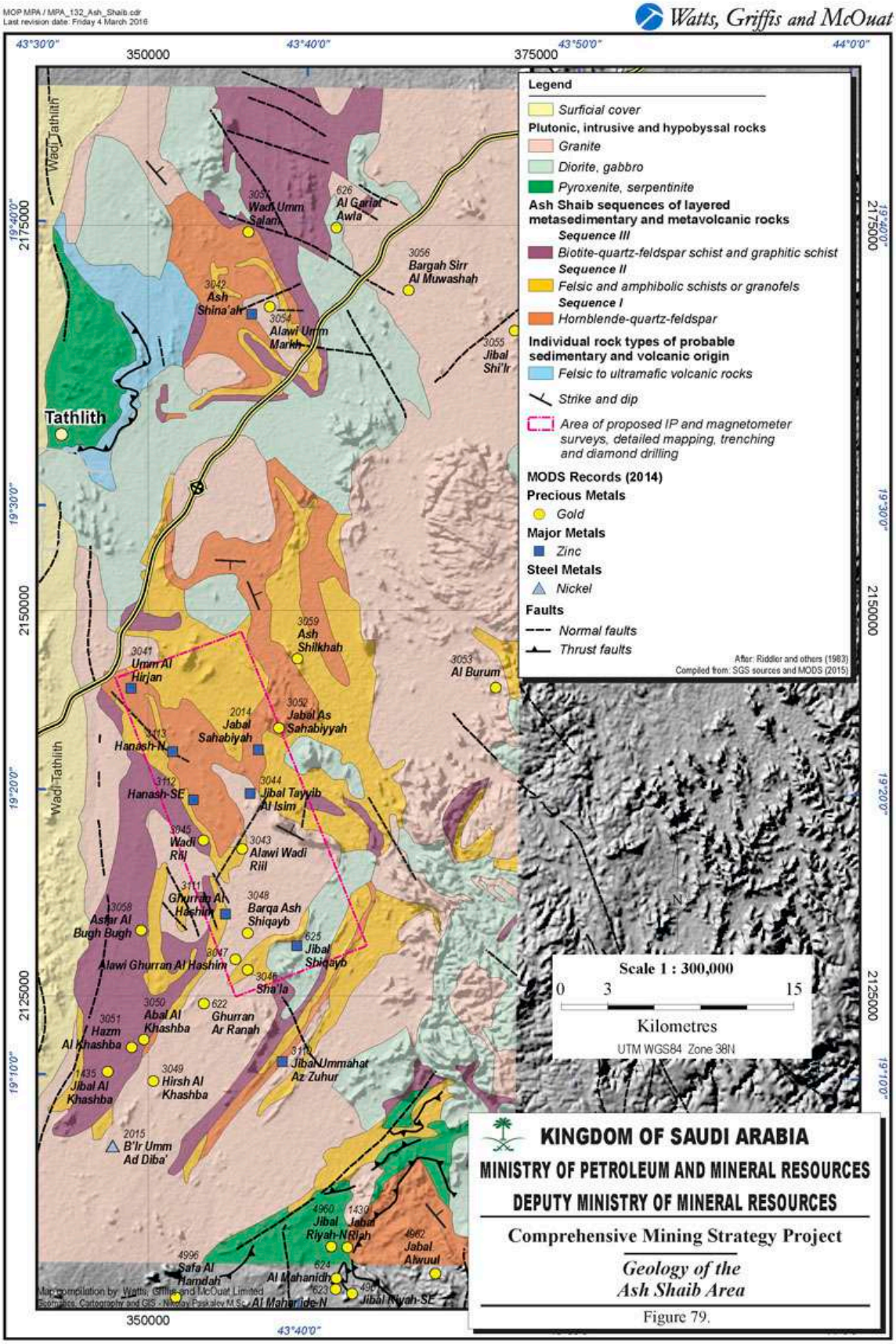
Geology

Mineralization at Ash Shaib consists of massive to disseminated stratiform pyrite, sphalerite and magnetite with minor amounts of pyrrhotite, chalcopyrite, galena, cubanite and molybdenite. The mineralization is hosted by quartz-feldspar schists and gneisses, cordierite pyroxene hornfels and cordierite-quartz granofels. Three stratigraphic subdivisions of the layered rocks have been recognized which comprise a south-facing, metasedimentary assemblage located on a flexure of the western limb of a major overturned

southwest-plunging syncline (Riddler and others, 1983). So-called “Sequence I” forms the base of the succession and is composed mainly of quartzo-feldspathic gneiss and granodiorite gneiss. Sequence II, which hosts the mineralization, is a heterogeneous unit of feldspar-quartz-pyroxene hornfels, schistose granofels, pyroxene-feldspar-quartz hornfels and dolomitic marble. Sequence III caps the succession and is composed of cordierite-pyroxene hornfels with interbanded graphitic schist. The geology is shown in Figure 79.

Recommendations

The Ash Shaib mineral belt has characteristics in common with some large base metal deposit districts in other areas of the world (Geco, Broken Hill), and it is considered to be very prospective. Despite the Riofinex resource estimate, the drill hole spacing is considered inadequate for resource modelling purposes, and the gold potential is untested. The favorable stratigraphic sequence away from the known mineralization has not been adequately explored, if at all. In addition to detailed exploration work, an airborne EM-Mag survey for the entire Ash Shaib VMS Belt is recommended. Detailed mapping at 1:1,000 scale is recommended for the Ash Shaib grid and its northeast and southwest extensions to define the prospects structure as an aid to mineral exploration. Geophysical survey coverage of the southwest and northeast grid extensions by Riofinex was sporadic and the grid line spacing is uneven. Accordingly, WGM recommends that a maximum grid array of 100 x 25 m be established over these areas and that this grid should be entirely covered by IP and magnetometer surveys to allow the geology to be better modelled, to search for new geophysics-indicated drill targets, to trace the known mineralization along strike, and to evaluate known geophysical anomalies.


MOP MPA / MPA_132_Ash_Shaib.cdr
Last revision date: Friday 4 March 2016
Watts, Griffis and McOuat
43°30'0"
43°40'0"
43°50'0"
44°0'0"
350000
375000
19°40'0"
19°30'0"
19°20'0"
19°10'0"
2175000
2150000
2125000
Wadi Tathlith
Tathlith
Legend
Surficial cover
Plutonic, intrusive and hypobyssal rocks
Granite
Diorite, gabbro
Pyroxenite, serpentinite
Ash Shaib sequences of layered metasedimentary and metavolcanic rocks
Sequence III
Biotite-quartz-feldspar schist and graphitic schist
Sequence II
Felsic and amphibolic schists or granofels
Sequence I
Hornblende-quartz-feldspar
Individual rock types of probable sedimentary and volcanic origin
Felsic to ultramafic volcanic rocks
Strike and dip
Area of proposed IP and magnetometer surveys, detailed mapping, trenching and diamond drilling
MODS Records (2014)
Precious Metals
Gold
Major Metals
Zinc
Steel Metals
Nickel
Faults
Normal faults
Thrust faults
After: Riddler and others (1983)
Compiled from: SGS sources and MODS (2015)
3057 Wadi Umm Salam
626 Al Garlat Awla
3056 Bargah Sirr Al Muwashah
3042 Ash Shina'ah
3054 Alawi Umm Markh
3055 Jibal Shi'ir
3059 Ash Shilkhah
3041 Umm Al Hirjan
3053 Al Burum
3052 Jabal As Sahabiyyah
2014 Jabal Sahabiyah
3113 Hanash-N
3112 Hanash-SE
3044 Jibal Tayyib Al Isim
3045 Wadi Rili
3043 Alawi Wadi Riil
3111 Ghurran Al Hashim
3048 Barqa Ash Shiqayb
3058 Asfar Al Bugh Bugh
625 Jibal Shiqayb
3047 Alawi Ghurran Al Hashim
3046 Sha'la
3050 Abal Al Khashba
622 Ghurran Ar Ranah
3051 Hazm Al Khashba
3110 Jibal Ummahat Az Zuhur
1435 Jibal Al Khashba
3049 Hirsh Al Khashba
2015 B'ir Umm Ad Diba'
4960 Jibal Riyah-N
1439 Jabal Rilah
4962 Jabal Atwuul
4996 Safa Al Hamdah
624 Al Mahanidh
623 Al Mahanidh-N
4961 Jibal Riyah-SE
Scale 1 : 300,000
0 3 15
Kilometres
UTM WGS84 Zone 38N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Ash Shaib Area
Figure 79.

3.2.3.15 Samran-Shayban VMS Belt

Location, History and Status

The Samran-Shayban VMS Belt is located in the Jiddah Terrane and it covers an area of about 13,315 km^2, making it one of the larger VMS belts (Figure 80). The belt encloses lithologies belonging to the Samran Group (825-745 Ma) that is composed of a bimodal mafic to felsic sequence of volcanic rocks with attendant volcaniclastic and sedimentary facies. This belt is bounded by the Labunah Fault along its western edge, and it is overlain by the Quaternary basalt flows of Harrat Rahat along the eastern margin. The southern portion of the belt disappears under Quaternary alluvial and eolian cover along the Red Sea coastal plain. Isolated windows (inliers) through the Harrat that expose Samran Group rocks indicate that the mineral belt is likely significantly larger than its current exposure.

This permissive belt contains three VMS deposits with a resource estimate attached and numerous occurrences attributed to a VMS origin. A listing of the VMS deposits/occurrences in this belt is presented in Table 52.

Table 52
Summary of Occurrences in the Samran-Shayban VMS Belt

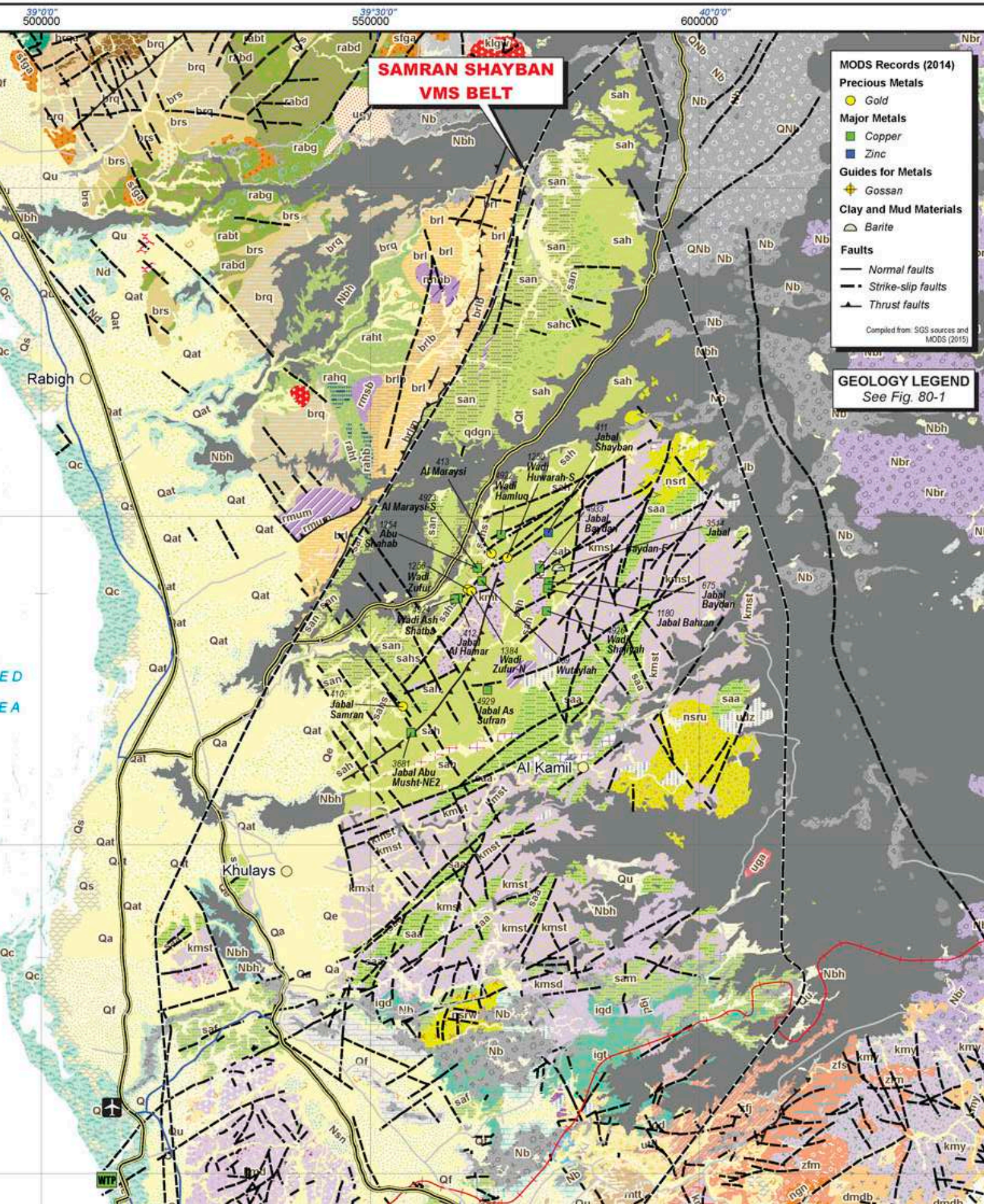
MODS	Name New	Name Old	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
3514	Jabal Baydan-E	Wadi Shajiyah	Ba	39.7641670	22.5350000	Khulays	Medium	dd, ms bed, v
0412	Jabal Al Hamar	Hamar	Cu	39.6154170	22.4931390	Khulays	Medium	dd, lenses
0669	Wutaylah	Wutaileh Gossan	Cu	39.6505560	22.5166670	Khulays	Low	dd, lenses, v
0675	Jabal Baydan	Wadi Shugea Area	Cu	39.7494440	22.5145000	Khulays	Medium	Lenses
0710	Bahrah	West Bahrah Gossan	Cu	39.5589720	21.3939170	Jiddah	Medium	Lenses
1180	Jabal Bahran	Bahran Gossan	Cu	39.7477780	22.5061390	Khulays	Medium	Undetermined
3681	Jabal Abu Musht-NE2	Abu Umm Shut-E	Cu	39.5447220	22.3086110	Khulays	Medium	Lenses
4922	Wadi Hamluq	Hamluq Area	Cu	39.6794440	22.5802500	Khulays	Very low	dd
4923	Al Maraysi-S	Almaraysi-SE	Cu	39.6438890	22.5345000	Khulays	Medium	dd
4924	Wadi Ash Shatba	Wadi Al Shatban	Cu	39.6102780	22.4919440	Khulays	Medium	dd
4926	Wadi Shajiyah	Wadi Shajiah	Cu	39.7458330	22.4747220	Khulays	Very low	dd
4929	Jabal As Sufran	Wadi Al Bihayr	Cu	39.6583330	22.3666670	Khulays	Very low	dd
4931	Jabal Bahran prospect	Jabal Bahran	Cu	39.7650000	22.5166670	Khulays	Very low	dd
4933	Jabal Baydan	Jabal Baydan	Cu	39.7358330	22.5336110	Khulays	Very low	dd
0410	Jabal Samran	Jabal Samran	Au	39.5332780	22.3442780	Khulays	Medium	dd, lenses, v
0413	Al Maraysi	Al Marasia	Au	39.6650280	22.5541390	Khulays	Medium	Undetermined
1250	Wadi Huwarah-S	Brumah	Au	39.6883610	22.5478060	Khulays	Undefined	Undetermined
1256	Wadi Zufur	Wadi Thufer	Au	39.6296670	22.5051110	Khulays	Very low	Lenses
1384	Wadi Zufur-N	Wadi Thufer	Au	39.6352780	22.5022220	Khulays	Undefined	Lenses
1254	Abu Shahab	Abu Shiaab	G	39.6438890	22.5345000	Khulays	Medium	Undetermined
0411	Jabal Shayban	Jabal Shayban	Zn	39.7490000	22.5827220	Khulays	Medium	dd, v

NOTES: 1) ranking according to MODS 2) v=veins, stwk = stockwork; dd = disseminated; bx = breccia; ms = massive; sb = stratabound
* many are classified as VMS based on limited descriptions – no resource estimates available

The Jabal Samran Cu-Au-Zn prospect is the most significant in the mineral belt. It is located approximately 90 km north-northeast of Jiddah. The ancient Mesaana Mine on the flanks of Jabal Samran is considered to be part of the Jabal Samran prospect (Rexworthy, 1972). It is estimated that miners in the eighth and ninth centuries A.D. extracted between 5,000 and 10,000 tons of Cu and Cu-Au ore (Liddicoat, 1971).

Modern exploration began when Manning (1940) sampled the four main vein systems and obtained values of up to 1.71 g Au/t. In 1964, Smith and Kahr (1965) mapped the prospect in detail and sampled the ancient workings; gold assays from particularly rich areas gave values of up to 1,088 g/t. In 1965, the USGS conducted topographic and EM surveys and petrographic studies. Several conductive anomalies were detected that were similar to those associated with some Canadian massive sulfide deposits. In 1966, the DGMR diamond drilled 18 holes totalling 3,490 m on EM and geological targets (Smith and Kahr, 1966). Fourteen of these holes were drilled in and around Jabal Samran, and the other holes were drilled elsewhere on EM targets. The conductive zones were associated with sheared rocks containing quartz, pyrite and chalcopyrite stringers. The copper content of the core was highest in quartz-veined dacite porphyry where a 1-metre section in DDH-22 assayed 8.7% Cu (Liddicoat, 1966). High values were also found in andesite and sludge samples collected from DDH-22 showed gold contents of 3.43 g/t and 5.5 g/t. The core contained little gold, but precious metals do not appear to have been determined on a regular basis. As a result of the drilling, the BRGM concluded that the copper mineralization at the prospect was entirely secondary in origin and of no economic importance (Troly, 1966).

During the 1967-68 field season, the DGMR carried out a mapping and sampling program on an altered shear zone in the vicinity of DDH-22 (Meaton and others, 1969). The shear zone averaged 0.2% Cu and 1.1% Zn over a width of 100 m with the highest values of up to 5.2% Cu being in samples taken from andesite dikes. Alluvial samples at Jabal Samran gave encouraging gold values, and further exploration for placer deposits was recommended. Geophysical surveys by ARGAS in 1975 indicated that wadi alluvium in the vicinity of the prospect was between 15 and 23 m thick. Subsequent bulk sampling by the DGMR produced disappointing results for gold. Samran and four were drilled elsewhere on EM targets.


39°0'0"
500000
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40°0'0"
600000
SAMRAN SHAYBAN
VMS BELT
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
Zinc
Guides for Metals
Gossan
Clay and Mud Materials
Barite
Faults
Normal faults
Strike-slip faults
Thrust faults
Compiled from: SGS sources and MODS (2015)
GEOLOGY LEGEND
See Fig. 80-1
Rabigh
Khulays
Al Kamil
411 Jabal Shayban
413 Al Maraysi
4923 Al Maraysi-S
4927 Wadi Hamluq
1256 Wadi Huwarah-S
4933 Jabal Baydan
3544 Jabal Baydan-E
1254 Abu Shahab
1256 Wadi Zufut
675 Jabal Baydan
1180 Jabal Bahran
4926 Wadi Shariyah
412 Jabal Al Hamar
1384 Wadi Zufur-N
Wutaylah
410 Jabal Samran
4929 Jabal As Sufran
3681 Jabal Abu Musht-NE2
WTP

Geology

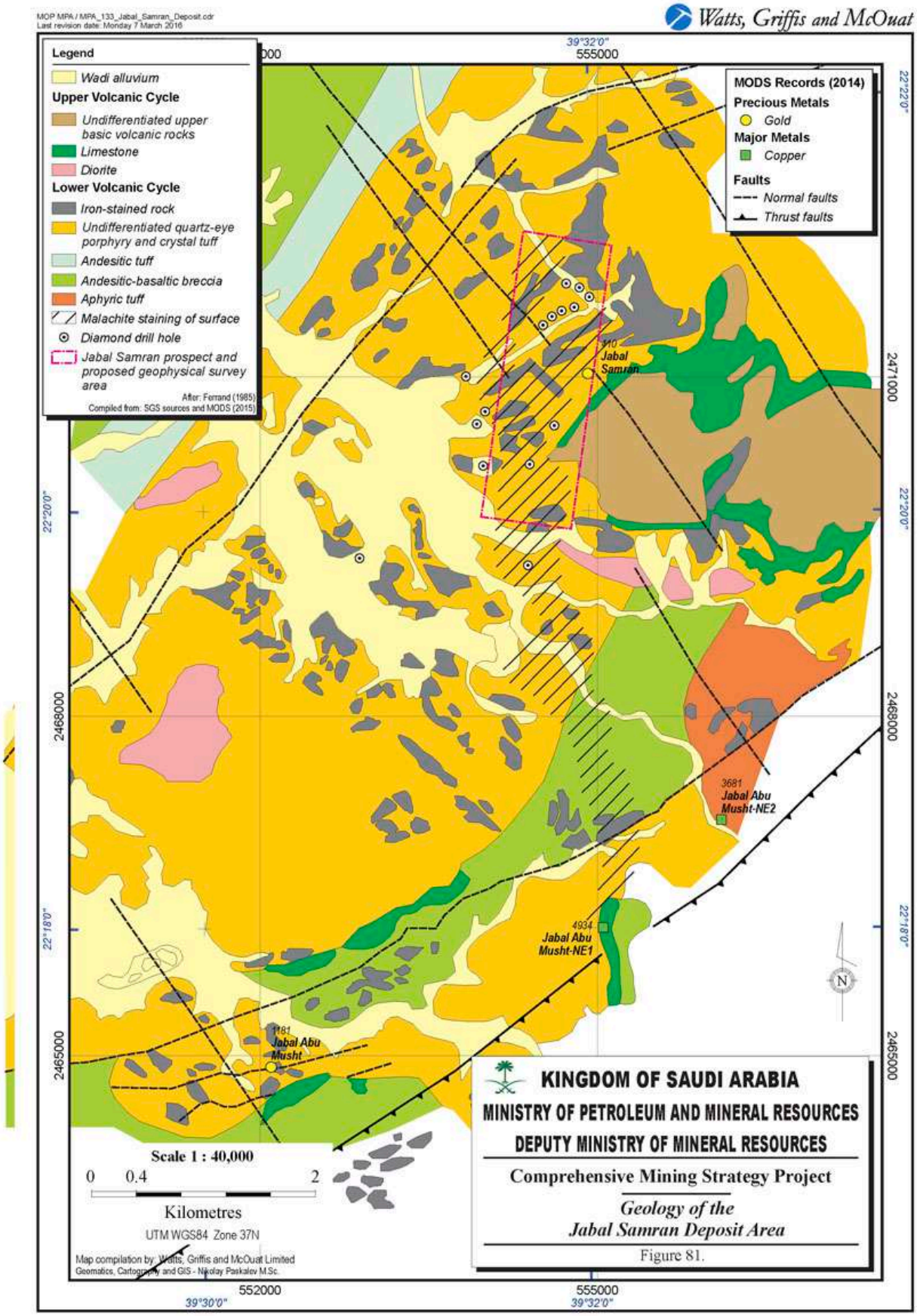
Mineralization is hosted by intensely deformed dacitic lapilli and fine-grained tuffs of the Samran Group (Bishop and Cumpstey, 1982). The rocks are isoclinally folded and have a well-developed axial-plane schistosity. Ferruginous alteration of the host rocks is widespread in the area. Pyrite, sphalerite, chalcopyrite, and gold occur within quartz and quartz-carbonate veins that parallel the schistosity in sheared fold limbs. A map showing the local geology in the Jabal Samran area is provided in Figure 81.

Recommendations

This belt hosts a large number of known and suspected VMS mineral occurrences thus it is considered to be very permissive. Exploration at the Jabal Samran prospect has demonstrated that significant Cu-Au mineralization is present with disseminated sulfide zones within altered volcanic rocks. Prospect scale recommendations made by WGM in 1992 (WGM-CR-11-14) are still valid.

The airborne EM-Mag survey carried out in 1984 should be redone with modern survey equipment as instrumentation methodologies have been significantly improved since that time and anomaly positioning may obviate the need for some ground surveys.

Existing exploration data on the Jabal Samran prospect should be compiled at scales of 1:1,000 and 1:10,000 for the prospect and surrounding area. The 100 x 50 m control grid for the 1966 drilling should be re-established and ground magnetic and IP surveys should be carried out over a 1 km x 3 km area. Oxide and sulphide-bearing zones should be remapped at 1:1,000 scale and chip sampled. The identification of any significant values should be followed by a program of trenching and further diamond drilling as justified by results.


MOP MPA / MPA_133_Jabal_Samran_Deposit.cdr
Last revision date: Monday 7 March 2016
Watts, Griffis and McOuat
Legend
Wadi alluvium
Upper Volcanic Cycle
Undifferentiated upper basic volcanic rocks
Limestone
Diorite
Lower Volcanic Cycle
Iron-stained rock
Undifferentiated quartz-eye porphyry and crystal tuff
Andesitic tuff
Andesitic-basaltic breccia
Aphyric tuff
Malachite staining of surface
Diamond drill hole
Jabal Samran prospect and proposed geophysical survey area
After: Ferrand (1985)
Compiled from: SGS sources and MODS (2015)
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
Faults
Normal faults
Thrust faults
940 Jabal Samran
3681 Jabal Abu Musht-NE2
4934 Jabal Abu Musht-NE1
Jabal Abu Musht
39°32'0"
555000
22°22'0"
22°20'0"
22°18'0"
2471000
2468000
2465000
552000
39°30'0"
N
Scale 1 : 40,000
0 0.4 2
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Jabal Samran Deposit Area
Figure 81.

3.2.4 SUMMARY OF PROSPECTIVE VMS DEPOSITS

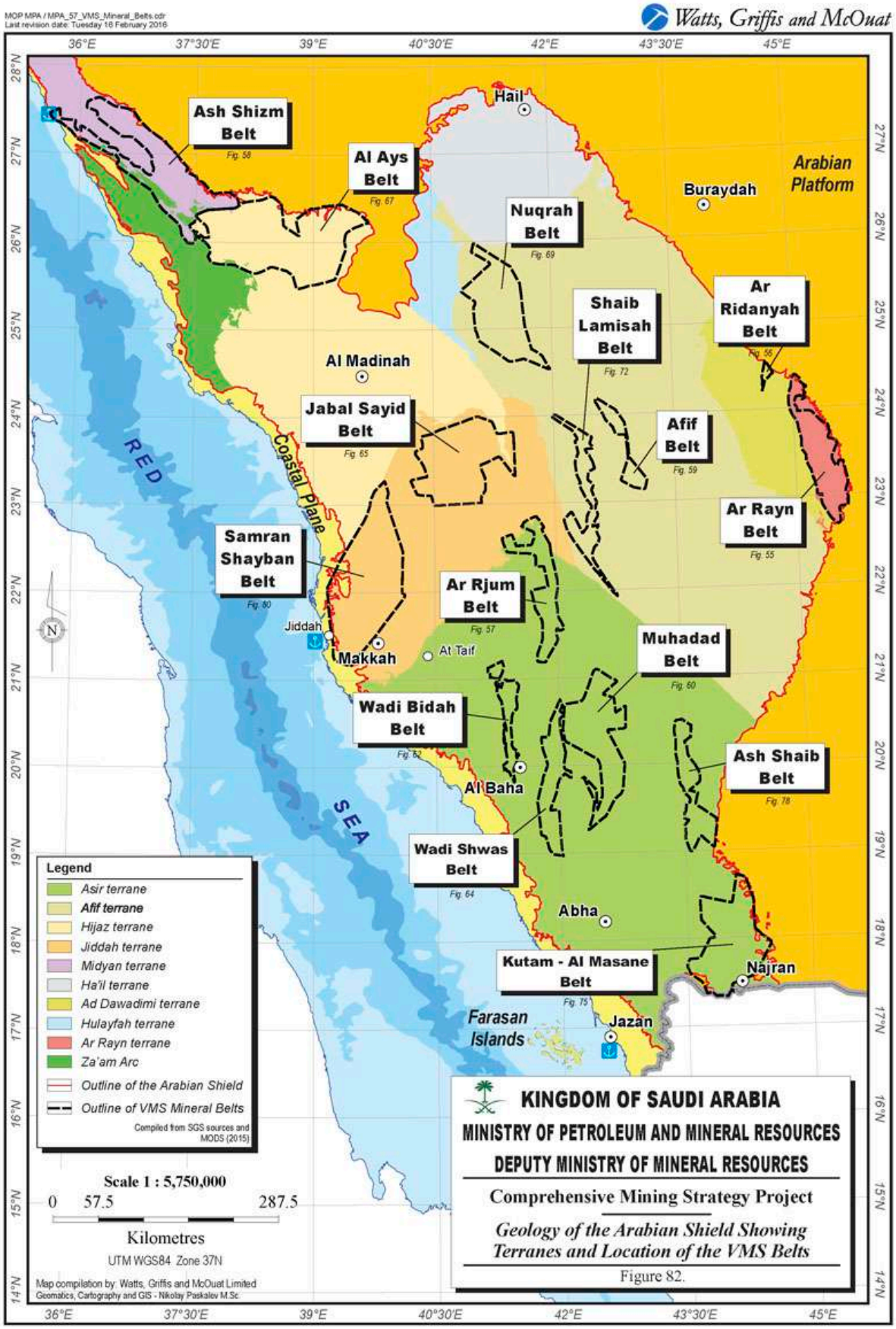
The VMS belts identified in the foregoing sections are shown in Figure 82 and summarized in Table 53 together with WGM's estimate as to how many new undiscovered gold deposits might exist in each belt. The estimate is primarily influenced by the following four parameters:

- number and distribution of existing mines, deposits and feasibility-level projects;
- an abundance of base metal occurrences irrespective of individual status;
- association with a favourable stratigraphic sequence, especially a calc-alkaline sequence containing felsic volcanic rocks;
- geological favourability based on known geological factors and compatibility with recognized deposit models;
- historical exploration results and the current status of base metal prospects; and,
- the overall size (area) of the VMS belt.

A large number of existing mines and advanced projects (deposits) is an obvious signal that the geological framework of an area is capable of producing an economically significant base metal deposit. Unlike gold, there are no clusters of base metal deposits in the Arabian Shield, however there are clusters of base metal prospects. For example, the proximity of the Al Amar and Khnaiguiyah deposits indicates excellent potential for additional deposits in the Ar Rayn VMS Belt.

As with the occurrence of mines and advanced prospects in an area, an abundance of base metal occurrences is important irrespective of whether those occurrences are individually attractive. Many deposits are outlined by zones in which many geochemical anomalies reflect an ore-field halo and this elevated litho-geochemical profile combined with a favourable stratigraphic setting is a clear indication that the geological framework is permissive for VMS-type deposits. A cluster of occurrences may indicate the presence of a volcanic centre from which exhalative fluids may have created massive sulphide deposits on the ancient seafloor. The individual occurrences, whether copper or zinc, must be evaluated in the context of the overall VMS model to assess whether the site of mineralization is proximal or distal to the volcanic centre as this will govern the on-going approach to exploration and the anticipated results.

The association of known deposits with a particular formation is vital to having a positive outlook on the potential of the belt as a whole. Stratigraphic associations point to a cohesive influence on the position of prospects such that explorers can be assured that the mineralization is not a random feature of the geological landscape. Other factors may influence the precise location of a deposit, such as cross-structures that may have controlled the topography of the ancient seafloor. The combination of favourable factors is the key to understanding the ancient setting and assessing where the most likely place is for mineralization to occur. Certainly, being close to a felsic volcanic centre is relevant, but such centres may exist and not be exposed on surface, consequently the need to deploy a wide range of exploration tools, especially geophysics and lithogeochemistry.


MOP MPA / MPA_57_VMS_Mineral_Belts.cdr
Last revision date: Tuesday 16 February 2016
Watts, Griffis and McOuat
Ash Shizm Belt
Fig. 58
Al Ays Belt
Fig. 67
Nuqrah Belt
Fig. 69
Shaib Lamisah Belt
Fig. 72
Ar Ridanyah Belt
Fig. 56
Jabal Sayid Belt
Fig. 65
Afif Belt
Fig. 59
Ar Rayn Belt
Fig. 55
Samran Shayban Belt
Fig. 80
Ar Rjum Belt
Fig. 57
Muhadad Belt
Fig. 60
Wadi Bidah Belt
Fig. 62
Ash Shaib Belt
Fig. 78
Wadi Shwas Belt
Fig. 64
Kutam - Al Masane Belt
Fig. 75
Hail
Buraydah
Arabian Platform
Al Madinah
Jiddah
Makkah
At Taif
Al Baha
Abha
Najran
Jazan
Farasan Islands
RED SEA
Coastal Plane
Legend
Asir terrane
Afif terrane
Hijaz terrane
Jiddah terrane
Midyan terrane
Ha'il terrane
Ad Dawadimi terrane
Hulayfah terrane
Ar Rayn terrane
Za'am Arc
Outline of the Arabian Shield
Outline of VMS Mineral Belts
Compiled from SGS sources and MODS (2015)
Scale 1 : 5,750,000
0 57.5 287.5
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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Comprehensive Mining Strategy Project
Geology of the Arabian Shield Showing Terranes and Location of the VMS Belts
Figure 82.

The geological favourability of any prospect, whether gold or base metal, is greatly enhanced if geologists can demonstrate that the prospect conforms to conventional metallogenic models, and is enhanced further if other known deposits in the region have the same geological setting and similar affiliations such as alteration and geochemical (indicator element) signatures.

It is clear that the exploration history of a prospect or group of prospects is important in respect to assessing potential. Economic realities change over time as commodity prices change, and what was once thought of as uninteresting can suddenly be a preferred exploration target. Negative results in the past must always be reconsidered in terms of the techniques and equipment used, the validity of the exploration model, the level of understanding of the geology at the time and the personal biases of those reporting the results. Many high-quality prospects in the Kingdom were previously dismissed as being of little or no interest based on a perceived lack of continuity. The Al Amar Mine was initially said to be uninteresting because the zinc mineralization lacked continuity without any regard to the great thickness of the sulphide sections and the overall impact of gold mineralization on mine economics. WGM has approached this review by assessing whether the available information is sufficient to justify walking away from a prospect, and if it is not, additional exploration is warranted in most instances where the exploration model is valid and poorly tested.

A total of 15 VMS mineral belts were outlined in the Arabian shield. These belts were defined on the basis of contained VMS deposits and favourable stratigraphic formations as presented on a series of 1:100,000 scale geology maps. The average mineral belt size is 6,439 km2 and the average deposit density is 0.0015 deposits per square kilometre. This contrasts with empirical observations of Canadian Proterozoic and Archean VMS districts that average 795 km^2 in size with a deposit density of 0.016 deposits per square kilometre and containing about 10 economic deposits. These differences are a function of two main factors, namely: (1) the level of compilation and mapping available for each mineral belt; and, (2) the intensity and duration of past exploration programs. It is expected that with additional work in the Arabian Shield, the statistical variances between the two areas (Canada and Saudi Arabia) will be brought into closer alignment. By extension, one must conclude that many economically viable VMS deposits remain to be discovered in Saudi Arabia.

WGM's rationale and predictions for the number of new (undiscovered) deposits in each VMS belt is summarized in the following table. The predicted number of VMS deposits at 10%, 50% and 90% levels of confidence was used as in-put parameters for EMINERS software analysis. Given the convergence of factors needed to create an economically viable VMS base metals deposit, the in-put parameters also included a positive answer to the possibility that any given belt might contain no viable deposits. In WGM's view, the probability of no deposits being discovered was greatest for the Al Ays Belt (70% chance), the Afif Belt (30% chance) and the Ar Rjum Belt (30% chance). However, all belts carry the possibility that they might contain no undiscovered VMS deposits that are economically viable.

Table 53
Summary of Rational for VMS Deposit Potential Assessments and EMINERS In-Puts

Name of VMS Belt	Major Occurrences	Area (km^2)	Rationale for Potential Assessment	Potential New Deposits		
				10%	50%	90%
Afif	2	1,550	Only 2 VMS occurrences - none with a resource. Rated Low Priority	3	1	1
Al Ays	2	15,030	Contains two possible VMS occurrences. Favourable formation covers large area. Rated Low Priority	1	0	0
Ar Rayn	10	5,380	Contains 22 possible VMS occurrences, 5 with a reserve/resource and two producers or near producers (Al Amar & Khnaiguiyah) – Rated High Potential	7	4	4
Ar Ridanyah	6	210	Rated Very High Potential	5	2	2
Ar Rjum	1	4,230	Contains 6 occurrences - one with a resource (Ar Ridaniyah, >median size). Small belt with limits obscured by cover - Rated High Potential	5	1	0
Ash Shaib	9	3,590	Only 1 VMS occurrence - Ranked Low Potential	8	3	1
Ash Shizm	11	10,270	Contains 9 VMS occurrences and 2 with a resource. Ash Shaib at 1.7 Mt is a > median size. Good geology - Rated Moderate Potential	6	3	1
Jabal Sayid	13	9,580	Contains 11 occurrences and 1 with a resource (Ash Shizm 1.6 Mt) in a very large area. Rated Moderate Potential	9	4	1
Kutam-Al Masane	13	8,790	Contains 13 occurrences of which 2 have reserves and 1 producer. The largest VMS deposit in KSA very high potential belt. Also contains the second largest deposit (Kutam - 16.4 Mt) in KSA. Rated High Potential	9	5	2
Muhadad	5	7,720	Contains 5 occurrences and 1 with a resource. Rated Moderate Potential	6	4	1
Nuqrah	9	7,670	Contains 9 VMS occurrences of which 4 have a resource. Nuqrah South (4 Mt) and As Sufra (18 Mt) should be brought to feasibility. Moderate to High Potential	7	3	2
Samran-Shayban	21	13,310	The belt contains 19 VMS occurrences and 3 with a resource. Good cluster of deposits. Rated High Potential	7	3	2
Shaib Lamisah	13	3,360	Contains 13 VMS occurrences and 1 (Shaib Lamisah) with a resource of 1.4 Mt. Rated Moderate Potential	7	4	1
Wadi Bidah	17	2,010	Third most prolific belt with 17 VMS occurrences and 5 with a resource (Rabathan - 2.1 Mt, Shaib at Tare - 4 Mt are the largest). Ranked as High Potential	10	4	2
Wadi Shwas	14	3,890	Contains 14 occurrences and 2 (Al Hajar 6.4 Mt and Jadmah 1.6 Mt) with a resource. Two past gold producers from supergene VMS deposits. Rated High Potential	8	4	1

3.2.5 EMINERS MODELLING OF VMS BELTS AND PROBABILISTIC OUT-COMES

The assessment of the geology and mineral occurrences in the Arabian Shield to identify VMS mineral belts was based on the use of 1:250,000 scale geology maps of the shield area, the MODS (mineral occurrence database) and selected referenced studies. This study resulted in the identification of permissive tracts or mineral belts that are favourable for VMS mineral deposits. These deposits and occurrences were located in each belt and related to the permissive lithologies as outlined on the maps, and the mineral belt outlines were extended outward from these areas. The shape and extent of each mineral belt is therefore dependent upon the detail of the mapping, and of the adequacy of the prior exploration programs.

As summarized in Section 3.1.5 of this report, the United States Geological Survey (USGS) developed a mineral assessment program named EMINERS (**E**conomic **M**ineral **R**esource **S**imulator) to assess the potential of selected mineral belts to host undiscovered deposits at different levels of probability. The assessment consists of three parts.

1. Development of grade and tonnage mineral deposit models;
2. Delineation of mineral tracts permissive for each deposit type; and,
3. Probabilistic estimation of the number of undiscovered deposits for each deposit type in each mineral belt.

Grade and tonnage models were compiled by the USGS for various types of deposits including the VMS (volcanogenic massive sulphide) type that is the subject of this section. Singer (2007) after conducting a sensitivity analysis, concluded that selection of the proper grade and tonnage model is more critical to the final assessment that small errors in estimates of the number of deposits.

Sangster (1980) calculated that the total metal content per volcanic centre (mineral belt) was 4.6 Mt with an average grade of about 6% combined base metal (copper, zinc, lead).

It is very easy to be distracted by very large VMS deposits that are occasionally found. These giant deposits, as a class, are outliers in any population of VMS deposits and Jabal Sayid probably fits into this group. Boldy (1977) has shown that the median size of a producing deposit in a Canadian VMS mineral belt is 1.6 Mt. Many VMS deposits in the KSA meet or exceed this threshold and by this measure they should be put into production. Boldy has also calculated that the probability of discovery of a median VMS deposit is 1:700; that is one out of 700 drill holes testing meaningful targets will meet with success. Most VMS deposits and mineral belts fall well short of this threshold suggesting that many more deposits remain to be discovered in the Arabian shield by continued focussed exploration efforts.

Based on the success of its approach to the assessment of the gold belts in the KSA, WGM initially modified the USGS model to exclude inappropriate volcanogenic deposit types, giant orebodies and to include appropriate deposits reflective of the region studied (i.e. the Arabian-Nubian shield). In addition deposits from a mature (from an exploration perspective) mineral belt with the requisite geological characteristics

were included. This modified model, as shown in Table 54, was used for the initial EMINERS simulation with the expectation that the size and grade of the undiscovered VMS deposits in the Kingdom will be similar to those in the model.

Table 54
Representative Deposits Comprising WGM's EMINERS Model for VMS Deposits in the KSA

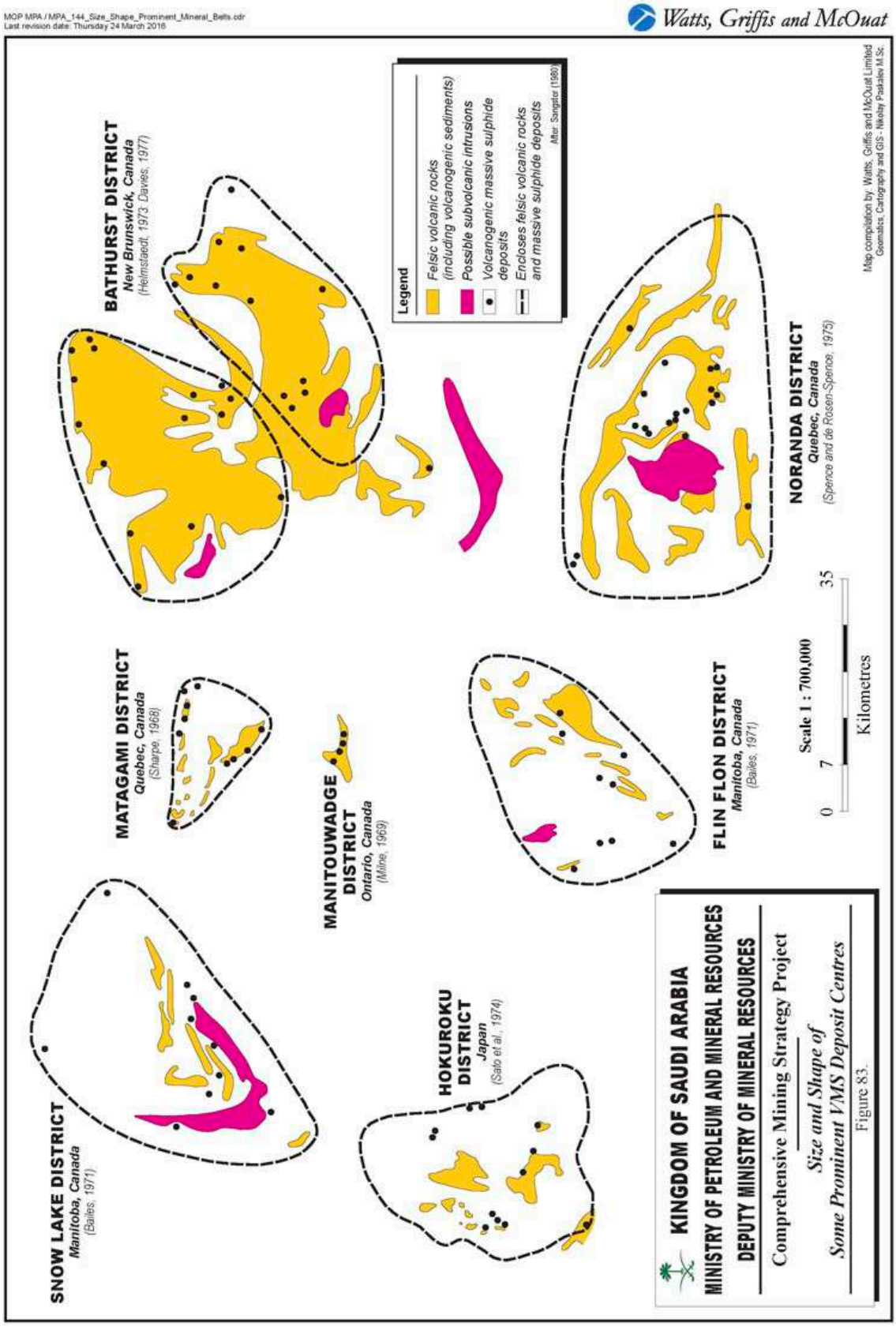
Deposit / Mine	Country	Tonnes	Copper (%)	Zinc (%)	Lead (%)	Silver (g/t)	Gold (g/t)
Woodlawn	Australia - Queensland	11.00	1.77	9.34	3.54	78.0	0.00
Mt. Chalmers	Australia - Queensland	4.29	1.64	3.51	1.01	42.0	2.05
Que River	Australia – Tasmania	6.00	0.40	12.50	7.00	171.0	3.40
Golden Grove	Australia – Western	39.20	1.84	4.50	0.15	41.6	0.42
HW	Canada – British Columbia	11.74	2.20	5.10	0.40	1.0	0.07
Myra Falls-Lynx	Canada – British Columbia	5.18	1.50	7.60	1.00	99.0	2.10
Silver Queen	Canada – British Columbia	0.36	0.76	6.00	2.10	275.0	3.10
Mamie	Canada – British Columbia	0.06	0.70	7.60	0.00	0.0	11.00
Ruttan	Canada – Manitoba	40.80	1.53	1.43	0.00	5.0	0.20
Fox	Canada – Manitoba	13.00	1.88	1.95	0.00	5.2	0.18
Heath Steele (B)	Canada – New Brunswick	40.42	1.11	4.71	1.61	63.8	0.93
Murray Brook	Canada – New Brunswick	21.50	0.44	1.95	0.86	31.2	0.00
HeathSteele(ACD)	Canada – New Brunswick	4.78	1.00	5.34	1.31	56.6	1.03
Nepisiguit	Canada – New Brunswick	2.64	0.28	2.30	0.54	10.3	0.00
Heath Steele(EF)	Canada – New Brunswick	1.40	1.51	4.39	2.01	79.9	1.03
HalfMileLake(SG)	Canada – New Brunswick	0.91	0.44	6.01	0.79	1.7	0.00
Rambler-Ming	Canada – Newfoundland	4.47	1.71	0.14	0.00	9.9	1.03
Izok Lake	Canada – Nunavut	10.90	2.82	13.70	1.42	70.0	0.00
High Lake	Canada – Nunavut	4.72	3.53	2.46	0.00	0.0	0.50
Mattabi	Canada – Ontario	11.67	0.91	7.67	0.84	107.0	0.24
Kam Kotia	Canada – Ontario	5.84	1.11	1.21	0.00	3.5	0.03
Lyon Lake	Canada – Ontario	3.70	1.15	6.66	0.63	116.0	0.34
Sturgeon Lake	Canada – Ontario	2.09	2.80	10.19	1.42	181.8	0.65
Uchi	Canada – Ontario	1.59	1.84	11.40	0.00	72.7	0.00
Mattagami Lake	Canada – Quebec	25.20	0.63	9.17	0.10	32.6	0.45
East Sullivan	Canada – Quebec	14.95	0.94	0.49	0.00	7.2	0.24
Normetal	Canada – Quebec	10.10	2.15	5.12	0.00	45.0	0.55
Lake Dufault	Canada – Quebec	4.09	3.20	5.60	0.00	44.2	0.79
Millenbach	Canada – Quebec	3.21	3.43	4.23	0.00	52.0	0.89
Mobrun	Canada – Quebec	2.72	0.69	2.18	0.00	21.3	1.78
Dumagami	Canada – Quebec	2.13	0.14	0.00	0.00	9.3	3.26
Joutel	Canada – Quebec	1.72	1.65	2.01	0.00	3.5	0.00
Emba Derho	Eritrea	85.03	0.67	1.29	0.00	8.6	0.23
Bisha	Eritrea	49.19	1.28	3.92	0.00	33.1	0.52
Adi Rassi	Eritrea	15.77	0.54	0.00	0.00	1.5	0.33
Debarwa	Eritrea	3.99	2.42	1.00	0.00	26.6	1.65
Adi Nefas	Eritrea	1.84	1.78	10.05	0.00	115.0	3.31
Terakimti	Ethiopia	6.05	1.25	1.57	0.00	17.5	1.30
Pyhasalmi	Finland	31.10	0.75	2.43	0.06	17.0	0.20
Metsamonttu	Finland	1.51	0.10	4.60	0.10	6.3	0.35
Paronen	Finland	1.50	1.00	0.00	0.00	0.0	0.00
Khnaiguiyah	Saudi Arabia	30.00	0.40	3.30	0.00	0.0	0.00
Jabal Sayid	Saudi Arabia	10.80	1.55	1.21	0.00	35.0	0.30
Wadi Kutam	Saudi Arabia	8.00	1.83	0.95	0.00	6.1	0.31
Al Masane	Saudi Arabia	7.21	1.42	5.31	0.00	40.2	1.19
Al Hajar S & N	Saudi Arabia	6.40	1.20	0.97	0.00	0.0	0.00
Jabal Bitran	Saudi Arabia	6.00	0.00	0.30	0.00	0.0	0.00
Shaib at Tayr	Saudi Arabia	4.00	0.37	0.50	0.00	0.0	0.00
Al Amar	Saudi Arabia	3.36	0.89	5.74	0.00	19.1	10.68
Ar Ridanyah	Saudi Arabia	3.00	0.00	3.00	0.00	0.0	0.00
Al Halahila	Saudi Arabia	2.10	0.34	2.74	0.03	19.7	0.30
Jabal Rabdhan	Saudi Arabia	2.10	2.50	0.50	0.00	1.5	1.20
Ash Shiab	Saudi Arabia	1.70	0.30	6.00	0.00	0.0	0.00
As Shizm	Saudi Arabia	1.60	2.90	0.75	0.00	18.0	0.00
Jadmah	Saudi Arabia	1.60	1.83	1.37	0.00	18.3	0.00
La Joya	Spain	2.88	0.50	0.60	0.65	0.0	0.00
Anaytk-Cakmakaya	Turkey	83.14	0.76	0.03	0.00	3.7	0.05
Madenkoy	Turkey	30.00	2.88	4.34	0.11	0.0	0.00
Kizilkaya	Turkey	9.07	0.80	0.50	0.00	0.0	0.00
Kalkanli	Turkey	0.15	2.27	0.00	0.00	0.0	0.00
Greens Creek	United States – Alaska	3.63	0.50	9.00	2.50	343.0	3.40
Jerome	United States – Arizona	29.00	5.00	0.20	0.00	49.7	1.37

WGM discussed the make-up of its VMS model with geologists at the USGS in Denver, Colorado to overcome some initial challenges involved in integrating its customized model into the EMINERS software. Once these teething problems were overcome, the in-put variables were entered into the EMINERS software in-put screens and the EMINERS Monte Carlo conditional simulation was run to produce probabilistic estimates of tonnage and contained metal for each VMS mineral belt at levels of confidence corresponding to 90%, 50% and 10% certainty of the predicted outcome.

Empirical observations regarding VMS deposit sizes, grades and mineral belt areas by Sangster (1980) and Boldy were used as a generalized guide in evaluating the results. Sangster (1980) made a quantitative study of Archean and Proterozoic VMS mineral belts, and he concluded that the mineral belts have an average diameter of 32 km, containing an average of 12 deposits (density = .016 deposits/km^2) (Figure 83). In order to test the validity of the EMINERS output the results were compared to these studies based on Canadian and worldwide mineral belts with a long production history. These studies outlined the following additional characteristics for a mature VMS mineral belt:

- a mineral belt contained 4 to 20 deposits with an average of 12;
- the average base metal content per belt was 4.6 Mt with a coefficient of variation of 32% (range 3.1-6.1 Mt);
- 78% to 80% of the deposits occupy the size range between 0.1 and 10 Mt, and half of these are less than 1 Mt;
- 40% of the VMS deposits in a mineral belt will be about 0.4 Mt of ore;
- the median deposit size in a mineral belt is 1.4 Mt, while the median size of a producing mine is 1.8 Mt;
- the distribution of the total base metal content among the 5 largest deposits will be 67%, 13%, 7.8%, 4.9% and 3.5%, meaning that the largest deposit will contain 67% of the total resources of the belt, and the second largest deposit will contain 13% of the total resources, and so on....;
- the average metal grade for a VMS deposit will be about 6% (Cu+Zn+Pb); and,
- a frequency distribution curve for VMS deposits indicates that a median sized deposit will only occur with a frequency of 15%

The largest mineral deposit in a typical mineral belt would contain about 3.1 Mt of base metals which would be approximately equivalent to Boldy's (1977) upper mid-decile deposit containing 50 Mt grading 1.94% Cu, 4.82% Zn, 1.03 g Au/t and 62.4 g Ag/t. These deposits occur with a frequency of 4%. The second largest deposit would contain 0.598 Mt of base metals which would be approximately equivalent to Boldy's arithmetic average deposit containing 8.9 Mt grading 1.95% Cu, 4.51% Zn, 1.03 g Au/t and 52.8 g Ag/t. These deposits occur with a frequency of 7.5%.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Last revision date: Thursday 24 March 2016
Watts, Griffis and McOuat
BATHURST DISTRICT
New Brunswick, Canada
(Helmstaedt, 1973; Davies, 1977)
NORANDA DISTRICT
Quebec, Canada
(Spence and de Rosen-Spence, 1975)
MATAGAMI DISTRICT
Quebec, Canada
(Sharpe, 1968)
MANITOUWADGE DISTRICT
Ontario, Canada
(Milne, 1969)
FLIN FLON DISTRICT
Manitoba, Canada
(Bailes, 1971)
SNOW LAKE DISTRICT
Manitoba, Canada
(Bailes, 1971)
HOKUROKU DISTRICT
Japan
(Sato et al., 1974)
Legend
Felsic volcanic rocks (including volcanogenic sediments)
Possible subvolcanic intrusions
Volcanogenic massive sulphide deposits
Encloses felsic volcanic rocks and massive sulphide deposits
After Sangster (1980)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pasikhin M.Sc.
Scale 1 : 700,000
0 7 35
Kilometres
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Comprehensive Mining Strategy Project
Size and Shape of Some Prominent VMS Deposit Centres
Figure 83.

WGM is not aware of any more recent studies that have statistically evaluated VMS deposits on a mineral belt basis even though it is widely recognized that VMS deposits tend to form clusters. Most recent studies have evaluated VMS deposits based on the subclass that they belong to rather than on their spatial distribution in a mineral belt. However, some recent studies of VMS deposits by the USGS (Mosier, 2009) on a worldwide basis have provided some data to substantiate the relevancy to modern times of the earlier studies by Boldy and Sangster. These recent studies have shown that the median size for all VMS classes is about 2.1 Mt and that approximately 72% of all VMS deposits fall in the range 0.1 to 10 Mt. These data, which include more recent discoveries, are not significantly different from the older calculations suggesting the continuing relevancy of the previous studies. However, none of the VMS mineral belts in the KSA can be considered as mature either from an exploration or production standpoint, therefore some variance is to be expected. Three examples bear this out:

1) AMAK continues to slowly enlarge the Al Masane deposit so the ultimate size is still an unknown;
2) substantial parts of all VMS belts remain largely unexplored due to explorers like Ma'aden favouring gold exploration over base metals; and,
3) significant deposits like Nuqrah and Shaib Lamisah are only shallowly explored, with little focused work to enlarge the area of interest beyond that which is currently tested.

These observations can provide some perspective on the expected size and content of the modelled mineral belts in the Arabian Shield. Unfortunately, the model favouring the known deposits in Africa and the Middle East region produced results that were biased towards smaller and more gold-rich deposits. When WGM further restricted the model to only deposits in the Arabian-Nubian shield, the outcomes were judged to be even less representative than what is currently seen in Saudi Arabia. That result was not what might have been expected, and appears to have been caused by a high degree of variance within the smaller (restricted) deposit population.

WGM amended its geological model to take in significantly more deposits from around the world, using the USGS worldwide data model containing approximately 435 VMS deposits. At the 10% confidence level, 12 of the 15 mineral belts meet or exceed the total base metal content threshold of a mature VMS mineral belt. At the 10% confidence level the simulation also estimated that the available undiscovered ore tonnages varied from 4 Mt to 120 Mt, while at the 50% confidence level the tonnages varied from zero (0 Mt) to 21 Mt. This indicates that there is significant freedom in many mineral belts for the discovery of an upper quartile deposit (~3.7 Mt) or an upper decile deposit (~13.3 Mt), and even the discovery of a mid-upper decile deposit (~50-80 Mt) is possible. These results were more in line with what is currently seen in the Arabian-Nubian Shield.

The outcomes from the EMINERS conditional simulation are totalled and summarized for the 15 delineated VMS mineral belts as follows Table 55 for all confidence levels. The physical characteristics of each belt are presented in Table 56 together with the EMINERS in-put parameters and details regarding the probabilistic outcomes from the software for each individual VMS belt. For economic viability modelling, WGM selected the 50% confidence outcomes as its base case.

Table 55:
EMINERS Model for VMS Base Metal Deposits in the KSA

Confidence Level	Number of New Deposits	Global Tonnes (millions)	Global Resources (Contained Metal)				
			Cu	Zn	Pb	Au	Ag
			(tonnes)			(ounces * 1,000)	
10%	98	1,284	13,148,000	30,536,00	6,296,900	21637	958,478
50%	45	189	2,234,000	4,383,900	448,900	1,865	95,938
90%	17	7	118,100	79,000	0	0	482

It is interesting that, as the confidence level is lowered from 50% to 10%, a 680% increase is seen in the tonnage (size) of the global resources whereas the contained copper increased 589%; zinc 697%; lead 1403%; gold 1160% and silver 999%. Average grades changes were Cu (-13%), Zn (+3%), Pb (+106%), Au (+71%) and Ag (+47%).

It is important not to falsely link potential with economic viability. Median sized VMS deposits (1.8 Mt of ore) and even modal-sized deposits (0.39 Mt of ore) may be economically viable depending on many factors such as location, infrastructure etc., and not every mineral belt will contain upper quartile or mid-upper decile sized deposits. An example of this is the Confederation Mineral Belt in Ontario, Canada where 19 VMS-type deposits and occurrences have been discovered, however only the largest at South Bay (1.59 Mt grading 1.84% Cu, 11.4% Zn, 72.2 g Ag/t) was ever mined.

In assessing the EMINERS outcomes in practical terms using the 50% confidence level to provide a resource base, certain conclusions result in respect to predicting the largest undiscovered mine (Table 57). Taking the EMINERS outputs to the next natural stage entailed allocating the global resources in each belt according to the anticipated size for each undiscovered deposit. To do this, WGM used the Boldy model so that the largest deposit in each belt was allocated 67% of the global resources based on tonnage. Tonnage was used for simplicity reasons because allocations based on grade would be complex and prone to breaking predicted ratios between the metals. Allocations based on grade would also require adjusting tonnages to ensure the grade X tonnage resource was consistent with the Boldy model. To ensure all predicted deposits were treated equally, the allocations were made on tonnage alone. The undiscovered deposits in each belt are predicted to have the sizes shown in Table 57.

WGM's input prediction of the number of undiscovered, economically viable deposits for each belt, as shown in Table 53, does not include an allowance for deposits that would be inherently uneconomic. Boldy's resource distribution curve takes in all VMS deposits, whether economically viable or not. Consequently, in using the percentage allocations in Boldy's model, there are left-over resources (excess tonnes) which might fall into small uneconomic deposits that are in addition to WGM's estimate made for in-put purposes. The unattributed resources are shown in the far right column in Table 57. Given the predictive character of the EMINERS output, for which the software gives a range of error (one standard deviation), a portion of these unallocated resources could also be added to the actual predicted tonnages shown for each deposit in terms of ranking.

In assessing the outcomes of EMINERS modeling, WGM concluded that it would be wrong to assign and potential for undiscovered deposits to a single confidence level. While choosing the 50% level provided a degree of safety or comfort, there is a likelihood that in some belts the 10% outcome will occur and in other belts the 90% outcome will occur. WGM's estimates for the number of undiscovered deposits were based on the number of quality prospects in each belt, yet the belts are not equally explored and this results in several fundamental questions such as: Is it reasonable to conclude that the Ar Rayn Belt has no potential for a 10 Mt deposit because the 26 Mt Khnaiguiyah deposit has already been found and this exceeds the maximum size limit for the predicted new discoveries in the belt? If so, then the presence of the Khnaiguiyah and Al Amar deposits would limit the maximum allowable size for a new discovery in this belt to approximately 1 Mt. If the 10% confidence level is accepted, then the Khnaiguiyah and Al Amar deposits take up only a small percentage of the total resources, and they could be accompanied by a much larger 40-45 Mt deposit somewhere in the belt. The same might also be said of the Kutam-Al Masane VMS Belt. As shown in Chart 1, the 16.4 Mt resources of the Kutam deposit marginally exceed the maximum deposit size predicted at the 50% confidence level for the belt, and the 9.4 Mt Al Masane deposit is 3X the predicted size of the second largest deposit in the belt. The predictive nature of EMINERS is therefore a tool that needs to be used cautiously in areas where the level of exploration is uneven – such as in immature exploration belts such as exist in Saudi Arabia. It can be debated whether the mineral resources in belts with existing deposits/mines should be reduced to account for exploration successes, or should a lower confidence level be used to reflect the potential of a belt with proven resources. Boldy's model would favour removing the known resources. Exploration geologists, being optimists by nature, would favour the use of a lower confidence threshold that accommodates the occurrence of deposits like Kutam and Al Masane in the same belt, and offering the potential for a larger deposit.

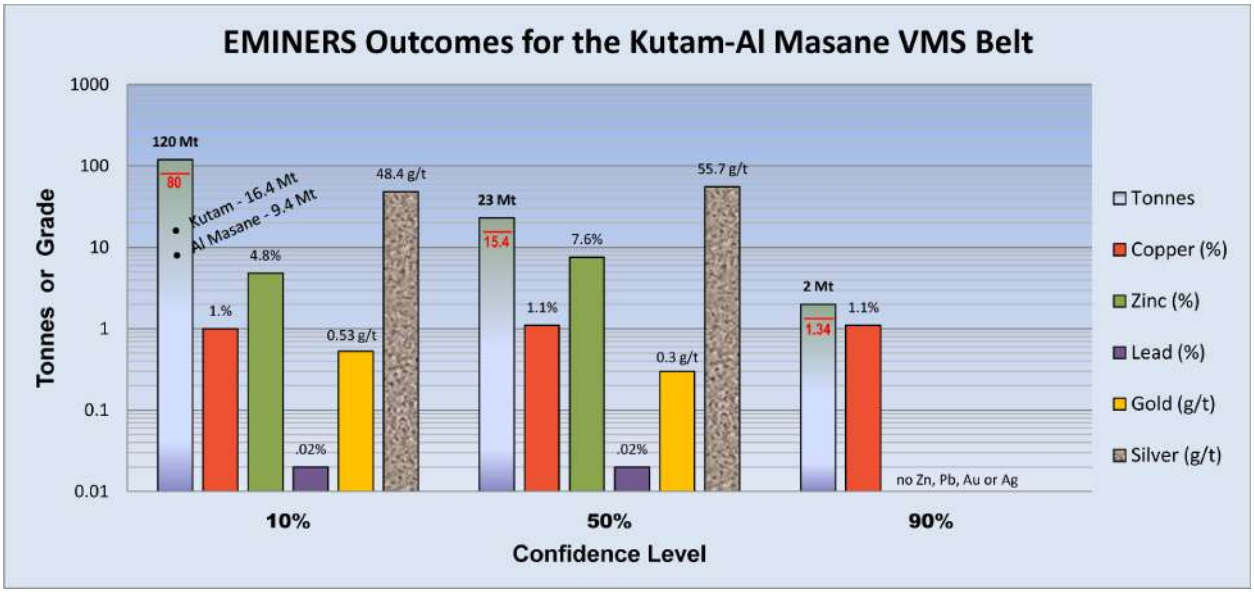

Chart 5: EMINERS outcomes for the Kutam-Al Masane VMS Belt at 10%, 50% and 90% confidence levels. The red bars indicate the largest permissible deposit size accounting for 67% of the global resources in the belt. The grades at each level of confidence are shown. The size of the Kutam and Al Masane deposits is shown at left – they cannot both be accounted for at the 50% confidence level.

Table 56
Summary of VMS Belts: Base Metal Occurrences and Mines in the Arabian Shield, EMINERS In-Puts and Projections

rea (km^2)	Known VMS Mines (includes feasibility-level projects)			EMINERS In-Puts: Anticipated New Deposits by Confidence Level			Chance of Zero Deposits	EMINERS Projections (Out-Puts): Number of New Deposits, Global Resourc																
								Number of Deposits	---------- Confidence Level ----------															
									10%							50%								
	Closed	Active	Planned	10%	50%	90%	(%)	(#)	Mt	Cu %	Zn %	Pb %	Au g/t	Ag g/t	Mt	Cu %	Zn %	Pb %	Au g/t	Ag g/t	Mt	Cu %
,550	0	0	0	3	1	0	yes	1.3	34	1.0	5.3	0.02	0.41	47.1	2	1.0	<0.1	0.00	0.00	<0.1	0	0
,030	0	0	0	1	0	0	yes	0.3	4	1.2	9.6	0.01	0.25	52.0	0	<0.1	<0.1	<0.1	<0.1	<0.1	0	0
,380	0	Al Amar	Khnaiguiyah	7	4	2	yes	4.2	100	1.0	4.3	0.02	0.56	46.4	17	1.2	7.6	0.02	0.29	56.0	1	1.9
210	0	0	0	5	2	1	yes	2.5	63	1.0	4.7	0.02	0.51	40.6	7	1.2	7.5	0.01	0.29	44.5	0	0
,230	0	0	0	5	1	0	yes	1.9	52	1.0	4.8	0.02	0.48	48.0	3	1.1	<0.1	0.00	0.00	<0.1	0	0
,590	0	0	0	8	3	1	yes	3.8	98	1.0	4.4	0.02	0.53	42.3	13	1.2	7.5	0.01	0.31	52.5	0	0
,270	0	0	0	6	3	1	yes	3.2	82	1.0	5.0	0.02	0.49	47.5	11	1.3	8.3	0.01	0.27	56.7	0	0
,580	0	Jabal Sayid	0	9	4	1	yes	4.5	120	1.0	4.2	0.02	0.54	43.1	18	1.2	6.3	0.01	0.33	48.3	0	0
,790	0	Al Masane	0	9	5	2	yes	5.2	120	1.0	4.8	0.02	0.53	48.4	23	1.1	7.6	0.02	0.30	55.7	2	1.1
,720	0	0	0	6	4	1	yes	3.6	87	1.1	4.6	0.02	0.53	45.7	14	1.1	7.8	0.01	0.29	52.5	0	0
,670	0	0	0	7	3	2	yes	3.8	96	1.0	4.2	0.02	0.54	40.4	15	1.2	6.4	0.02	0.33	44.0	1	1.4
,310	0	0	0	7	3	2	yes	3.8	100	1.0	5.2	0.02	0.46	50.0	14	1.2	7.8	0.02	0.29	55.0	1	1.4
,360	0	0	0	7	4	1	yes	3.9	98	1.0	4.4	0.02	0.53	42.3	15	1.1	6.6	0.02	0.33	48.0	0	0
,010	0	0	0	10	4	2	yes	5.1	120	1.1	4.0	0.02	0.60	38.9	21	1.2	5.9	0.02	0.38	46.3	2	1.0
,890	0	0	0	8	4	1	yes	4.2	110	1.0	4.6	0.02	0.51	44.6	16	1.3	7.6	0.02	0.31	54.0	0	0
,590	**0**	**3**	**1**	**98**	**45**	**21**		**51.3**	**1,284**						**189**						**7**	
,439				**6.5**	**3.0**	**1.4**		**3.4**	**86**	**1.02**	**4.57**	**0.02**	**0.52**	**44.5**	**13**	**1.18**	**6.96**	**0.01**	**0.31**	**50.0**	**0.5**	**1.27**

3.2.6 TECHNICAL AND ECONOMIC VIABILITY OF PREDICTED UNDISCOVERED VMS DEPOSITS

Introduction

The out-put from the EMINERS modeling was used as the basis for estimating the economic viability of the predicted new and undiscovered VMS-type deposits. WGM used these outcomes which we believe are indicative, however like with the EMINERS outcomes for gold, the probabilistic approach almost certainly under-estimates potential at the 50% and 90% levels of confidence. We believe some predictions are most likely at the 10% level of confidence. The primary reason for under-reporting is the fact that a probabilistic approach allows little or no influence by deposits that are outliers – the extremely large deposits. This is particularly the case for the VMS class of deposits within which approximately 1% of the global population are giant deposits exceeding 100 Mt. Because the average deposit size globally is minute by comparison, these tend to have a very strong influence on overall results. It is not surprising therefore that the average grade of the EMINERS predictions decreases as confidence level is reduced because a greater number of smaller, lower grading deposits are taken into the sample population.

As discussed in the preceding section, the undiscovered base metal resources were allocated amongst the predicted number of deposits (Table 57). This information was provided to WGM's engineering group for further assessment such that a provisional mining schedule could be developed as a basis for determining what mining method might be appropriate given the "average" geometric configuration of such gold deposits. This was used as a basis for selecting and sizing equipment as well as estimating capital, operating and other cost factors.

Mining and Processing

In order to evaluate undiscovered mines, cost estimates were prepared for a range of typical mines in the Kingdom. These are order-of-magnitude cost estimates, designed to get an initial reading on potential viability. WGM initially prepared personnel lists for typical small, medium, and large mines, both open pit and underground, six lists in all. Only underground mining operations were modelled for VMS deposits, with an on-site concentrator producing copper and zinc concentrates. Equipment requirements are summarized in Table 58. Gold and silver that is typically present in this style of mineralization would be recovered for credit in the concentrates. Lead contents were not economically significant.

Mining and maintenance personnel quantities were estimated based on a mining fleet analysis. For each mine, a few positions were assigned international salaries; for all other jobs filled by Saudi nationals, wages

and benefit estimates were based on the 2014 SGS report “Directory of Mining Services Cost in Saudi Arabia”. These positions are summarized in Table 59. Quantities of consumables were then prepared for each of the three underground models. Costs were prepared using price information from WGM data. Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine site costs for Mining.

Table 57
Base Case VMS Resource Allocation Summary by Mine Size at 50% Confidence Level

Mineral Belt	Number of Mines	Global Resources						Largest Mine	2nd Largest Mine	3rd Largest Mine	4th Largest Mine	5th Largest Mine	Unassigned Resources (Mt)	Current Mines and Major Deposits	
		Tonnes	Cu	Zn	Pb	Au	Ag							Mt	Grade
		(Mt)	(%)			(g/t)		Tonnes (M)							
Afif	1	2	1.0	<0.1	0.00	0.00	<0.1	**2.0**	------	------	------	------	**0.0**		
Al Ays	0	0	----	----	----	----	----	**0.0**	------	------	------	------	**0.0**		
Ar Rayn	4	17	1.2	7.6	0.02	0.29	56.0	**11.4**	**2.2**	**1.3**	**0.8**	------	**1.3**	26.1 [A] 6.8 [B]	0.24% Cu, 3.3% Zn 0.48% Cu, 4.61% Zn, 5.2 g Au/t 14 g Ag/t
Ar Ridanyah	3	7	1.2	7.5	0.01	0.29	44.5	**4.7**	**0.9**	**0.5**	------	------	**0.9**		
Ar Rjum	2	3	1.1	<0.1	0.00	0.00	<0.1	**2.0**	**0.4**	------	------	------	**0.6**		
Ash Shaib	4	13	1.2	7.5	0.01	0.31	52.5	**8.7**	**1.7**	**1.0**	**0.6**	------	**1.0**		
Ash Shizm	3	11	1.3	8.3	0.01	0.27	56.7	**7.4**	**1.4**	**0.9**	------	------	**1.3**		
Jabal Sayid	5	18	1.2	6.3	0.01	0.33	48.3	**12.1**	**2.3**	**1.4**	**0.9**	**0.6**	**0.7**	25.0 [C]	2.55% Cu
Kutam-Al Masane	5	23	1.1	7.6	0.02	0.30	55.7	**15.4**	**3.0**	**1.8**	**1.1**	**0.6**	**1.1**	9.4 [D] 16.4 [E]	1.21% Cu, 4.2% Zn, 0.97 g Au/t 31 g Ag/t 1.03% Cu, 0.51% Zn, 0.1 g Au/t
Muhadad	4	14	1.1	7.8	0.01	0.29	52.5	**9.4**	**1.8**	**1.1**	**0.7**	------	**1.0**		
Nuqrah	4	15	1.2	6.4	0.02	0.33	44.0	**10.1**	**2.0**	**1.2**	**0.7**	------	**1.0**	0.89 [F]	1.3% Cu, 9.6% Zn, 3.9% Pb, 6.5 g Au/t, 293 g Ag/t
Samran-Shayban	4	14	1.2	7.8	0.02	0.29	55.0	**9.4**	**1.8**	**1.1**	**0.7**	------	**1.0**		
Shaib Lamisah	4	15	1.1	6.6	0.02	0.33	48.0	**10.1**	**2.0**	**1.2**	**0.7**	------	**1.0**		
Wadi Bidah	5	21	1.2	5.9	0.02	0.38	46.3	**14.1**	**2.7**	**1.6**	**1.0**	**0.7**	**0.9**		
Wadi Shwas	4	16	1.3	7.6	0.02	0.31	54.0	**10.7**	**2.1**	**1.3**	**0.8**	------	**1.1**	4.2 [G] 8.0 [H]	2.91 g Au/t and 25 g Ag/t (mined out) 1.34% Cu, 0.55% Zn, 0.31 g Au/t 13.6 g Ag/t

NOTES ON REFERENCED DEPOSITS: (A) Khnaiguiyah; (B) Al Amar; (C) Jabal Sayid; (D) Al Masane; (E) Kutam; (F) Nuqrah; (G) Al Hajar (original gold-silver resource mined out); (H) Al Hajar (current base metal deposit)

Capital cost estimates for Mining were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM and BBA data. The following tables illustrate the equipment and personnel requirements for the Mining Department at a typical underground mine. The mine is modelled at 1,000 t per day of ore, 5 days per week. Long-hole open stopes are assumed, with trucks hauling the ore up an access ramp to surface.

Table 58
Typical Major Equipment Fleet – Underground VMS Mine

Item	Description	Quantity
Production Drill	89 mm	1
Development Jumbo Drill	1 boom	1
Rock Breaker	Hydraulic	1
Load-Haul-Dump machine	7 t	2
Truck, Haulage	30t	3
Truck, Haulage	15 t	2
Rock bolting rig		1
Scissor lift truck		2
Explosives Truck		1
Grader	Underground	1
Service Truck		1
Utility Vehicle		8

Table 59
Typical Personnel Roster – Open Pit Gold Mine

Responsibility Level	Number	Responsibility Level	Number
Mine Superintendent	1	Mine Engineer	2
Mine Captain	3	Surveyor	1
Shift Boss	6	Mining Technician	2
Clerk	3	Geologist	3
Jumbo Drill Operator (Prod. & Dev.)	9	Sampler	3
LHD - Truck Driver	21	Maintenance General Foreman	1
Rock Bolter	12	Maintenance Foreman	3
Relief Operator	4	Maintenance Planner	1
Blaster	6	Heavy Equipment Mechanic	8
Service Truck driver	3	Welder	3
Services Miner	12	Automotive Electrician	1
Mine Labourer	32	Maintenance Assistant	16
Mine Technical Superintendent	1	**Total: Mining Underground**	**157**

The anticipated process flowsheet would consist of two flotation circuits in sequence to recover the metal concentrates which would be filtered and dried prior to shipment from the site. In the interest of adapting the mill capacity to satellite deposits that may be trucked to the concentrator, parallel process lines at 50% of the mill capacity were included in the flowsheet of the medium and large-scale concentrators.

General and Administration

As with the gold deposits, each of the mines was considered to be remote and developed as a self-contained site with camp accommodation for the workforce and a diesel power generation facility. Operating costs were estimated based on the development of personnel requirements and major consumables for each mine site. Capital costs were developed from WGM and BBA data for similar operations.

Economic Analysis

In order to assess the economic viability of each project, WGM created an Excel spreadsheet that integrates ore resources, grades and metal recoveries, capital and operating costs into a single economic model. This model includes calculations for depreciation of the capital infrastructure, corporate taxes payable to the government, various economic parameters including earnings before interest taxes depreciation and amortization ("**EBITDA**"), internal rate of return ("**IRR**"), net cash flow ("**NCF**") and net present value ("**NPV**") at various discount rates etc.

The model also captures material consumption data including diesel fuel, explosives, electrical consumption, water consumption, specific processing consumption including cyanide, lime and grinding media.

Net Cash Flow is defined as:

- Revenue
- Minus Operating Costs
- Minus Capital Costs
- ± Changes in Working Capital
- Minus Corporate Taxes
- Equals Net Cash Flow to the project.

All revenues and costs are taken in the year in which they occur.

Revenue is based on the following forecast long term metal prices provided by McKinsey:

Gold	$1,225	/oz	$39.37	/g
Copper	$7,535	/t	$3.42	/lb
Zinc	$2,161	/t	$0.98	/lb
Silver	$20.20	/oz	$0.65	/g
Nickel	$15,000	/t	$6.80	/lb
Platinum	$1,350	/oz	$43.40	/g
Palladium	$700	/oz	$22.51	/g
Cobalt	$35,000	/t	$15.88	/lb

The undiscovered VMS base metal projects produce a copper and a zinc concentrate where the copper concentrates also includes payable gold and silver. WGM has included typical mining industry smelter contracts to calculate the "Net Smelter Return" to the project. These contracts include provisions for metal deductions at the smelter, payable metal calculations, smelting and refining charges and costs for transportation of the concentrate to the smelter.

Operating and capital costs included in the net cash flow calculations are discussed above.

In the case of the 10% probability EMINER projects, WGM has projected capital and operating costs by fitting curves to the original costs. While these are less accurate than the costs used in the 50% probability cases, WGM believes that they are sufficiently accurate to reflect the accuracy of the EMINER estimates themselves.

The model also calculates additional capital items including

- Ongoing / Replacement Capital
- Capital for Rehabilitation of the minesite.
- Changes in Working Capital.

Ongoing / Replacement Capital: The model calculates ongoing or replacement capital as a percentage of the initial capital. The model uses a rate of 5% of initial capital and assumes no ongoing capital in the first year and last two years of production.

Mine Rehabilitation: At the end of mine life there is a requirement to restore the mine site. The model allocates 15% of the initial capital to be spent over the last three years of the mine life to rehabilitate the mine site.

Changes in Working Capital: Working capital represents the funds required to keep the project functioning until revenues are actually received. The cash flow model

shows revenues as occurring at the time that the products (i.e. gold bullion or base metal concentrates) are produced. In reality, the product first goes into inventory until there is sufficient material to ship. Then the product may be either sold at the mine gate or at the time it is produced as a metal at the smelter/refinery. The product purchaser usually takes some time (often 30 days) before making payment to the producer. As well the project must buy spare parts as well as consumable supplies (for instance cyanide, explosives etc.) long before they are utilized This is represented as Spare Parts and Supplies Inventory. The model also calculates spare parts and the inventory of consumable supplies as 5% of initial capital. Finally, the project does not necessarily pay its own suppliers immediately but after 30 to 45 days depending on the terms that have been negotiated. The current excel model allows two weeks of revenue for product inventory, another four weeks for accounts receivable, and two weeks of operating costs for accounts payable. Labour costs must be paid in the month incurred, accounting for the shorter time period for accounts payable. All working capital is recovered in the last year of the mine life.

The Net Cash Flow is calculated after Corporate Taxes (Table 60). The model assumes that the projects are owned and developed by foreign corporations paying Saudi corporate tax at the rate of 20% of net income where net income is calculated at revenue less operating costs and depreciation. Depreciation is based on the 10 Year Straight Line Method. Note that the model includes the ability to assume that the project owner is a Saudi National, in which case the project is required to pay Zakat as well as Severance Tax but no Corporate Tax.

For taxable depreciation the model uses the straight line method (10 years), while for the cash flow calculation itself, the model uses the "Units of Production" method. In the later method, capital assets are written off equally for each tonne of ore production.

The model also tests the robustness of each project by increasing and decreasing the metal prices, and capital and operating costs by ±40%. Typically a project with a base 15% IRR will still be marginally profitable if the metal prices drop by 35% and will still be quite profitable even if operating or capital costs increase by 40%. A summary sheet for a single project (Ar Rayn #2) is shown in Table 61.

The model creates a number of reports for each project including:

- A detailed Net Cash Flow and Production Statement
- A summary sheet for all the important variables in each project.
- Three charts showing the impact of changes in metal prices and operating and capital costs on:

- The project Internal Rate of Return
- The project Net Cash Flow
- The Project's Net Present Value discounted at 10%

The following pages contain:

- A sample Cash Flow calculation for a VMS project
- A sample Summary sheet for a VMS project
- Three charts showing the impact of changes in metal prices and operating and capital costs on respectively the IRR, the NCF and the NPV.

Table 60
Sample Net Cash Flow Calculation for a Predicted (Typical) Underground Mine in the Ar Rayn Belt

NET CASH FLOW CALCULATION

Mine Type: Underground **(US$ thousands)** **Resource Classification: Potential Deposit**

Location:

Project --> Ar Rayn #2	Units	Total/ Average	Year 1 -2	Year 2 -1	Year 3 +1	Year 4 +2	Year 5 +3	Year 6 +4	Year 7 +5	Year 8 +6	Year 9 +7	Year 10 +8	Year 11 +9	Year 12 +10	Year 13 +11	Year 14 +12
Metal Prices																
Copper	**US$/t**	$7,535	-	-	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535	$7,535
Zinc	**US$/t**	$2,161	-	-	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161	$2,161
Gold	**US$/oz**	$1,225	-	-	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225	$1,225
Silver	**US$/oz**	$20.20	-	-	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20	$20.20
Production	**0**	**-**														
Ar Rayn #2	**0**	**-**														
Ore Mined	**kt**	**2,210**	**-**	**-**	200	200	200	200	200	200	200	200	200	200	200	10
Ore Milled	**t**	**2,210**	**-**	**-**	200	200	200	200	200	200	200	200	200	200	200	10
Total Ore Mined/Milled	**kt**	**2,210**	-	-	200	200	200	200	200	200	200	200	200	200	200	10
Ore Grades	**0**	**-**	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gold	**g/t**	**0.29**	-	-	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
Silver	**g/t**	**56.0**	-	-	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0	56.0
Copper	**%**	**1.20%**	-	-	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%	1.2%
Zinc	**%**	**7.60%**	-	-	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%
Copper Concentrate																
Milled Grade	**%**	**1.20%**	-	-	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%	1.20%
Copper Recovery	**%**	**90.0%**	-	-	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
Copper Conc. Grade	**%**	**25%**	-	-	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Gold Recovery to Copper Con.	**%**	**85%**	-	-	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%
Gold Grade	**g/t**	**5.71**	-	-	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71	5.71
Silver Recovery to Copper Con.	**%**	**75%**	-	-	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%	75%
Silver Grade	**g/t**	**972.2**	-	-	972.2	972.2	972.2	972.2	972.2	972.2	972.2	972.2	972.2	972.2	972.2	972.2
Production - Concentrate	**t**	**95,472**	-	-	8,640	8,640	8,640	8,640	8,640	8,640	8,640	8,640	8,640	8,640	8,640	432
Net Smelter Return	**$/dmt**	**$2,319**	-	-	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319	$2,319
Total Copper Conc Rev.	**k$**	**221,387**	-	-	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	20,035	1,002
Zinc Concentrate																
Milled Grade	**%**	7.60%	-	-	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%	7.60%
Recovery	**%**	85.00%	-	-	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%	85.0%
Zinc Concentrate Grade	**%Zn**	55.00%	-	-	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%	55.0%
Gold Grade	**g/t**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Silver Grade	**g/t**	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Concentrate Production	**t**	**259,575**	**-**	**-**	23,491	23,491	23,491	23,491	23,491	23,491	23,491	23,491	23,491	23,491	23,491	1,175
Zinc Net Smelter Return	**$/dmt**	**$631.40**	-	-	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40	$631.40
Total Zinc Conc Revenue	**k$**	**163,896**	**-**	**-**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**14,832**	**742**
Total Revenue	**k$**	**385,282**	-	-	34,867	34,867	34,867	34,867	34,867	34,867	34,867	34,867	34,867	34,867	34,867	1,743

Table 60 (continued)
Sample Net Cash Flow Calculation for a Predicted (Typical) Underground Mine in the Ar Rayn Belt

NET CASH FLOW CALCULATION

Mine Type: Underground **(US$ thousands)** **Resource Classification: Potential Deposit**

Location:

Project --> Ar Rayn #2	Units	Total/ Average	Year 1 -2	Year 2 -1	Year 3 +1	Year 4 +2	Year 5 +3	Year 6 +4	Year 7 +5	Year 8 +6	Year 9 +7	Year 10 +8	Year 11 +9	Year 12 +10	Year 13 +11	Year 14 +12
Operating Costs	0															
Waste Mining	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stockpile Rehandling	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mining	k$	96,577	-	-	8,740	8,740	8,740	8,740	8,740	8,740	8,740	8,740	8,740	8,740	8,740	437
Processing	k$	35,515	-	-	3,214	3,214	3,214	3,214	3,214	3,214	3,214	3,214	3,214	3,214	3,214	161
G&A	k$	20,885	-	-	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	1,890	95
Trucking to Offsite Mill	$	8,840	-	-	800	800	800	800	800	800	800	800	800	800	800	40
Total Operating Costs	k$	161,816	-	-	14,644	14,644	14,644	14,644	14,644	14,644	14,644	14,644	14,644	14,644	14,644	732
EBITDA	k$	223,466	-	-	20,223	20,223	20,223	20,223	20,223	20,223	20,223	20,223	20,223	20,223	20,223	1,011
Capital Cost Schedule																
Mining	k$	16,000	8,000	8,000	-	-	-	-	-	-	-	-	-	-	-	-
Processing	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Infrastructure	k$	2,000	1,000	1,000	-	-	-	-	-	-	-	-	-	-	-	-
Total Initial Capital	k$	18,000	9,000	9,000	-	-	-	-	-	-	-	-	-	-	-	-
Ongoing Capital	$	8,100	-	-	-	900	900	900	900	900	900	900	900	900	-	-
Rehabilitation/Restoration	$	1,800	-	-	-	-	-	-	-	-	-	-	-	600	600	600
Total Capital	k$	27,900	9,000	9,000	-	900	900	900	900	900	900	900	900	1,500	600	600
Less: Depreciation (UOP)	k$	27,900	-	-	1,629	1,719	1,818	1,930	2,057	2,206	2,384	2,607	2,902	3,633	4,205	810
Zakat	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saudi Severance Taxes	$	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Saudi Corporate Taxes	k$	39,679	-	-	3,685	3,667	3,649	3,631	3,613	3,595	3,577	3,559	3,541	3,403	3,763	-
Total Taxes & Zakat (always hide)	k$	39,679	-	-	3,685	3,667	3,649	3,631	3,613	3,595	3,577	3,559	3,541	3,403	3,763	-
Net Income After Taxes & Depr.	k$	155,887	-	-	14,910	14,838	14,757	14,663	14,553	14,422	14,262	14,058	13,781	13,187	12,256	201
NET CASH FLOW to PROJECT																
Net Income After Taxes & Depr.	k$	155,887	-	-	14,910	14,838	14,757	14,663	14,553	14,422	14,262	14,058	13,781	13,187	12,256	201
Plus: Depreciation	k$	27,900	-	-	1,629	1,719	1,818	1,930	2,057	2,206	2,384	2,607	2,902	3,633	4,205	810
Less: Capital Investment	$	-27,900	-9,000	-9,000	-	-900	-900	-900	-900	-900	-900	-900	-900	-1,500	-600	-600
Working Capital	k$	-	-	-	-4,360	-	-	-	-	-	-	-	-	-	-	4,360
Net Cash Flow to Project	k$	155,887	-9,000	-9,000	12,179	15,657	15,675	15,693	15,711	15,729	15,747	15,765	15,783	15,321	15,861	4,771
Accum. NCF to Project	k$	155,887	-9,000	-18,000	-5,821	9,835	25,510	41,202	56,913	72,641	88,388	104,153	119,935	135,256	151,116	155,887
Project Metrics	various				Internal Rate of Return (IRR)		60.8%		EBITDA/Capital		8.01					
Project Net Present Value	M$		@5% -	$103.4M		@10% -	$70.5M		@15% -	$49.2M						
Project Payback Period	Years		3.4 Years after Start of Development					1.4 Years after Start of Production								

Table 61
Sample Summary Sheet for an Undiscovered VMS Project

Project	**Ar Rayn #2**				
Number of Mines	4				
Ownership	na				
Location					
Resource Type	**Potential Deposit**				
Mine Type	Underground				
Proposed Start Date	na				
Resources	2,210,000 tonnes				
Major Commodities	Cu, Zn, Au, Ag				
Grade(s)	Cu-1.2%;Zn-7.6%;Au-0.29 g/t;Ag-56.00 g/t				
Production					
Annual	200,000 tpa				
Mine Life	11.1 Years				
Concentrate Grades & Value	**Copper**	**Zinc**	**Gold**	**Silver**	**Value**
Copper Concentrate	25%	-	5.71 g/t	972.22 g/t	$2,319/t conc.
Zinc Concentrate	-	55%	-	-	$631/t conc.
	Annual	**Total**	**/tonne Ore**		
Copper Concentrate	8,640 t	95,472 t	$100.17		
Zinc Concentrate	23,491 t	259,575 t	$74.16		
Revenue	M$32.1	M$385	$174.34		
Operating Costs	M$14.6	M$162	$73.22		
Capital Costs	**Total**	**/tonne Ore**			
Initial	M$18.0	$8.14			
Ongoing	M$8.1	$3.67			
Rehabilitation	M$1.8	$0.81			
Total	M$27.9	$12.62			
	Per Year	**Man Years**	**Tonnes/Man Year**		
Employment	214	2,365	935		
Material Consumption	**Per Year**	**Total**	**Per Tonne Ore**		
Diesel Fuel (l)	2,000,000	22,100,000	10.00		
Explosives (kg, 99% Anfo)	120,000	1,326,000	0.60		
Electricity (Kwh)	11,800,000	130,390,000	59.00		
Water (l)	80,000,000	884,000,000	400.00		
Taxes/Zakat Paid	**Per Year**	**Total**			
Zakat	na	na			
Severance Taxes	na	na			
Corporate Taxes	k$3,607	k$39,679			
Total Zakat & Taxes	k$3,607	k$39,679			
Internal Rate of Return	60.8%				
Net Cash Flow Discounted at	0%	5%	10%	15%	
	k$155,887	k$103,368	k$70,515	k$49,152	
Payback from Start of:	**Development**	**Production**			
	3.4 Years	1.4 Years			
	Commodity Prices				
Commodity	**Base**	**Price Req'd**	**Price Req'd**	**Price**	
Price	**Price**	**for 10% IRR**	**for 15% IRR**	**Units**	
Copper	$7,534.78	$4,732.46	$4,921.72	US$/t	
Zinc	$2,160.74	$1,357.12	$1,411.40	US$/t	
Gold	$1,224.66	$769.19	$799.95	US$/oz	
Silver	$20.20	$12.69	$13.19	US$/oz	
	-	-	-		
	-	-	-		
	-	-	-		

The model creates three charts showing the impact of changes in metal prices and operating and capital costs on respectively the IRR, the NCF and the NPV. As part of its sensitivity analysis, WGM varied prices and costs from -40% to +40% to allow for the accuracy of the estimated metal prices and operating and capital costs. In the sample case below, the IRR remains positive even when metal prices have decreased by 40%. In all cases the effect of changes in metal prices is always greater than the changes in either operating or capital costs. These variances were used to plot spider diagrams to illustrate a project's sensitivity to various factors (Charts 6, 7 and 8).

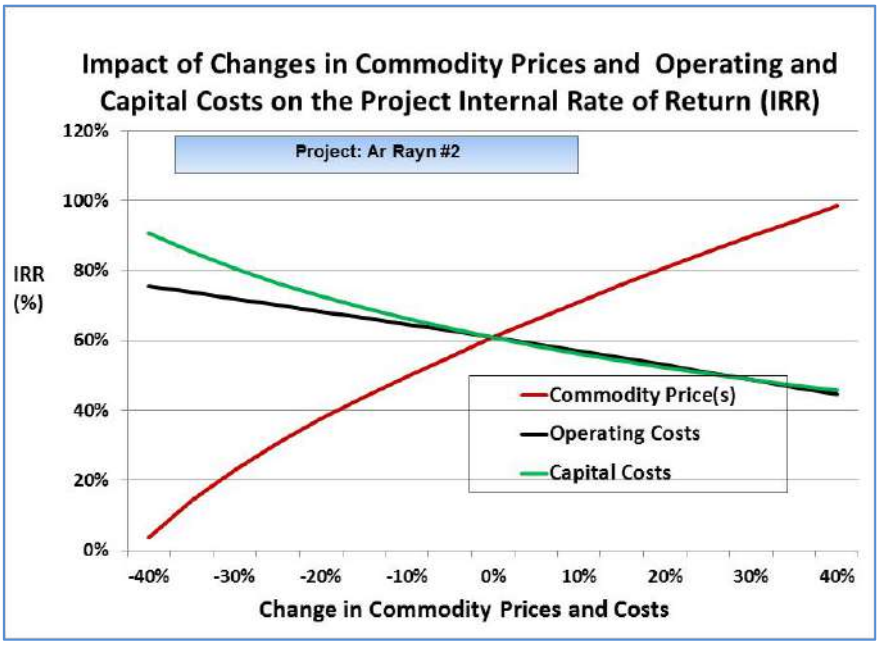

Chart 6: Spider Diagram Showing Sensitivity Analysis for the Internal Rate of Return

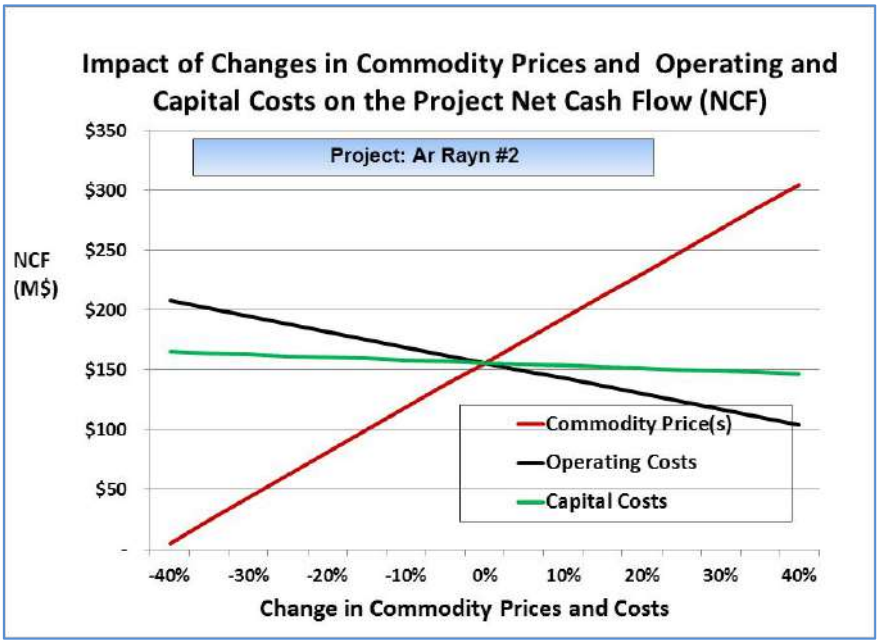

Chart 7: Spider Diagram Showing Sensitivity for the Net Cash Flow to a Project

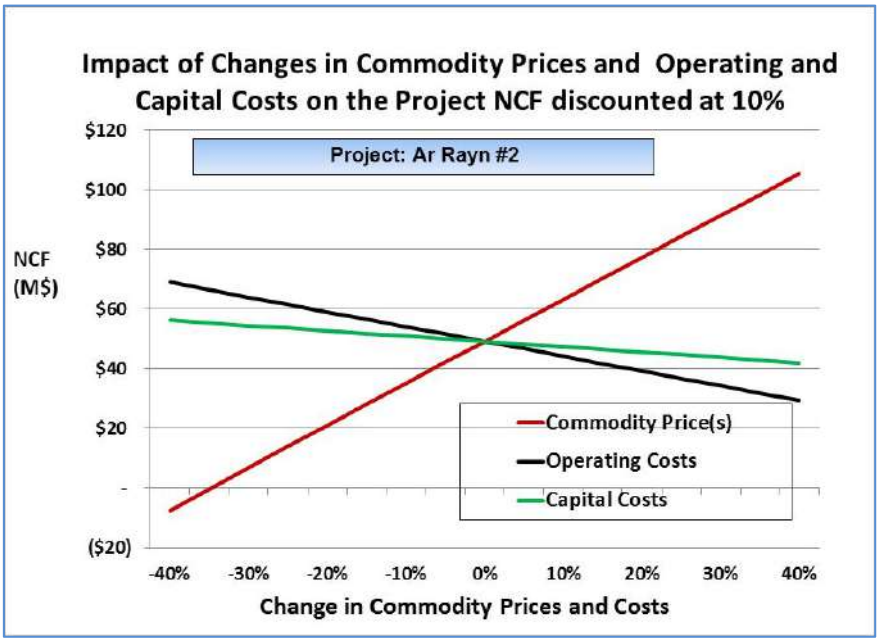

Chart 8: Spider Diagram Showing Sensitivity Analysis for the Discounted NCF

Summary of Analysis

Table 62 provides the results of WGM's analysis of the predicted VMS deposits at EMINERS' 50% confidence level, including the average internal rate of return ("IRR") and the total net cash flow for each VMS belt. Note that several belts fail to generate a positive cash flow at the 50% confidence level.

Table 62
Summary of Results of Economic Evaluation of VMS Projects

VMS Mineral Belt	# of Mines	Average IRR (%)	Total Net Cash Flow	
			($/t ore)	($M - total)
Afif	1	0%	-	-
Ar Rayn	4	45%	82.95	1,306
Ar Ridanyah	3	30%	63.68	389
Ar Rjum	2	0%	-	-
Ash Shaib	4	43%	78.34	940
Ash Shizm	3	52%	87.98	853
Jabal Sayid	5	36%	70.87	1,228
Kutam-Al Masane	5	48%	83.58	1,831
Muhadad	4	42%	76.85	999
Nuqrah	4	39%	69.44	972
Samran-Shayban	4	44%	81.97	1,066
Shaib Lamisah	4	37%	67.65	947
Wadi Bidah	5	42%	72.13	1,450
Wadi Shwas	4	47%	86.82	1,294
Averages / Totals (above cut)	**47**	**42%**	**62.56**	**13,273**

Of the 52 VMS base metal mines modelled at a 50% level of confidence, 47 showed a positive IRR, ranging from 22% to 66%. The belts these occurred in produced average IRR's ranging from 30% to 52%. The overall average IRR was 42%. Of this group, the average NCF per tonne of ore was US $76.82 with an average life-of-mine NCF of $270.9 million, or $13.3 billion for all predicted VMS projects.

The VMS projects are extremely robust. Only three projects are uneconomic (one at Afif and two at Ar Rjum) at the base metal prices provided to WGM by McKinsey. At the these prices, 49 of the projects achieve an IRR greater than zero and 48 are greater than 10%. If we reduce the metal prices by 40%, then 21 of the projects remain viable (IRR greater than zero), and 12 of the VMS projects still achieve an IRR greater than 10%. By contrast, if we increase the operating costs by 40%, the number of viable projects remains at 49, and 43 of the projects still achieve an IRR greater than 10%. Raising the capital costs by 40% has an even smaller impact. As before, all 49 projects have an IRR greater than zero and 48 exceed 10%.

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3.3 CU-NI-PGE DEPOSITS

3.3.1 METALLOGENIC MODEL AND EXISTING MINES

There are basically only two types of nickel mineralization known in the world. They are lateritic nickel and sulphide nickel. Only the latter type is known in Saudi Arabia.

Ni-Cu-PGE sulphide deposits (the "**NCP** Model") are located at or near the base of mafic to ultramafic intrusive bodies that often form large masses of tens or even hundreds of kilometres. Mantle derived magma is transported to the crust and during this process sulphur needs to be added usually from sulphur rich sedimentary rocks. As a result the magma becomes saturated in sulphur and an immiscible sulphide liquid may be formed which can react with the magma to become enriched in Ni-Cu and PGE's due to the high partition coefficients of these metals. The sulphide droplets are denser than the silicate liquid and they can migrate and concentrate near the base of an ultramafic rock. Fractionation of the sulphide liquid may

result deposits that exhibit a strong metal zonation. Subsequent deformation and metamorphism of the

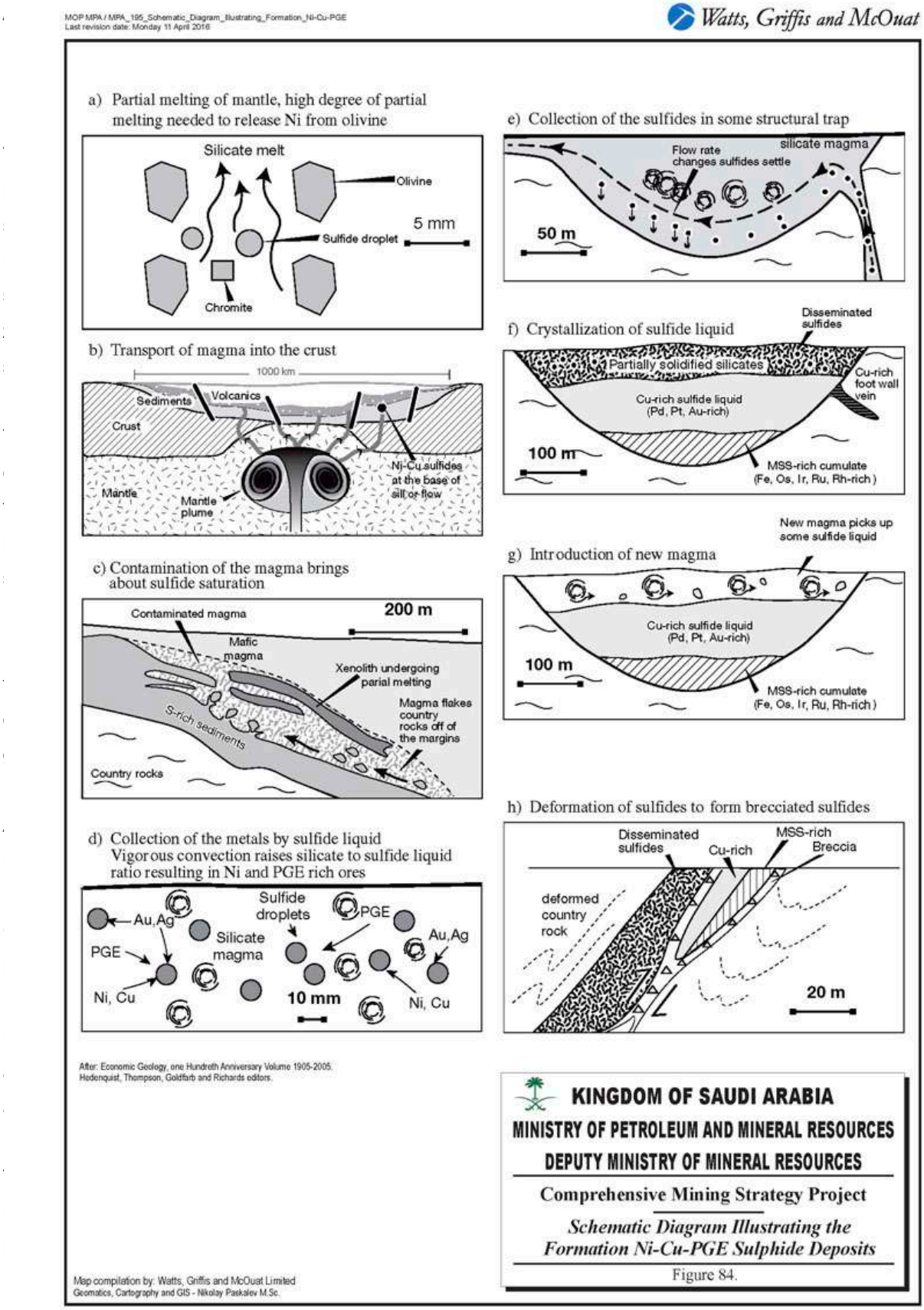


Figure 84: Schematic Diagram Illustrating the Formation of Ni-Cu-PGE Sulphide Deposits.

3.3.2 DISTRIBUTION OF DEPOSITS

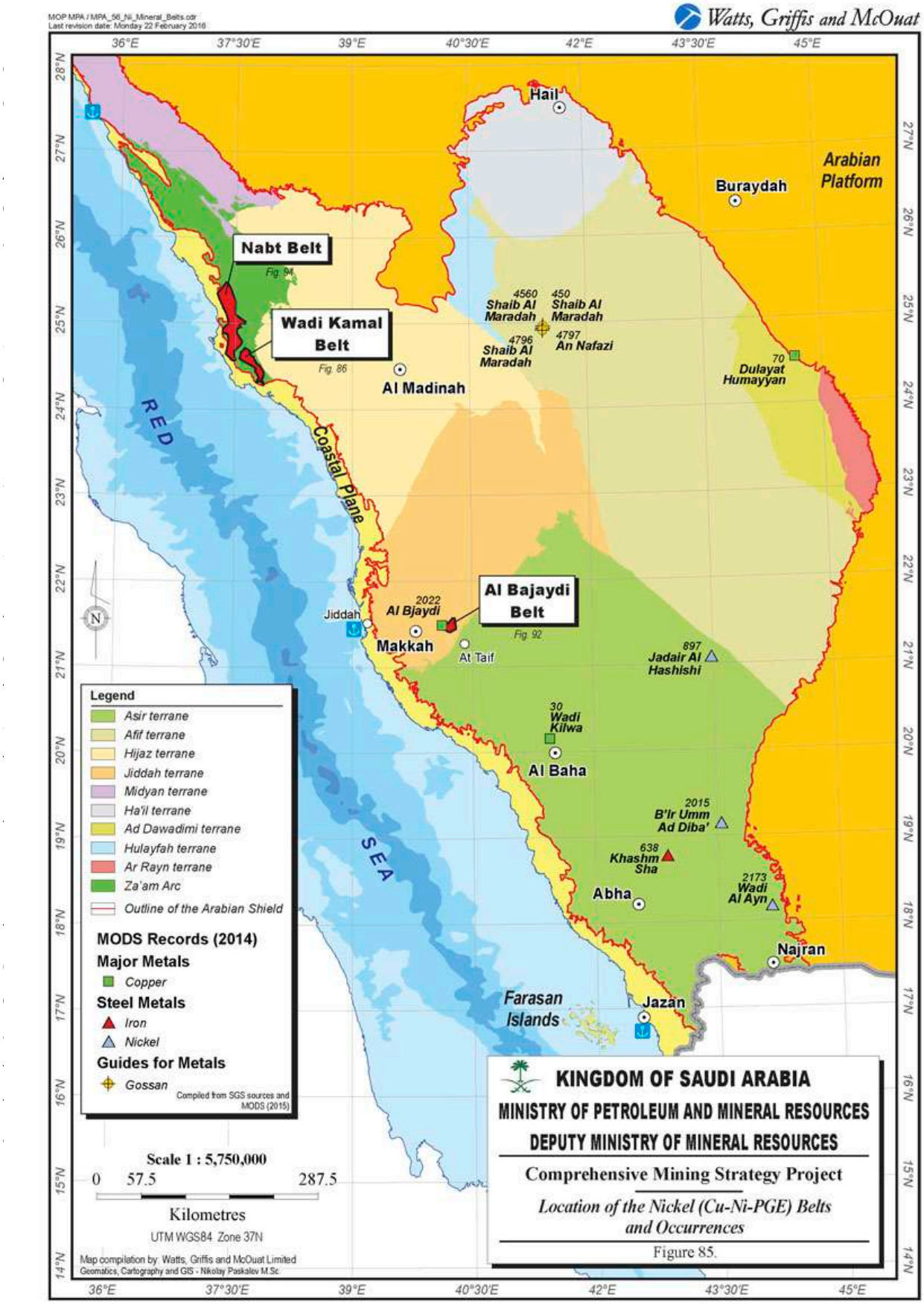


Figure 85: Location of Nickel (Cu-Ni-PGE) Mineral Belts and Occurrences

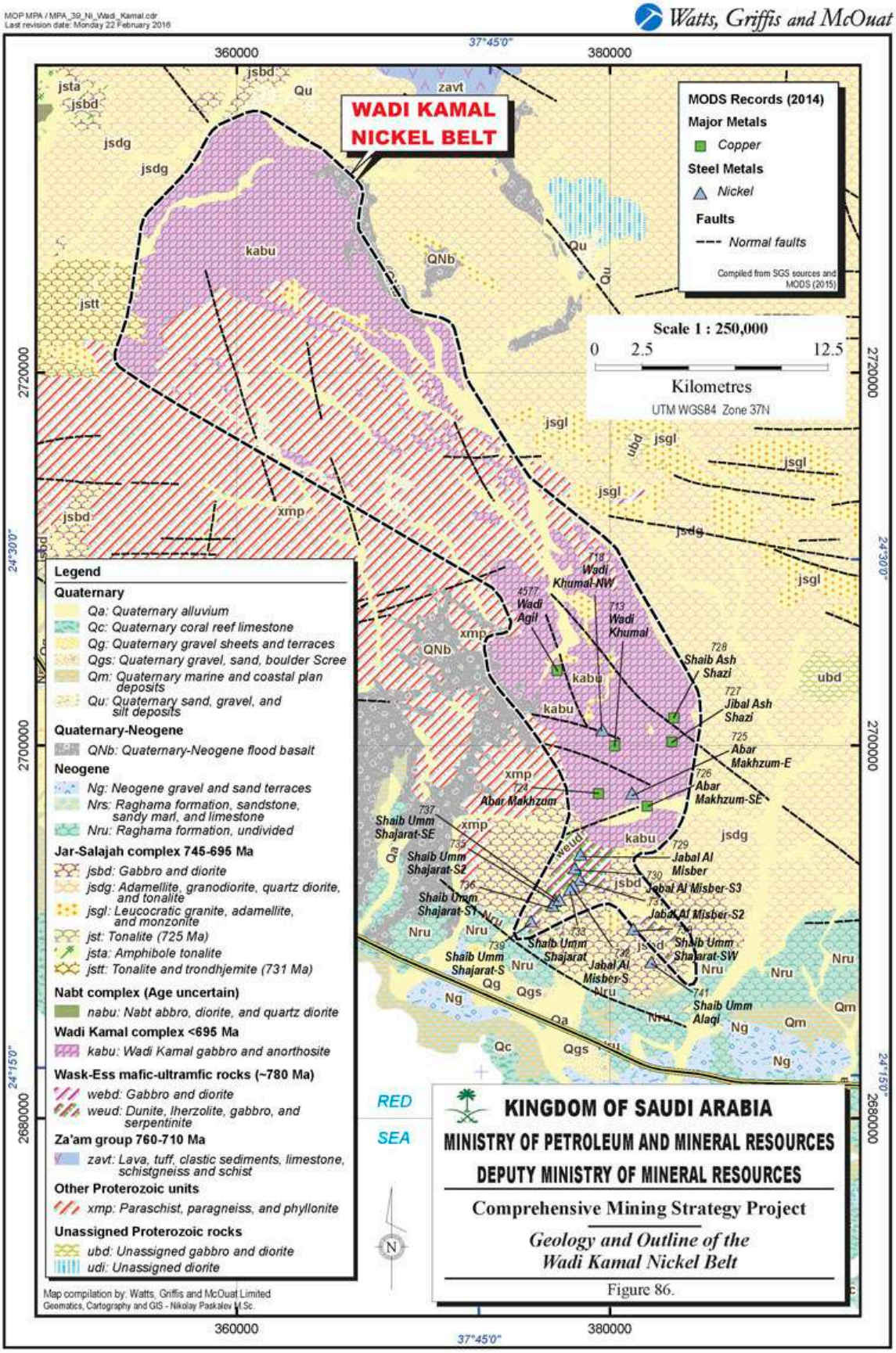
2) A south ultramafic-mafic layered unit consists of amphibolitized pyroxenite dikes, which cut the serpentinite of unit 1, and a differentiated series of dunite, lherzolite, websterite, wehrlite, and pyroxenite, which is clearly younger than the central dunite and is now present as relicts on the roof of the amphibole gabbro (unit 3).
3) An amphibole gabbro unit cuts both units 1 and 2. Pellaton (1979a) assigned unit 3 to the Nabt Complex.
4) A north basic layered unit is composed of leuconorite, anorthosite, gabbro, gabbronorite, dunite, jotunite *(hypersthene monzodiorite)* and mangerite, and forms an antiform.
5) north mafic layered unit is composed of melatroctolite, leucotroctolite, melagabbro, and leucopyroxenite within the unit 4 antiform, and intrudes unit 4. The rocks in the Wadi Murattijah area consist of anorthosite, leucogabbronorite, leuconorite, gabbro, and ferrogabbro, and are a subdivision of unit 5.
6) An assemblage of intermediate intrusive rocks cuts all of the above. The magnetite-ilmenite layers (12 occurrences in the MODS database) are found in distinct settings as follows.

The major nickel-copper occurrences are summarized in Table 63. Hashem (1976) mapped more than 100 broadly distributed gossan occurrences in the Wadi Kamal complex, containing highly variable amounts of copper and nickel (Figure 87). Chevremont and Johan (1981b) classified the gossans into several types, including:

i. 'false gossans' as defined by Daniels (1977) and derived from the weathering of serpentinite; the copper and nickel were originally contained in olivine;
ii. malachite-chrysocolla mineralized gossans of several square meters in the south ultramafic-mafic layered unit; they contain up to 2.5% Cu and 1.75% Ni;
iii. oxidized sulfide-bearing joints with low nickel content; and,
iv. numerous gossans in the north basic layered series, including those over Fe-Ti oxide accumulations; the principal type was determined by Daniels (1977)to be derived mostly from pyrrhotite, with minor pyrite and chalcopyrite, and rare pentlandite oxide and sulfide types overlap.

Sulfide mineralization has been encountered beneath gossans in three areas. In the southern part of the complex within unit 2, disseminated and veinlet sulfides in pyroxenite consist of pyrrhotite, pentlandite (altered to violarite), chalcopyrite and pyrite in drill hole KMS1 (Areal). In the west, disseminated to nearly massive pyrrhotite, with exsolutions of pentlandite, chalcopyrite and pyrite (up to 50% total sulphides), occurs as stratiform and 'intrusive' types in pyroxene-rich rocks in a zone containing numerous Fe-Ti oxide lenses. In the east, disseminated pyrrhotite, pentlandite, chalcopyrite and bravoite occur in feldspathic pyroxenite veins and pyroxene-rich gabbro and disseminated/interstitial and stringer sulfides. In general, pyrrhotite always greatly predominates over other sulfide minerals.

Chevremont and Cassard (1986) found enhanced Ni (up to 2.9%) and Cu (up to 10.6%) values as well as significant PGE values (up to 7,200 ppb Pt and 1,000 ppb Pd) from gossans around DDH KMS1. Additionally they collected two core samples from this drill hole that assayed 359 and 1,132 ppb PGE (Figure 87).


MOP MPA / MPA_39_Ni_Wadi_Kamal.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
WADI KAMAL
NICKEL BELT
MODS Records (2014)
Major Metals
Copper
Steel Metals
Nickel
Faults
Normal faults
Compiled from SGS sources and MODS (2015)
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 37N
Legend
Quaternary
Qa: Quaternary alluvium
Qc: Quaternary coral reef limestone
Qg: Quaternary gravel sheets and terraces
Qgs: Quaternary gravel, sand, boulder Scree
Qm: Quaternary marine and coastal plan deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Neogene
Ng: Neogene gravel and sand terraces
Nrs: Raghama formation, sandstone, sandy marl, and limestone
Nru: Raghama formation, undivided
Jar-Salajah complex 745-695 Ma
jsbd: Gabbro and diorite
jsdg: Adamellite, granodiorite, quartz diorite, and tonalite
jsgl: Leucocratic granite, adamellite, and monzonite
jst: Tonalite (725 Ma)
jsta: Amphibole tonalite
jstt: Tonalite and trondhjemite (731 Ma)
Nabt complex (Age uncertain)
nabu: Nabt abbro, diorite, and quartz diorite
Wadi Kamal complex <695 Ma
kabu: Wadi Kamal gabbro and anorthosite
Wask-Ess mafic-ultramfic rocks (~780 Ma)
webd: Gabbro and diorite
weud: Dunite, lherzolite, gabbro, and serpentinite
Za'am group 760-710 Ma
zavt: Lava, tuff, clastic sediments, limestone, schistgneiss and schist
Other Proterozoic units
xmp: Paraschist, paragneiss, and phyllonite
Unassigned Proterozoic rocks
ubd: Unassigned gabbro and diorite
udi: Unassigned diorite
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
RED
SEA
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology and Outline of the Wadi Kamal Nickel Belt
Figure 86.
360000
380000
37°45'0"
2720000
2700000
2680000
24°30'0"
24°15'0"

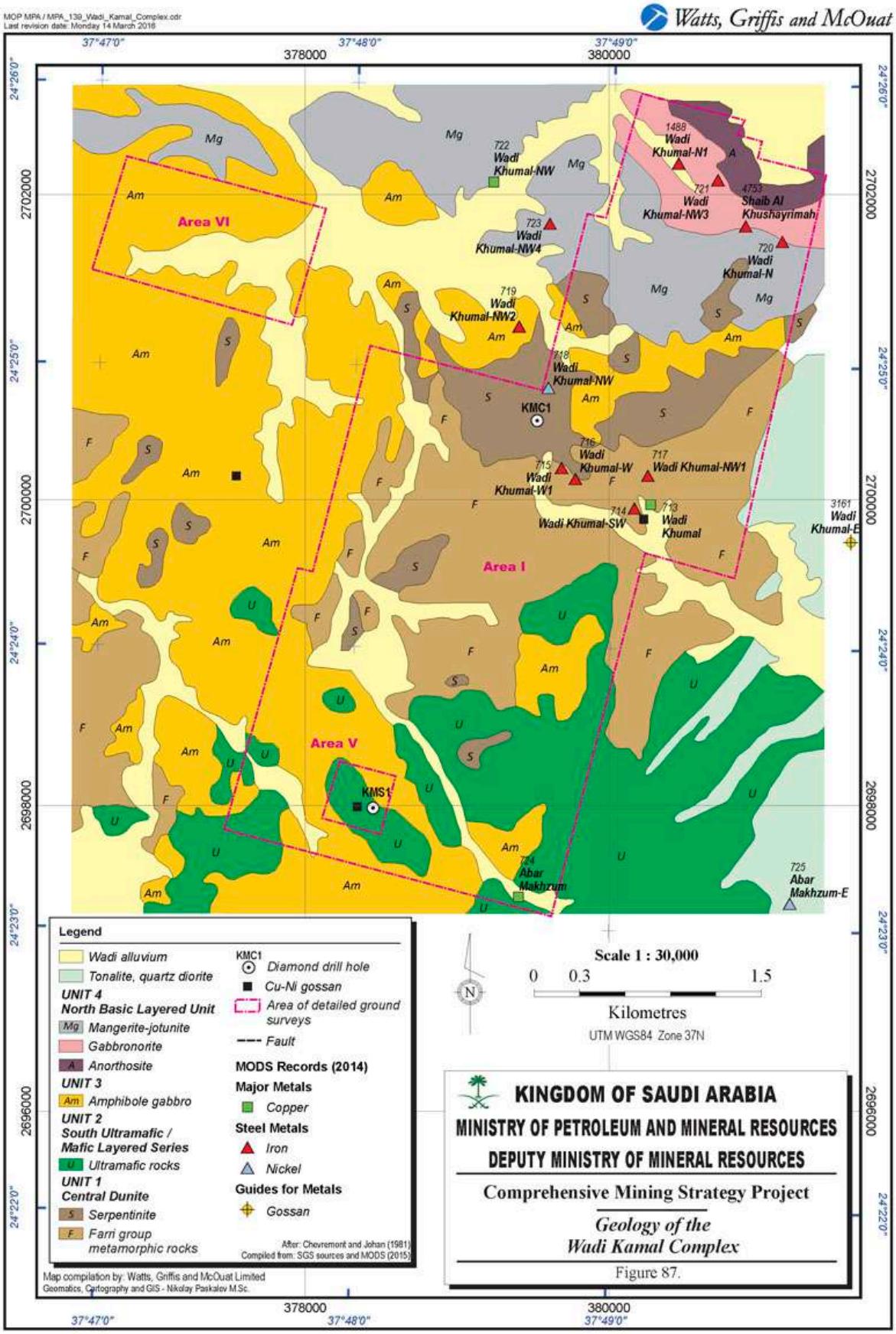

MOP MPA / MPA_139_Wadi_Kamal_Complex.cdr
Last revision date: Monday 14 March 2016
Watts, Griffis and McOuat
37°47'0"
37°48'0"
37°49'0"
378000
380000
2702000
2700000
2698000
2696000
24°26'0"
24°25'0"
24°24'0"
24°23'0"
24°22'0"
Area VI
Area I
Area V
722 Wadi Khumal-NW
1488 Wadi Khumal-N1
721 Wadi Khumal-NW3
4753 Shaib Al Khushayrimah
723 Wadi Khumal-NW4
720 Wadi Khumal-N
719 Wadi Khumal-NW2
718 Wadi Khumal-NW
KMC1
716 Wadi Khumal-W
717 Wadi Khumal-NW1
715 Wadi Khumal-W1
714 Wadi Khumal-SW
713 Wadi Khumal
3161 Wadi Khumal-E
KMS1
724 Abar Makhzum
725 Abar Makhzum-E
Legend
Wadi alluvium
Tonalite, quartz diorite
UNIT 4
North Basic Layered Unit
Mangerite-jotunite
Gabbronorite
Anorthosite
UNIT 3
Amphibole gabbro
UNIT 2
South Ultramafic / Mafic Layered Series
Ultramafic rocks
UNIT 1
Central Dunite
Serpentinite
Farni group metamorphic rocks
Diamond drill hole
Cu-Ni gossan
Area of detailed ground surveys
Fault
MODS Records (2014)
Major Metals
Copper
Steel Metals
Iron
Nickel
Guides for Metals
Gossan
After: Chevremont and Johan (1981)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
Scale 1 : 30,000
0 0.3 1.5
Kilometres
UTM WGS84 Zone 37N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Wadi Kamal Complex
Figure 87.

Table 63
Cu-Ni-PGE Records in the MODS for the Wadi Kamal area in Saudi Arabia

MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
4577	Wadi Agil	Wadi Kamal	Cu	37.7883330	24.4447220	Yanbu	low	undetermined
0728	Shaib Ash Shazi	Wadi Ash Shathi	Cu	37.8502780	24.4222220	Yanbu	low	lenses
0718	Wadi Khumal NW	Wadi Khushermah	Ni	37.8125000	24.4152780	Yanbu	undefined	lenses
0727	Jibal Ash Shazi	Wadi Ash Shathi	Cu	37.8494440	24.4105560	Yanbu	medium	veins
0713	Wadi Khumal	Wadi Kamal	Cu	37.8191940	24.4085280	Yanbu	medium	lenses
0724	Abar Makhzum	Wadi Makhzum	Cu	37.8108330	24.3852780	Yanbu	low	veins
0725	Abar Makhzum E	Wadi Kamal	Ni	37.8284440	24.3849170	Yanbu	undefined	lenses
0726	Abar Makhzum SE	Wadi Mahllah	Cu	37.8363890	24.3794440	Yanbu	low	veins
0729	Jabal Al Misber	Jabal Marghah	Ni	37.8013890	24.3550000	Yanbu	undefined	lenses
0730	Jabal Al Misber S3	Wadi Kamal	Ni	37.7986110	24.3483330	Yanbu	undefined	massive
0731	Jabal Al Misber S2	Wadi Bayadah	Ni	37.8013890	24.3427780	Yanbu	undefined	massive
0732	Jabal Al Misber S	Jabal Ash Sherat	Ni	37.7977220	24.3396940	Yanbu	undefined	massive
0733	Shaib Umm Shajarat	Jabal Ash Sherat	Ni	37.7962220	24.3378610	Yanbu	undefined	massive
0737	Shaib Umm Shajarat SE	Jabal Ash Sherat	Ni	37.7905280	24.3328610	Yanbu	undefined	veins
0735	Shaib Umm Shajarat S2	Jabal Ash Sherat	Ni	37.7880830	24.3323360	Yanbu	undefined	massive
0736	Shaib Umm Shajarat S1	Jabal Ash Sherat	Ni	37.7870560	24.3300000	Yanbu	undefined	massive
0739	Shaib Umm Shajarat S	Jabal Ash Sherat	Ni	37.7755830	24.3222250	Yanbu	undefined	undetermined
0738	Shaib Umm Shajarat SW	Wadi Ash Sherat	Ni	37.8296670	24.3191390	Yanbu	undefined	veins
0741	Shaib Umm Alaql	Wadi Alagl	Ni	37.8394720	24.3031690	Yanbu	undefined	veins

History and Status

The Fe-Ti oxide and gossan mineralization of the complex was first recognized during mapping at 1:100,000 scale (Alabouvette and Pellaton, 1975). Between 1972 and 1979, the BRGM conducted extensive mapping at various scales, rock and wad)-sediment geochemistry, air borne and a variety of ground geophysical surveys, and diamond drilling (totalling 2,758 m) in the complex. No further work was done until Chevremont and Cassard (1986), as part of a broad study on mafic-ultramafic rocks, sampled gossans and drill core for platinum group elements (PGE) and precious metals associated with copper-nickel mineralization. Follow-up of airborne electromagnetic anomalies was carried out about the same time (Gelot, 1987), but no significant exploration has been conducted since 1979.

In 2001 Eberle et al. carried out a short geological study of the KMS1 drill hole along with some wadi sediment sampling in the surrounding area. They concluded that the surface mineralization could be detected in wadi sediment samples for a distance of 500 m from the source. They also resampled the core from KMS1 and calculated an inferred resource for the prospect of 1.4 Mt grading 0.24% Ni, 0.14% Cu and 0.42 g Pt+Pd per tonne.

Recommendations

The recommendations presented in WGM-Cr-11-10 (re-assays of existing samples, gossan sampling, wadi sediment sampling and drilling) are still valid and should be carried out particularly the re-assaying for PGE's. WGM considers the Ni-Cu-PGE results from the KSM1 area to be highly encouraging and more work is warranted to assess their potential. Initial stage PGE exploration requires the collection of a large number of samples and even samples considered to be weakly mineralized (<3% sulphide) should be sampled. In addition, a modern airborne EM-magnetometer survey (the last one was in 1977) is recommended for the entire complex and the limits of the survey should extend out into the surrounding high grade paraschist and paragneiss units to check for any possible remobilized sulphide material. The results from this survey combined with a compilation of previous work and the wadi sediment sampling data would form a good knowledge base for future exploration programs.

3.3.3.2 Wadi Kilwa Prospect

Location, History and Geology

This prospect (MODS 0030), formerly known as Wadi Khadra, is located in the Asir Terrane and it consists a series of gossans along the contact of a mafic intrusion over a distance of about 1.7 km. The gossans typically contain malachite and chalcocite after pyrite/pyrrhotite and pentlandite. Samples taken from the gossans returned maximum values of 1.1% Ni and 1.4% Cu (Whorl and Wynn, 1982). Untested geophysical anomalies (SP, EM, IP) were outlined coincident with the gossans. USGS geologists visited the area in May-June 1979 and carried out mapping and detailed sampling that consisted of 74 grab and selected grab samples and 10 channel samples (Worl and Wynn, 1979). Geophysical surveys consisting of electromagnetic and self-potential surveys were also completed by the Arabian Geophysical and Surveying Company ("ARGAS") and a magnetometer survey was completed by USGS. The USGS geologists recommended a drilling program over the anomaly and oxidation zone, however this work was not completed for reasons that are now known. During 2009, the SGS returned to the site to reassess the encouraging results of the earlier program. The SGS program included topographically surveying a 425 m by 750 m area, geological mapping and lithogeochemical sampling, geophysical surveys and core drilling.) for detailed mapping and sampling, and assistance in locating drill holes. A total of 458 surface samples were analysed from various units including mineralized and alteration zones. The samples were collected on a 25 m grid basis and analysed at the SGS laboratory in Jeddah. A 4-hole diamond core drilling program resulted in 906 m of drilling in the area of the main oxidized Ni-Cu zone and on the SW anomaly. The drilling was generally in a SSW to W direction at an angle of 55º to 65º, and resulted in a total of 957 one-metre samples for analysis (Al-Jahdli et al, 2015). The drilling resulted in several economically interesting intersections

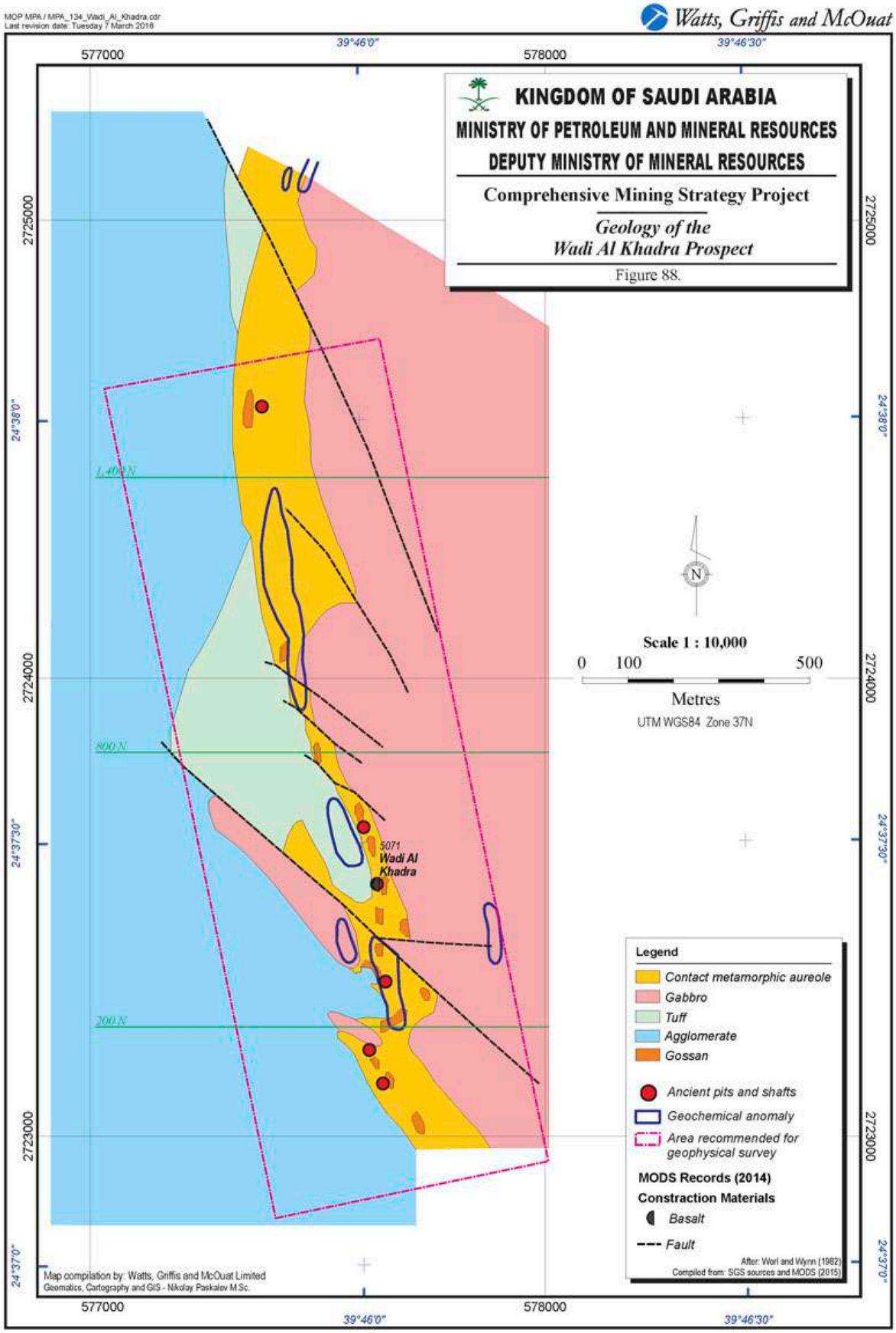
The SGS estimated that the total potential resource for the Wadi Al Khadra deposit was 2.3 Mt averaging 0.83% Cu and 0.25% Ni containing 19,000 t of Cu and 5,700 t of Ni. The survey also identified a geochemically anomalous Cu-Ni target area about 360 m north of the mineralized zone for which drilling was recommended.

The Wadi al Khadra prospect is a stratabound, disseminated copper-nickel deposit within a thin-layered series of ultramafic to mafic lava flows that vary from normal flows to agglomerates. Although mainly greenschist facies, the host rocks are deformed and metamorphosed locally to the amphibolite-serpentinite facies. The mineral assemblage mainly consists of copper, nickel and iron sulphide (+ arsenopyrite) which is strongly oxidized in the near-surface weathering zone to reddish hematite, goethite and traces of limonite and copper on the surface. Mineralization occurs as veinlets, clusters, patches, and stringers along the foliation or in fractures. On the basis of the sulfide content and mineral associations, the mineralized zone is a volcanogenic massive sulfide (VMS) type, which has been highly altered and metamorphosed. The potential resource of copper and nickel is located along a 250 m wide shear zone which strikes 300°-305° azimuth and dips 85° to 90° NE. Hypogene sulphide mineralization occurs at depth consisting of pyrite, chalcopyrite, pentlandite(?), and niccolite, which is a typical mineral assemblage associated with these lithologies. A figure detailing the geology is shown in Figure 88. This prospect is not extensive enough to form a mineral belt and it should be evaluated as a standalone prospect.

Recommendations

The most recent work carried out by the SGS resulted in a successful exploration program on which the SGS should build. WGM believes that the prospect certainly warrants systematic follow-up drilling. As first step, additional geophysical and detailed mapping and sampling should be carried out along strike as previously recommended. All existing and additionally generated anomalies should be diamond drilled with holes positioned in locations and drilled at angles appropriate for the targets generated.

The SGS recommended that a regional exploration program should be carried out along strike to the north and to the south from the Wadi Al Khadra deposit. Future studies for target selection should consider remote sensing, geophysical, and radiometric surveys, followed by field visits with tactical sampling to define new areas. Additional surface exploration consisting of systematic stream sediment and rock sampling programs with follow-up drilling was recommended for the southern extension.


MOP MPA / MPA_134_Wadi_Al_Khadra.cdr
Last revision date: Tuesday 7 March 2016
Watts, Griffis and McOuat
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the
Wadi Al Khadra Prospect
Figure 88.
577000
578000
39°46'0"
39°46'30"
2725000
2724000
2723000
24°38'0"
24°37'30"
24°37'0"
1,400 N
800 N
200 N
5071
Wadi Al
Khadra
N
Scale 1 : 10,000
0 100 500
Metres
UTM WGS84 Zone 37N
Legend
Contact metamorphic aureole
Gabbro
Tuff
Agglomerate
Gossan
Ancient pits and shafts
Geochemical anomaly
Area recommended for geophysical survey
MODS Records (2014)
Constraction Materials
Basalt
Fault
After: Worl and Wynn (1982)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

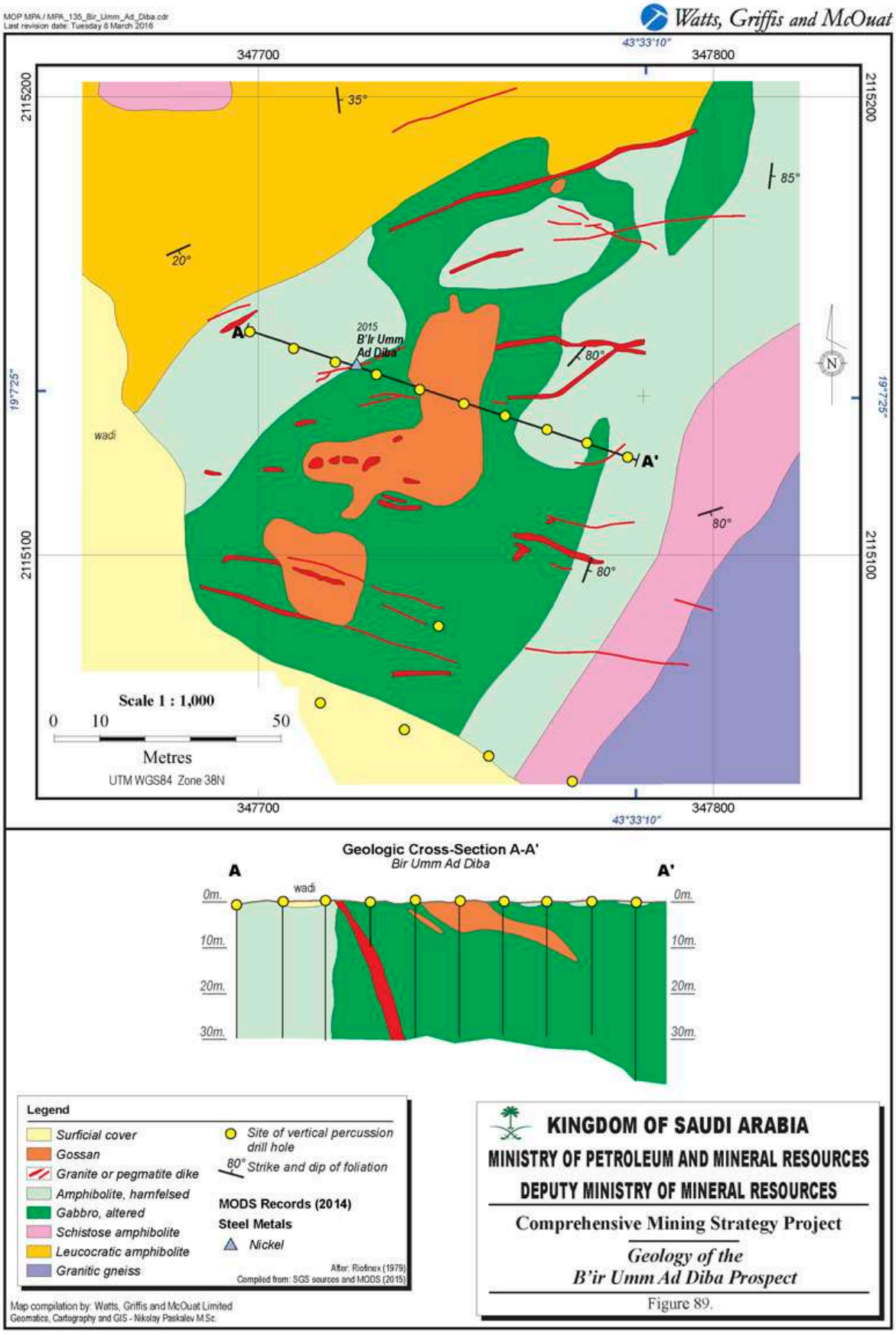
3.3.3.3 Bi'r Umm ad Diba Prospect (MODS 2015)

Location, History and Geology

The Bir Umm ad Diba prospect is located in the Asir Terrane, consisting of a gossan in gabbro (Figure 89). The prospect was mapped in detail by Riofinex in 1977 at a scale of 1:500. Soil sampling and ground magnetic surveying were also carried out at this time. Subsequently, 15 very shallow percussion drill holes totalling 446 m were drilled to an average depth of about 30 m. Surface grab samples returned values of up to 7,800 ppm (0.78%) Ni, 9,600 ppm (0.96%) Cu and 430 ppm (0.04%) Cr. A percussion drill hole gave an intersection of 1.8% Ni over 3.5 m.

Recommendations

The mapping, IP surveying and drilling recommended in WGM-CR-11-14 are still current and valid. One significant component of WGM's previous review was the criticism concerning the use of percussion drilling. This drilling technique was extensively used in the kingdom as a means of drilling prospects without the need to assure a water supply. Unfortunately air-blast percussion drilling suffers from two major deficiencies. Firstly, it is unable to penetrate below the water table and so its depth capabilities are extremely limited. Secondly, great care must be taken in evaluating the analytical results of percussion holes because the diameter of such holes is uneven depending on variations in the hardness of the rock formations being drilled. This variability causes some rock formations to be under-sampled and some to be over-sampled. Mixing of sample within the hole is also possible as is smearing high-grade material down the hole. The overall result is that the assay results retuned from percussion hole samples must be taken as a general indication of mineralization, and where significant values are found, as is the case at Bir Umm ad Diba, follow-up diamond drilling must be carried out.


MOP MPA / MPA_135_Bir_Umm_Ad_Diba.cdr
Last revision date: Tuesday 8 March 2016
Watts, Griffis and McOuat
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347800
43°33'10"
2115200
2115100
19°7'25"
35°
85°
20°
80°
2015
B'ir Umm
Ad Diba
A
A'
wadi
N
Scale 1 : 1,000
0 10 50
Metres
UTM WGS84 Zone 38N
Geologic Cross-Section A-A'
Bir Umm Ad Diba
0m.
10m.
20m.
30m.
Legend
Surficial cover
Gossan
Granite or pegmatite dike
Amphibolite, hornfelsed
Gabbro, altered
Schistose amphibolite
Leucocratic amphibolite
Granitic gneiss
Site of vertical percussion drill hole
Strike and dip of foliation
MODS Records (2014)
Steel Metals
Nickel
After: Riofinex (1979)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
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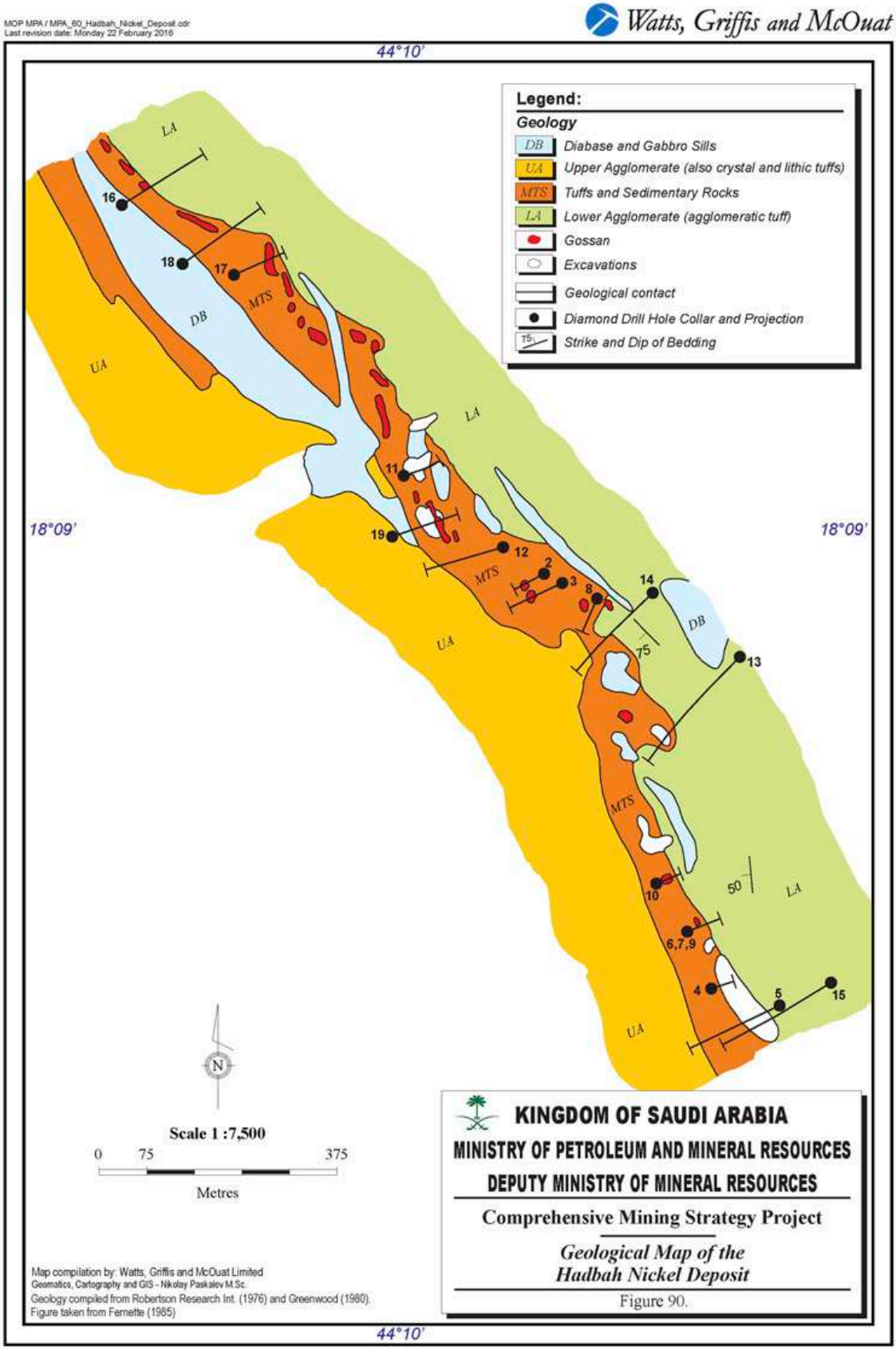
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the
B'ir Umm Ad Diba Prospect
Figure 89.

3.3.3.4 Wadi al Ayn Deposit

Location, History and Geology

This deposit (MODS 2173), formerly known as Hadbah, is located in the Asir Terrane specifically in the Wadi Wassat-Wadi Qatan area where numerous ironstone gossans have been discovered (Figure 90). The Hadbah gossan appears to be hosted by a series of tuffs, black shales and epiclastic rocks and it outcrops intermittently over a strike length of about 2,000 m.

The gossans were discovered in 1966 by Hatem El Khalidi during aerial reconnaissance of the area. During the period 1967 to 1974 the USGS carried out detailed and reconnaissance geologic mapping and gossan sampling of the area. In 1971, the Arabian Shield Development Company obtained an exploration license covering the Hadbah deposit, and subsequently carried out geological, geochemical and geophysical surveys, culminating in the diamond drilling of 19 holes totalling 2,432 m during 1973-77. Distinct magnetic and electromagnetic anomalies were defined coincident with the gossans. The best intersection from the drilling program was a very significant 5.2 metre interval averaging 2.20% Ni. Hancock and others (1975) calculated indicated resources for the deposit of 1.8 Mt grading 1.35% Ni. Given the amount of work carried out at that time, it is certain that this estimate would not conform to current regulatory standards, however WGM believes that it is indicative of potential, in essence, that the mineralization is just not a simple, small occurrence. Petrographic studies carried out by Robertson Research showed that much of the nickel was tied up in the pyrite-pyrrhotite lattice, or present as very fine exsolution lamellae which would result in metallurgical concentration problems. This deposit is not typical for a nickel deposit and it appears to have VMS affinities.


MOP MPA / MPA_60_Hadbah_Nickel_Deposit.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
44°10'
18°09'
Legend:
Geology
DB Diabase and Gabbro Sills
UA Upper Agglomerate (also crystal and lithic tuffs)
MTS Tuffs and Sedimentary Rocks
LA Lower Agglomerate (agglomeratic tuff)
Gossan
Excavations
Geological contact
Diamond Drill Hole Collar and Projection
Strike and Dip of Bedding
LA
UA
DB
MTS
16
18
17
11
19
12
2
3
8
14
13
75
50
10
9
6,7,9
4
5
15
N
Scale 1 :7,500
0 75 375
Metres
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geological Map of the
Hadbah Nickel Deposit
Figure 90.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
Geology compiled from Robertson Research Int. (1976) and Greenwood (1980).
Figure taken from Fernette (1985)

Recommendations

The Wadi al Ayn (Hadbah) nickel deposit and environs would benefit from detailed geological mapping as outlined in WGM CR-11-14 to define the geological environment with certainly. Data compilation and sampling as previously recommended by WGM is also required in order to effectively plan additional exploration. Before any substantial exploration program is carried out, the metallurgical treatment of ore similar to the Hadbah mineralization should be studied. Certainly the nature of the mineralization studied to date suggests that this would be a higher-cost style of ore to process, requiring very fine grinding. Exploitation would be dependent on finding a means to liberate the nickel-rock minerals from the iron-rich sulphides.

3.3.3.5 Jadair al Hashishi Prospect

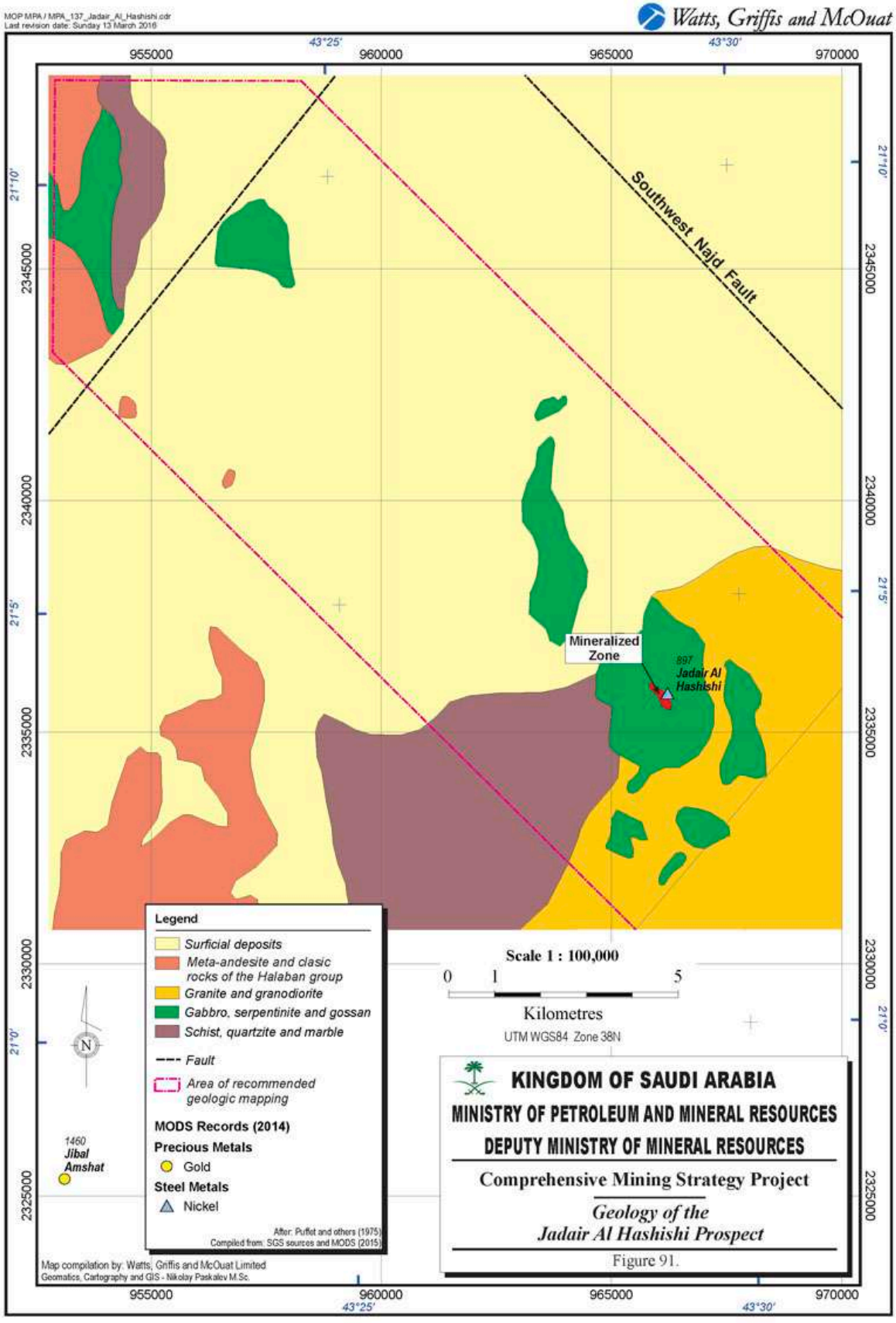
Location, History and Geology

Formerly known as Jabal Jedair, the nickel prospect (MODS 0897) is located in the Asir Terrane. It comprises a number of gossans in a pyroxenite member of a gabbro-serpentinite body (Figure 91). This prospect is a singularity of limited regional extent and thus it does not lend itself to inclusion as part of a mineral belt.

The gossans were examined by Gonzalez (1970). He excavated and sampled 28 prospect pits in the area. In 1974, magnetic, SP, Turam, and gravity surveys were carried out over the gossans, concurrent with detailed mapping. Subsequently, two holes totalling 316.2 m were diamond drilled to test the gossans and associated geophysical anomalies. Puffet and others (1975) estimated that 8.5 Mt of pyrrhotite-rich rock were indicated. Previous sampling of the prospect by the USGS returned values of 1.5% Ni and 0.43% Ni from gossanous and fresh material respectively.

Recommendations

In order to evaluate the prospect and the favorable lithologies, a 1:25,000-scale mapping and prospecting program is recommended for the area outlined in Figure 91. In areas of extensive surficial cover, pitting or trenching may be necessary to expose bedrock. Particular attention should be directed towards outlining the disposition of various phases in the gabbro-serpentinite unit and in determining the stratigraphic facing in the area. Since this area may also host PGE mineralization, surface samples, and future drill core should be analyzed for these elements in addition to Cu and Ni. In addition, the numerous untested gossan occurrences in the area should be further evaluated by trenching. This is estimated to require approximately 1,000 m of trenching.


MOP MPA / MPA_137_Jadair_Al_Hashishi.cdr
Last revision date: Sunday 13 March 2016
Watts, Griffis and McOuat
43°25'
43°30'
955000
960000
965000
970000
21°10'
21°5'
21°0'
2345000
2340000
2335000
2330000
2325000
Southwest Najd Fault
Mineralized Zone
897
Jadair Al Hashishi
1460
Jibal Amshat
Legend
Surficial deposits
Meta-andesite and clasic rocks of the Halaban group
Granite and granodiorite
Gabbro, serpentinite and gossan
Schist, quartzite and marble
Fault
Area of recommended geologic mapping
MODS Records (2014)
Precious Metals
Gold
Steel Metals
Nickel
After: Puffet and others (1975)
Compiled from: SGS sources and MODS (2015)
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 38N
N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Jadair Al Hashishi Prospect
Figure 91.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

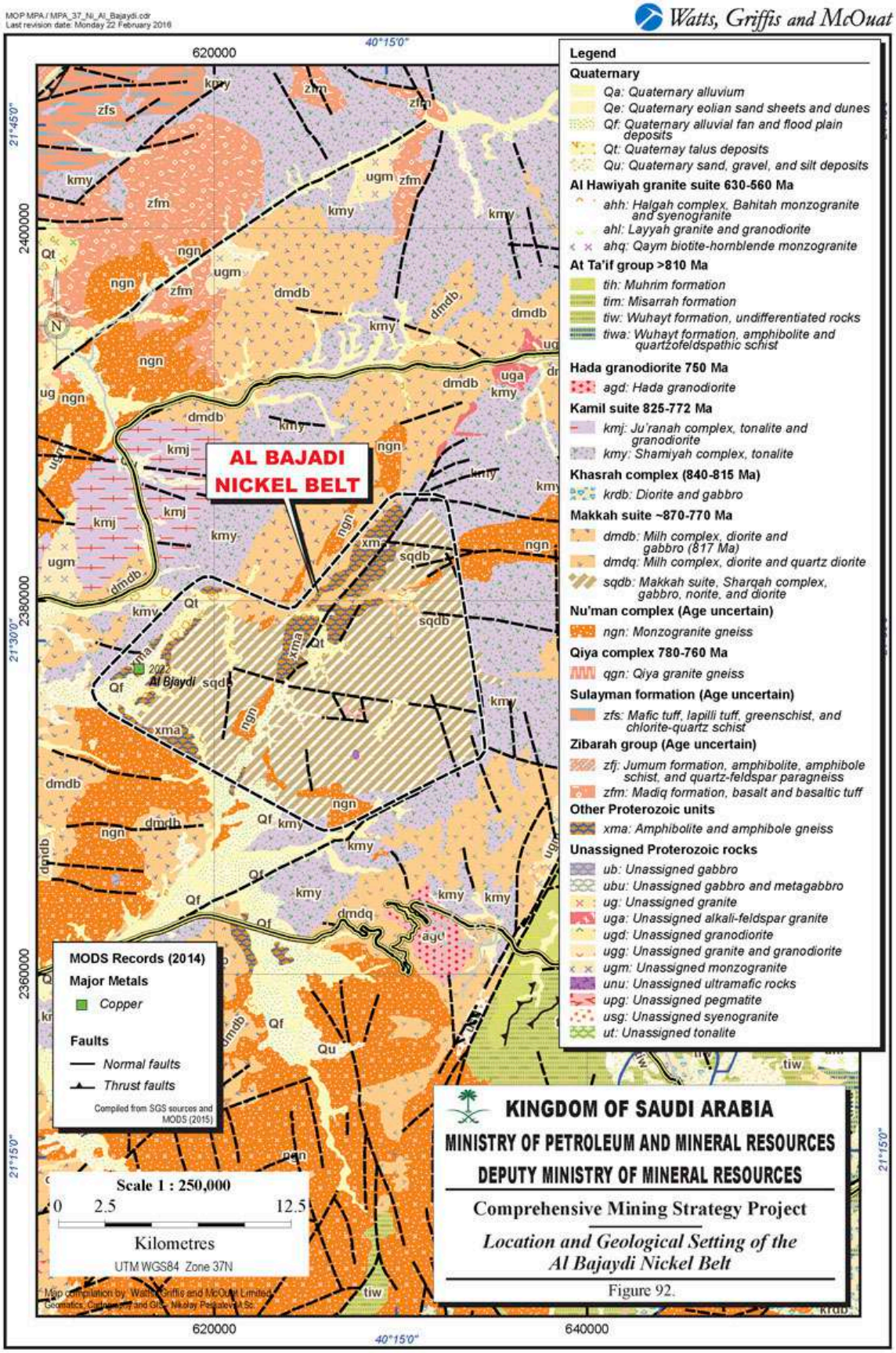
3.3.3.6 Al Bjaydi Ni-Cu Belt

Location, History and Geology

The Al Bjaydi occurrence (MODS 2022), previously known as Al Bajaydi, is located in the Jiddah Terrane. It was originally discovered during 1:100,000 regional mapping of the At Taif Quadrangle and a recent 1:250,000 scale geological compilation indicates that it lies along the western edge of a group of gabbro-norite rocks identified as the Makkah suite dated at 870-770 Ma. The occurrences cover an area of about 224 km^2. Four gossans are hosted by a gabbro-quartz feldspar gneiss-amphibolite assemblage and grab samples assayed a maximum of 0.5% Cu and 0.3% Ni. Later work in the area discovered boulders assaying up to 1.1% Ni and 0.2% Cu which were never traced back to their source. The location of the mineral belt is shown in Figure 92.

Recommendations

This prospect is significant in that it lies along the contact of the Makkah gabbro-norite suite with an amphibolite unit and its position near the possible base of the intrusion is considered to be significant and it indicates the prospectivity of the contact area to host Ni-Cu mineralization. This concept is further enhanced by the Riofinex (Bowden and Morfett, 1981) discovery of mineralized (Ni-Cu) boulders in the area that were never traced back to their source. A program of detailed mapping, prospecting, sampling and boulder tracing is recommended for the basal contact area and environs and for the entire area underlain by the Makkah suite to assess their potential.


MOP MPA / MPA_37_Ni_Al_Bajaydi.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
620000
640000
40°15'0"
21°45'0"
21°30'0"
21°15'0"
2400000
2380000
2360000
AL BAJADI NICKEL BELT
Al Bjaydi
Legend
Quaternary
Qa: Quaternary alluvium
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qt: Quaternay talus deposits
Qu: Quaternary sand, gravel, and silt deposits
Al Hawiyah granite suite 630-560 Ma
ahh: Halgah complex, Bahitah monzogranite and syenogranite
ahl: Layyah granite and granodiorite
ahq: Qaym biotite-hornblende monzogranite
At Ta'if group >810 Ma
tih: Muhrim formation
tim: Misarrah formation
tiw: Wuhayt formation, undifferentiated rocks
tiwa: Wuhayt formation, amphibolite and quartzofeldspathic schist
Hada granodiorite 750 Ma
agd: Hada granodiorite
Kamil suite 825-772 Ma
kmj: Ju'ranah complex, tonalite and granodiorite
kmy: Shamiyah complex, tonalite
Khasrah complex (840-815 Ma)
krdb: Diorite and gabbro
Makkah suite ~870-770 Ma
dmdb: Milh complex, diorite and gabbro (817 Ma)
dmdq: Milh complex, diorite and quartz diorite
sqdb: Makkah suite, Sharqah complex, gabbro, norite, and diorite
Nu'man complex (Age uncertain)
ngn: Monzogranite gneiss
Qiya complex 780-760 Ma
qgn: Qiya granite gneiss
Sulayman formation (Age uncertain)
zfs: Mafic tuff, lapilli tuff, greenschist, and chlorite-quartz schist
Zibarah group (Age uncertain)
zfj: Jumum formation, amphibolite, amphibole schist, and quartz-feldspar paragneiss
zfm: Madiq formation, basalt and basaltic tuff
Other Proterozoic units
xma: Amphibolite and amphibole gneiss
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubu: Unassigned gabbro and metagabbro
ug: Unassigned granite
uga: Unassigned alkali-feldspar granite
ugd: Unassigned granodiorite
ugg: Unassigned granite and granodiorite
ugm: Unassigned monzogranite
unu: Unassigned ultramafic rocks
upg: Unassigned pegmatite
usg: Unassigned syenogranite
ut: Unassigned tonalite
MODS Records (2014)
Major Metals
Copper
Faults
Normal faults
Thrust faults
Compiled from SGS sources and MODS (2015)
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS: Nikolay Petrashevich Sc
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Location and Geological Setting of the Al Bajaydi Nickel Belt
Figure 92.

3.3.3.7 Khashm Sha Prospect

Location, History and Geology

The Jabal Shayi prospect (MODS 0638) was previously known as Jabal Shayi and consists of disseminated sulphide mineralization in a layered gabbro intrusion that is part of the Thalath complex in the Asir Terrane. The complex is late Proterozoic, dated at 640-630 Ma. The Jab al Shayi layered gabbro was first noted by the USGS during 1:500,000 scale regional mapping. The complex was mapped at a scale of 1:10,000 using a controlled aerial photograph mosaic, contoured using a 2 m interval, and a gravity survey with 156 stations was completed. Rock samples were collected to determine the physical, petrographic, and chemical variation of the intrusive, and three diamond drill holes (767 m) were put down to test disseminated sulfides within and at the margins of the complex (Coleman and others 1973). The work proved that the intrusion is layered, but that Ni-Cu values within sulfides were of geochemical interest only (200-300 ppm). Samples returned only anomalous Cu and Ni values but the PGE's were not determined.

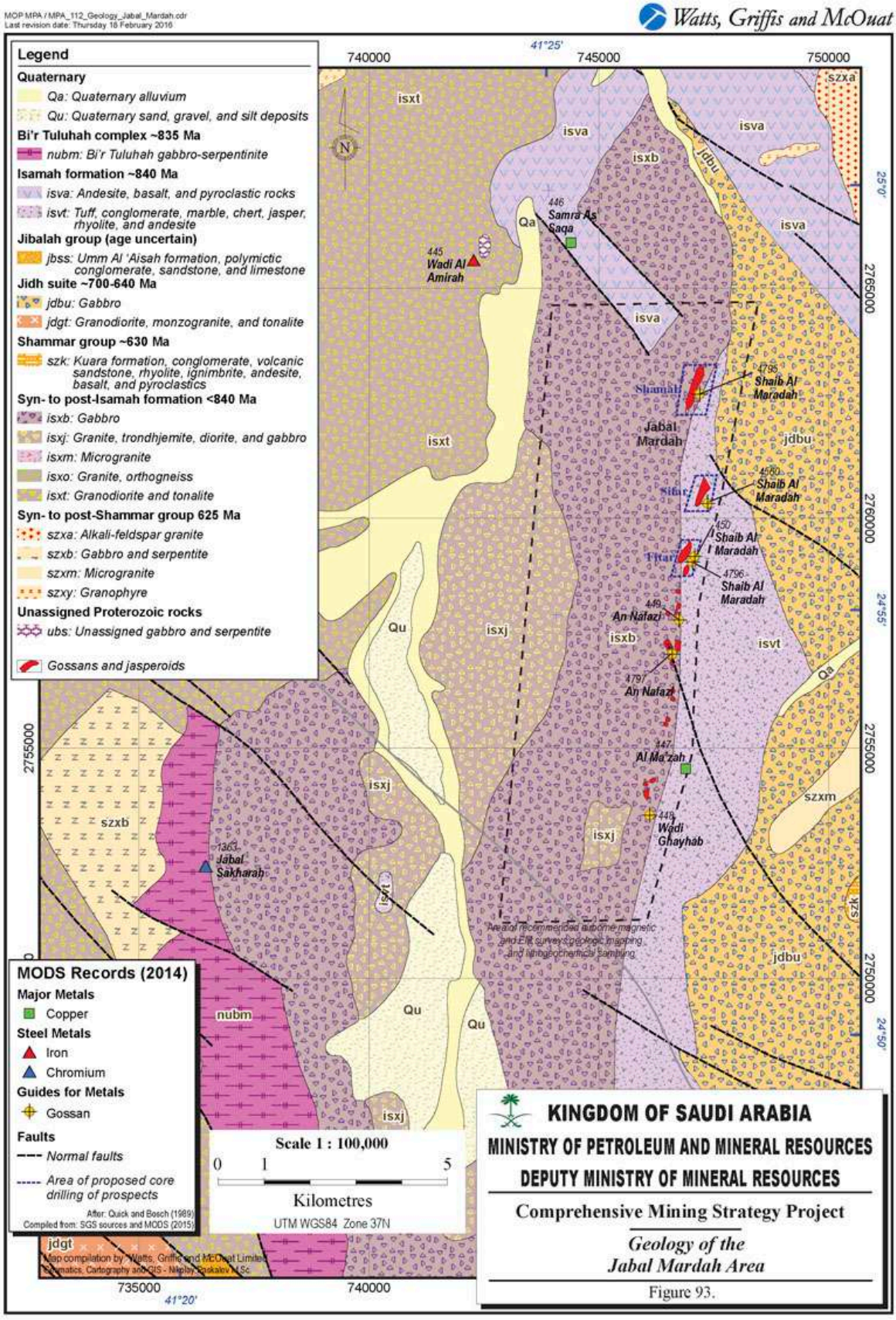
Recommendations

All of the samples collected during previous exploration programs should be analysed for PGE content and the entire layered intrusion should be carefully prospected for any signs of sulphide mineralization as recommended by WGM in 1992 in WGM-CR-11-14. PGE-bearing sulphides can be very subtle (<3% sulphide) and are easily overlooked. In the Lac des Iles Complex, the average (total) PGE content discovered during the original diamond drilling was approximately 3.7 ppm, however the PD and Pt (7:1 ratio) was strongly partitioned in the NI-Cu sulphides. Even though average nickel and copper sulphide contents were only about 1%, the ability to inexpensively make a flotation concentrate of these sulphides effectively increased the PGE grade in the concentrate by 50 times making it a very high-value product at the mine gate.

3.3.3.8 Shaib al Maradah Deposit

Location, History and Geology

The Shaib al Maradah Deposit (MODS 0450, 4560, 4795, 4796 and 4797) is located in the Afif Terrane. It was previously known as Jabal Mardah. It consists of a series of gossans exposed intermittently over a strike length of approximately 10 km. A listing of the gossan occurrences in the area believed to have potential nickel associations is presented in Table 64.


MOP MPA / MPA_112_Geology_Jabal_Mardah.cdr
Last revision date: Thursday 18 February 2016
Watts, Griffis and McOuat
Legend
Quaternary
Qa: Quaternary alluvium
Qu: Quaternary sand, gravel, and silt deposits
Bi'r Tuluhah complex ~835 Ma
nubm: Bi'r Tuluhah gabbro-serpentinite
Isamah formation ~840 Ma
isva: Andesite, basalt, and pyroclastic rocks
isvt: Tuff, conglomerate, marble, chert, jasper, rhyolite, and andesite
Jibalah group (age uncertain)
jbss: Umm Al 'Aisah formation, polymictic conglomerate, sandstone, and limestone
Jidh suite ~700-640 Ma
jdbu: Gabbro
jdgt: Granodiorite, monzogranite, and tonalite
Shammar group ~630 Ma
szk: Kuara formation, conglomerate, volcanic sandstone, rhyolite, ignimbrite, andesite, basalt, and pyroclastics
Syn- to post-Isamah formation <840 Ma
isxb: Gabbro
isxj: Granite, trondhjemite, diorite, and gabbro
isxm: Microgranite
isxo: Granite, orthogneiss
isxt: Granodiorite and tonalite
Syn- to post-Shammar group 625 Ma
szxa: Alkali-feldspar granite
szxb: Gabbro and serpentite
szxm: Microgranite
szxy: Granophyre
Unassigned Proterozoic rocks
ubs: Unassigned gabbro and serpentite
Gossans and jasperoids
MODS Records (2014)
Major Metals
Copper
Steel Metals
Iron
Chromium
Guides for Metals
Gossan
Faults
Normal faults
Area of proposed core drilling of prospects
After: Quick and Bosch (1989)
Compiled from: SGS sources and MODS (2015)
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 37N
Map compilation by Watts, Griffis and McOuat Limited
Cartography and GIS - Nikolay Spasskiev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Jabal Mardah Area
Figure 93.
740000
745000
750000
41°25'
41°20'
735000
2765000
2760000
2755000
25°0'
24°55'
24°50'
Samra As Saqa
Wadi Al Amirah
Shaib Al Maradah
Jabal Mardah
Shamali
Sifar
Tifar
An Nafazi
Al Ma'zah
Wadi Ghayhab
Jabal Sakharah
Area of recommended airborne magnetic and EM surveys, geologic mapping and lithogeochemical sampling

The Jabal Maradah Ni-Cu deposit was first recognized by Petot (1976) and subsequently by Delfour (1981) during regional mapping. The gossans are hosted by a zone of volcanosedimentary rocks, overlain by pillow basalts, gabbro and diabase all forming a septa bounded on the east and west by granitic plutons. The deposit is atypical for a nickel deposit and it appears to have volcanogenic affinities. The deposit has been referred to by previous workers as an exhalative volcanogenic deposit. The closest analogy is the Potter mine in the Canadian Shield which is Archean in age and associated with a spinifex-bearing komatiite sequence. The geology of the Shaib al Maradah area is presented in Figure 93.

Table 64
Gossan Occurrences in the Shaib al Maradah Area

MODS	Name (old)	Name (new)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0450	Jabal Mardah	Shaib al Maradah	Gossan	41.4461110	24.9266940	Al Hinakiyah	Medium	dd, lenses
4560	Jabal Mardah Sifar	Shaib al Maradah	Gossan	41.4496670	24.9381110	Al Hinakiyah	Medium	lenses
4795	Jabal Mardah Shamal	Shaib al Maradah	Gossan	41.4483610	24.9596390	Al Hinakiyah	Medium	lenses
4796	Jabal Mardah Fiter	Shaib al Maradah	Gossan	41.4466390	24.9277500	Al Hinakiyah	Medium	lenses
4797	Jabal Mardah W	An Nafazi	Gossan	41.4414170	24.9086670	Al Hinakiyah	Medium	lenses

NOTES: 1) ranking according to MODS; dd = disseminations

Three of the largest gossans (Shamal, Sifar, and Fitar) have the subject of follow-up exploration consisting of trenching, sampling, ground electromagnetic surveys (CEM) and diamond core drilling (4 holes totalling 666.9 m). The drill holes were targeted on coincident gossan outcrops and geophysical anomalies, and sulfide-rich (pyrite, polydyrnite, millerite ± sphalerite ± chalcopyrite) immature sandstone and reworked tuff were intersected. Drilling in the Sifar gossan also intersected stockwork mineralization (pyrite, pyrrhotite, pentlandite) cutting hydrothermally altered basalt (albite ± epidote ± chlorite ± pumpellyite ± sericite ± calcite) stratigraphically underlying the conformable mineralization. A resource of 1.5 Mt at 0.8% Ni was estimated by Carten and Thyeb (1989) for the main Jabal Maradah deposit and this estimate has been widely quoted in various technical papers since that time. There is no doubt that the estimate is indicative of potential however it is based on too little data to be compliant under current regulatory standards such as Canada's National Instrument 43-101 or Australia's JORC Code.

Recommendations

The proposed program of drilling, sampling and airborne surveying previously recommended by WGM in WGM-CR-11-12 is still current and recommended. This work entailed an airborne survey over the host volcanic units covering a 14 km strike length with 3-4 km long flight lines (profiles) on a 200 m spacing. WGM also recommended diamond core drilling of the ground geophysical surveys coinciding with the Shamal, Sifar and Fitar gossans. A 50 m hole separation was recommended, and a total budget sufficient for 10,000 m of drilling would be appropriate to initially define metaologenic and alteration patterns. In addition to Ni-Cu-PGE analysis, the core should be analysed for the major oxides to define the lithogeochemical setting and associations of the mineralization.

3.3.3.9 Nabt Mineral Belt

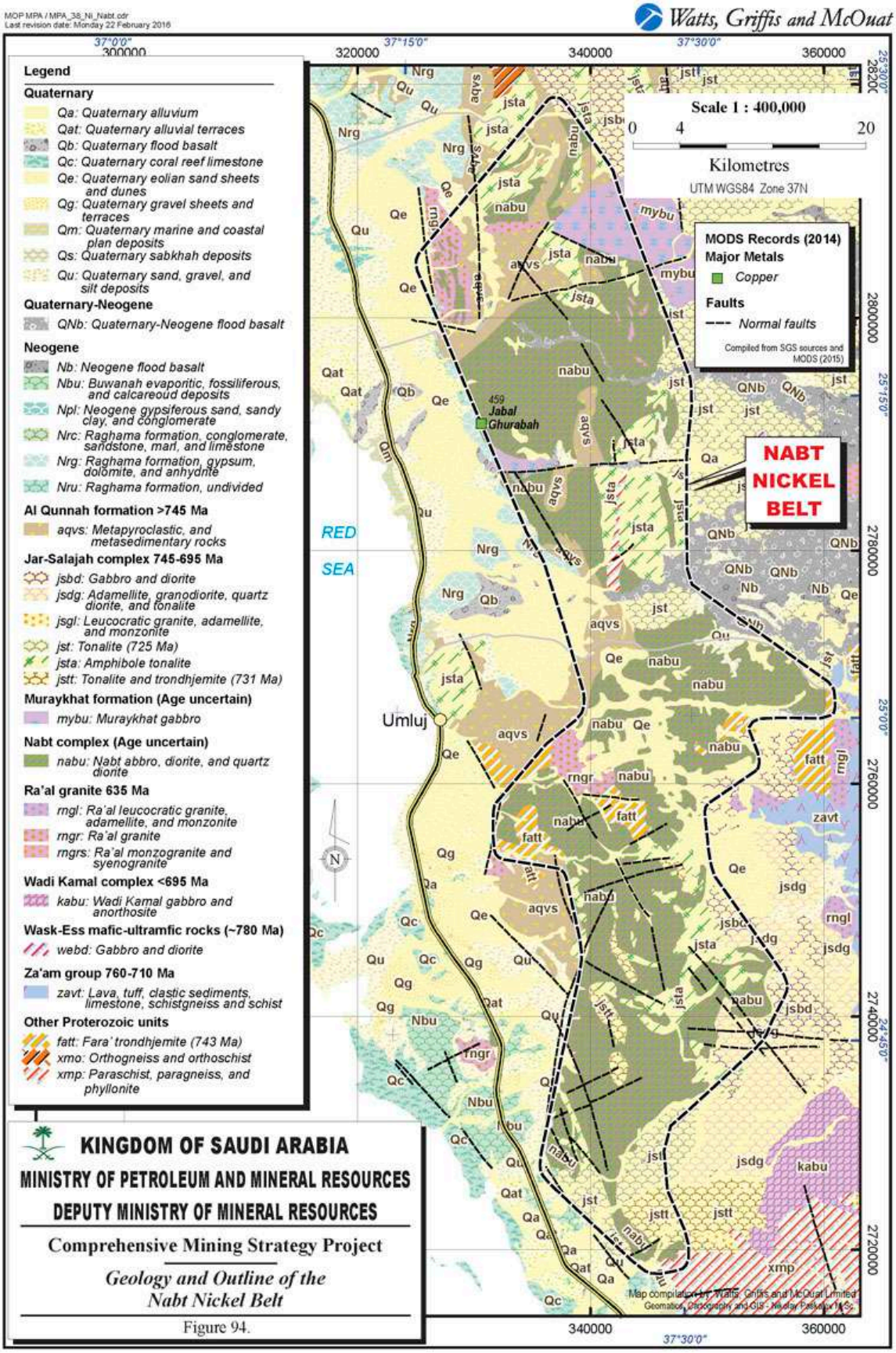
Location, History and Geology

The Nabt Complex is a composite mafic-ultramafic suite (age uncertain) extending along the Red Sea coastal plain in the Midyan Terrane. It covers an area of about 1,512 km^2 (Figure 94). It contains a variety of rock types including gabbro, quartz gabbro, amphibolite, diorite, tonalite and local ultramafic rocks. There is some speculation (Pellaton, 1979) that the Nabt Complex may be part of or coeval with the Wadi Kamal Complex which is known to host numerous Cu-Ni-PGE occurrences.

The Jabal Ghurabahn prospect (MODS 459), formerly known as Jabal Gharalbah, is the only known Ni-Cu occurrence in the Nabt Complex. The prospect consists of a series of gossans on a serpentinized ultramafic (cumulate phase) that extends along strike for about 800 m. Within the ultramafic rocks, the gossans form a chain about 200 m in length and they have been found to correspond with disseminated sulphide mineralization. Trench sampling by the BRGM during 1974 returned maximum values of 1.2% Ni and 1.2% Cu (Bache and Henry, 1980). The best PGE sample assayed only 14 ppb Pt, however only 4 gossan samples were analysed for PGE and this is considered to be inadequate. WGM previously examined this work and concluded that the Gharalbah prospect had not been adequately explored (WGM-CR-11-10).

Recommendations

A systematic mapping and wadi sediment sampling program is recommended for the entire Nabt Complex and in addition, age determinations for this complex are needed to correlate these rocks with those of the Wadi Kamal Nickel Belt. WGM recommended a program of re-assaying (Au and PGE) of existing samples followed by diamond drilling for the Jabal Gharabah prospect, and these recommendations are still valid (WGM-CR-11-10). Regional, reconnaissance-level wadi sediment geochemical sampling was previously recommended, however the density recommended (1 site/3-5 km^2) could be substantially increased in areas with rock formations thought to be more highly prospective. Definitive geochemical sampling would require an average of 5 samples sites/km^2. An IP survey is also recommended for the prospect to determine the 3D configuration of the mineralization and to attempt to define targets for drilling.


MOP MPA / MPA_38_Ni_Nabt.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qb: Quaternary flood basalt
Qc: Quaternary coral reef limestone
Qe: Quaternary eolian sand sheets and dunes
Qg: Quaternary gravel sheets and terraces
Qm: Quaternary marine and coastal plan deposits
Qs: Quaternary sabkhah deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Neogene
Nb: Neogene flood basalt
Nbu: Buwanah evaporitic, fossiliferous, and calcareous deposits
Npl: Neogene gypsiferous sand, sandy clay, and conglomerate
Nrc: Raghama formation, conglomerate, sandstone, marl, and limestone
Nrg: Raghama formation, gypsum, dolomite, and anhydrite
Nru: Raghama formation, undivided
Al Qunnah formation >745 Ma
aqvs: Metapyroclastic, and metasedimentary rocks
Jar-Salajah complex 745-695 Ma
jsbd: Gabbro and diorite
jsdg: Adamellite, granodiorite, quartz diorite, and tonalite
jsgl: Leucocratic granite, adamellite, and monzonite
jst: Tonalite (725 Ma)
jsta: Amphibole tonalite
jstt: Tonalite and trondhjemite (731 Ma)
Muraykhat formation (Age uncertain)
mybu: Muraykhat gabbro
Nabt complex (Age uncertain)
nabu: Nabt abbro, diorite, and quartz diorite
Ra'al granite 635 Ma
rngl: Ra'al leucocratic granite, adamellite, and monzonite
rngr: Ra'al granite
rngrs: Ra'al monzogranite and syenogranite
Wadi Kamal complex <695 Ma
kabu: Wadi Kamal gabbro and anorthosite
Wask-Ess mafic-ultramfic rocks (~780 Ma)
webd: Gabbro and diorite
Za'am group 760-710 Ma
zavt: Lava, tuff, clastic sediments, limestone, schistgneiss and schist
Other Proterozoic units
fatt: Fara' trondhjemite (743 Ma)
xmo: Orthogneiss and orthoschist
xmp: Paraschist, paragneiss, and phyllonite
Scale 1 : 400,000
0 4 20
Kilometres
UTM WGS84 Zone 37N
MODS Records (2014)
Major Metals
Copper
Faults
Normal faults
Compiled from SGS sources and MODS (2015)
NABT NICKEL BELT
RED SEA
Jabal Ghurabah
Umluj
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology and Outline of the Nabt Nickel Belt
Figure 94.
Map compilation by Watts, Griffis and McOuat Limited
Geomatics, Photogrammetry and GIS - Toronto, Canada
320000
340000
360000
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2760000
2740000
2720000

3.3.3.10 Dulayat Humayyan Prospect

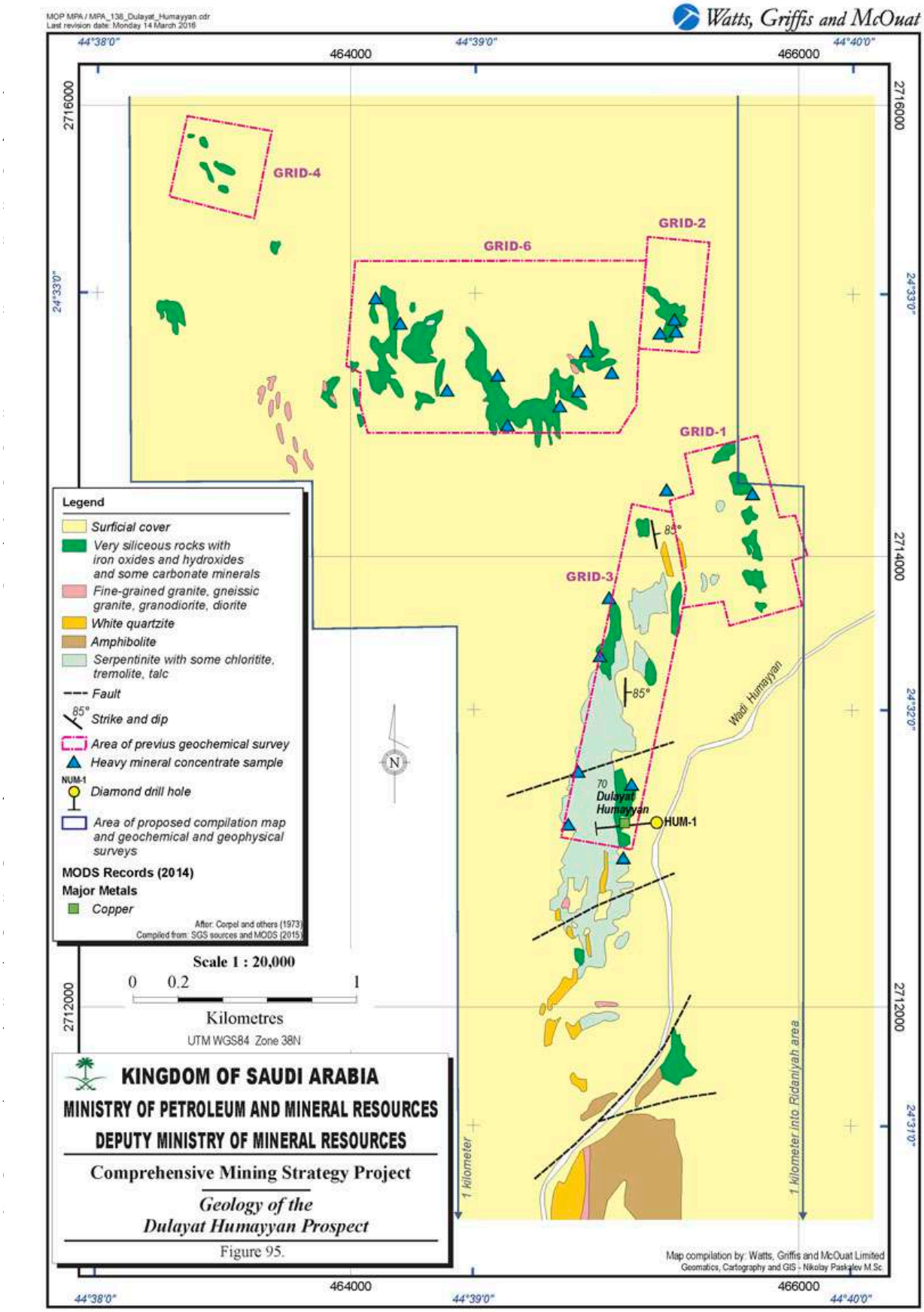

Figure 95: Geology Map of the Humayyan Prospect.

3.3.4 EMINERS MODELLING OF NI-CU (+/- PGE) BELTS AND PROBABILISTIC OUT-COMES

As stated in earlier sections of this report, the United States Geological Survey ("USGS") developed a quantitative mineral assessment program called EMINERS (**E**conomic **M**ineral **R**esource **S**imulator) to assess the potential of selected mineral belts to host undiscovered deposits at different levels of probability. The assessment consists of three parts:

1) Development of grade and tonnage mineral deposit models;
2) Delineation of mineral tracts permissive for each deposit type; and,
3) Probabilistic estimation of the number of undiscovered deposits for each deposit type in each mineral belt.

Grade and tonnage models were compiled by the USGS for various types of deposits including the Ni-Cu-PGE ("**NCP**") type. WGM has modified the USGS model to include deposits from a mature (from an exploration perspective) mineral belt with the requisite geological characteristics. This modified model has been used for the EMINERS simulation with the expectation that the size and grade of the undiscovered deposits will be similar to those in the model. However, because there are no Ni deposits in the Arabian shield with significant resources, the model cannot be reliably verified in the Saudi context as was the case for gold and VMS-type deposits. After conducting a sensitivity analysis, Singer (2007) concluded that the selection of the proper grade and tonnage model is more critical to the final assessment that small errors in estimates of the number of deposits. Given that there are no mature deposits in the Kingdom, meaning that there are no deposits that have been entirely drilled off and rigorously defined, it is very difficult or perhaps even impossible to select analogues from similar terranes elsewhere in the world.

Permissive tracts or mineral belts were developed using the 1:250,000 scale geology maps of the shield area and the MODS mineral occurrence database as well as selected referenced studies. NCP mineral occurrences were located in each area and related to the permissive lithologies as outlined on the maps and the mineral belt outlines were extended outward from these areas. The shape and extent of each mineral belt is therefore dependent upon the detail of the mapping, and of the adequacy of the prior exploration programs. The final part of the assessment consists of the probabilistic estimation of the number of undiscovered NCP mineral deposits in each area compiled as a subjective estimation by the modeller(s). Estimates were prepared at the 90^{th}, 50^{th} and 10^{th} percentiles of confidence. Empirical observations regarding NCP deposit sizes, grades and mineral belt areas by Lesher (2007)) were used as a generalized guide in preparing the estimates and evaluating the results.

Once the steps outlined above have been completed then the data is entered into the EMINERS software which uses a Monte Carlo statistical process to produce probabilistic estimates of tonnage and grade for the model selected. A summary of the results of WGM's probabilistic estimations and the EMINERS simulation data for the 3 delineated NCP mineral belts is presented in Table 65.

Table 65
Summary of NCP Belts: Ni-Cu (+/- PGE) Occurrences and Deposits in the Arabian Shield, EMINERS In-Puts and Projections

nces	Area (km^2)	Known NCP Mines (includes feasibility-level projects)			Anticipated New Deposits by Confidence Level			Chance of Zero Deposits	EMINERS Projections (Out-Puts): Number of New Deposits, Global Resources														
									Number of Deposits	---------- Confidence Level ----------													
										10%								50%					
		Closed	Active	Planned	10%	50%	90%	(%)	(#)	Mt	Cu %	Ni %	Co %	Pt %	Pd g/t	Au g/t	Mt	Cu %	Ni %	Co %	Pt %	Pd g/t
	224	0	0	0	1	0	0	yes	0.3	3	0.1	1.7	0.0	0.0	0.0	0.00	0	0.0	0.0	0.00	0.0	0.0
	1,512	0	0	0	2	1	0	yes	0.8	20	0.1	0.9	0.1	0.0	0.0	0.00	1	0.0	1.4	0.0	0.0	0.0
	461	0	0	0	7	2	1	yes	3.1	43	1.2	1.2	0.2	0.09	0.16	0.07	9	0.1	1.2	0.0	0.0	0.0
	96,590	**0**	**0**	**0**	**10**	**3**	**1**		**5.2**	**66**	**0.8**	**1.1**	**0.2**	**0.06**	**0.11**	**0.05**	**10**	**0.1**	**1.2**	**0.0**	**0.0**	**0.0**

The EMINERS out-put at the 90% confidence level indicated that no new discoveries would be made, perhaps reflecting and underscoring the fact that no actual Ni-Cu-PGE mines or mineable deposits are known to exist in the Kingdom at this time. Individual users will need to determine for their own purposes the degree to which the outcomes at 10% and 50% confidence levels are useful. At the 50% level, EMINERS forecasts 5 new deposits with an aggregate tonnage of 10 Mt grading 1.2% Ni and 0.1% Cu with no measurable Co, Pt, Pd or Au. This outcome is thought to be a good reflection of the current status of NCP project advancement in the KSA, however it probably is not a useful reflection of what might result from systematic and sustained exploration focused on this deposit type. Discoveries are seldom made based on a single exploration program and it is only through sustained effort, building new knowledge upon the foundation of older data that new mineable deposits are assembled from smaller components. Individual orebodies may be found which by themselves are less than what is needed to sustain a viable mining operation, however the discovery of additional satellite orebodies in the proximity of Jabal Maradah would certainly change the economic outlook of this project. This project and others like it with a current resource base would be good places to begin the work needed to determine the true viability of this deposit type.

3.3.5 TECHNICAL AND ECONOMIC VIABILITY OF PREDICTED UNDISCOVERED NI-CU (+/- PGE) DEPOSITS

Introduction

The out-put from the EMINERS modeling was used as the basis for estimating the economic viability of the predicted new and undiscovered Ni-Cu-PGE deposits. Several sub-types of these deposits are permissive in the Arabian Shield, however their geometric configuration and grade have sufficient commonality that they can be treated as the same for the purpose of this study. WGM used the EMINERS outcomes at the 50% confidence level which we believe are indicative, however like with the EMINERS outcomes for gold and for base metals, the probabilistic approach almost certainly under-estimates potential at the 50% and 90% levels of confidence. We believe some predictions are possible at the 10% level of confidence. The primary reason for under-reporting is the fact that a probabilistic approach allows little or no influence by deposits that are outliers – the extremely large deposits. The average size of EMINERS' predicted deposits increases substantially as confidence level is reduced and most grades increased, especially for the associated metals (Co, Au and PGE's).

The predicted undiscovered nickel-copper-PGE resources were allocated amongst the predicted number of deposits (Table 66). On the basis of geological evidence, WGM believes that all of these small, relatively low grade deposits would be open pit operations as dictated by mining costs. This information was provided to WGM's engineering group for further assessment such that a provisional mining schedule could be

developed as a basis for determining what mining method might be appropriate given the “average” geometric configuration of such deposits. This was used as a basis for selecting and sizing equipment as well as estimating capital, operating and other cost factors.

Table 66
Summary of WGM's Allocation of 50% Confidence Level Resources to Undiscovered Mines for Viability Modeling

Name of Ni-Cu-PGE Belt	EMINERS Output at 50% Confidence Level								
	Number of Mines	Total Tonnes (millions)	Average Tonnes per Undiscovered Mine (millions)	Average Grade of Each Undiscovered Mine					
				Ni (%)	Cu (%)	Co (%)	Pt (g/t)	Pd (g/t)	Au (g/t)
Al Bajaydi	0	0	**0.0**	0.0%	0.0%	0.00%	0.0	0.0	0.0
Nabt	1	1	**1.0**	2.15%	0.0%	0.00%	0.0	0.0	0.0
Wadi Kamal	2	9	**4.5**	1.24%	0.08%	0.00%	0.0	0.0	0.0
	EMINERS Output at 10% Confidence Level								
Al Bajaydi	1	3	**3.0**	1.7%	0.1%	0.00%	0.00	0.00	0.00
Nabt	2	20	**10**	0.9%	0.1%	0.01%	0.00	0.10	0.00
Wadi Kamal	7	43	**6.1**	1.2%	0.2%	0.02%	0.09	0.16	0.07

Mining and Processing

In order to evaluate undiscovered mines, cost estimates were prepared for a range of typical mines in the Kingdom. These are order-of-magnitude cost estimates, designed to get an initial reading on potential viability. WGM initially prepared personnel lists for typical small, medium, and large mines, both open pit and underground: six lists in all. Only open pit mining was predicted for the undiscovered Ni-Cu mines.

Mining and maintenance personnel quantities were estimated based on a mining fleet analysis. For each mine, a few positions were assigned international salaries; for all other jobs filled by Saudi nationals, wages and benefit estimates were based on the 2014 SGS report "Directory of Mining Services Cost in Saudi Arabia". Quantities of consumables were then prepared for each of the six models. Costs were prepared using information from WGM data.

The EMINERS output resulted in a predicted tonnage for each undiscovered mine. The undiscovered Ni-Cu mines are predicted to be open pit mines with a low stripping ratio. An annual throughput rate was selected that results in a mine life of approximately 10 years, although round numbers were chosen; for Ni-Cu mines either 500,000 tonnes per year or 100,000 tonnes per year. Mining of waste rock was modelled at a constant annual tonnage.

Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine site costs for Mining. Equipment lists and personnel lists for typical medium-sized open pit mines are shown in Table 32 in the gold section of this report.

Capital cost estimates for Mining were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM data sources.

The processing required for this style of mineralization has a sensitivity to the grade-recovery relationship and usually requires production of one low-grade concentrate (12 to 15% Ni) to achieve economic recovery of the nickel. The requirement to fine grind the ore to allow production of a separate copper concentrate is usually not an option, and the one concentrate produced will contain Ni along with some Cu and PGE's which unfortunately are likely to provide no identifiable credit in the NSR. In other words, the smelter will simply take the value (credits) received from these associated metals into its own revenue stream.

The flowsheet used will have a crushing and grinding circuit followed by a multiple stage flotation circuit producing a single concentrate for filtering and drying for transport from the site. The process would employ a high recycle of water and filtering and dry stacking of the tailings to reduce water consumption.

General and Administration

The sites envisioned would be self contained with an accommodation camp and power generation as included in the gold and VMS projects detailed in the foregoing sections.

Economic Analysis

The economic analysis of the undiscovered mines within the Nickel-Copper-PGE Belts yielded the results summarized in the following table. From this the improvement in project economics is clear at the lower confidence level. The single, rather small Al Bajaydi project (mine) generates an exceptionally high IRR because it is assumed that this ore would be processed at another mine, thus the project requires comparatively little capital investment leading to a very high IRR.

Table 67
Summary of Economic Modeling of the Undiscovered Ni-Cu-PGE Deposits

Mineral Belt	Project	Total IRR (%)	Net Cash Flow ($ / t ore)	Net Cash Flow ($ M)
50% Confidence Level (Base Case)				
Wadi Kamal	Wadi Kamal #1	17.2%	$34.2	$153.9
Wadi Kamal	Wadi Kamal #2	17.2%	$34.2	$153.9
Nabt Mineral Belt	Nabt	9.6%	$39.6	$39.6
Total/Average	**3 Undiscovered Mines**	**14.7%**	**$36.0**	**$347.4**
10% Confidence Level				
Wadi Kamal	Wadi Kamal #1	19.2%	$38.84	$238.6
Wadi Kamal	Wadi Kamal #2	19.2%	$38.84	$238.6
Wadi Kamal	Wadi Kamal #3	19.2%	$38.84	$238.6
Wadi Kamal	Wadi Kamal #4	19.2%	$38.84	$238.6
Wadi Kamal	Wadi Kamal #5	19.2%	$38.84	$238.6
Wadi Kamal	Wadi Kamal #6	19.2%	$38.84	$238.6
Wadi Kamal	Wadi Kamal #7	19.2%	$38.84	$238.6
Nabt Mineral Belt	Nabt #1	17.1%	$26.25	$262.5
Nabt Mineral Belt	Nabt #2	17.1%	$26.25	$262.5
Al Bajaydi Belt	Al Bajaydi	111.9%	$73.28	$241.8
Total/Average	**10 Undiscovered Mines**	**28.0%**	**$39.77**	**$2,436.8**

Unlike the mines for VMS base metal deposits, the undiscovered nickel-copper-PGE projects produce a single nickel concentrate as the projects' copper content is too low to produce a viable separate copper concentrate. Rather the recovered copper is included in the nickel concentrate. WGM has used typical nickel concentrate smelter contracts to forecast the value of the nickel concentrates produced by the undiscovered nickel projects.

The nickel and copper prices used to generate these results were $15,000/tonne and $7,535/tonne, respectively, as provided by McKinsey. At the 50% confidence level, the Internal Rates of Return ("**IRR**s") are marginal at best at these metal prices. The problem appears to be low copper values and no significant platinum group elements (PGE's). The nickel grades are also lower than usual for most operating nickel mines. On the positive side, these are forecast to be open pit mines which enjoy much lower mining costs. As shown in Table 67, the EMINERs lower (10%) confidence level result provides for the potential of the undiscovered deposits to contain PGE's as well as cobalt and gold. These additional metals marginally improve the IRRs for such deposits.

At the 50% base-case confidence level, the 3 undiscovered NCP mines modelled had an IRR ranging from 9.6% to 17.2%, and averaging 14.7%, or marginal at best. The average NCF per tonne of ore was US $36.00 with an average total life-of-mine NCF of $347 million. The nickel grades are also lower than usual for most operating nickel mines. On the positive side, these are forecast to be open pit mines which enjoy much lower mining costs. **This improved substantially at the 10% confidence level due to the addition of other metals (Co, Pt, Pd and Au) to the resource base and an increase in the size of the resource base. The number of mines also increased to 10, largely in the Wadi Kamal Belt. At this level of confidence the IRR ranged from 17.1% to 111.9%, and averaging 20%. The high value IRR is an outlier created by the Al Bajaydi Belt and represents a very small deposit with low capital investment due to its ore being processed at a separate mill. The average NCF per tonne of ore was US $39.77 with a total life-of-mine NCF of $2,437 billion for all the NCP mines.**

3.3.6 REFERENCES

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3.4 NB-TA-REE DEPOSITS

3.4.1 METALLOGENIC MODEL AND EXISTING MINES / MAJOR DEPOSITS

The REEs are commonly mentioned as if they are a homogenous group of 15 "rare metals" plus yttrium (Table 68). In fact, they are not. Some make the error of including tantalum, niobium, lithium and zirconium as REEs, and although they can be associated with REEs, they are not part of the group.

Table 68
Summary of the Rare Earth Elements and Yttrium

	Element	Symbol	Atomic Number	Abundance (ppm)
				Upper Crust
LREE	Lanthanum	La	57	30
	Cerium	Ce	58	64
	Praseodymium	Pr	59	7.1
	Neodymium	Nd	60	26
	Promethium	Pm	61	n.a.
	Samarium	Sm	62	4.5
	Europium	Eu	63	0.88
HREE	Gadolinium	Gd	64	3.8
	Terbium	Tb	65	0.64
	Dysprosium	Dy	66	3.5
	Holmium	Ho	67	0.80
	Erbium	Er	68	2.3
	Thulium	Tm	69	0.33
	Ytterbium	Yb	70	2.2
	Lutetium	Lu	71	0.32
	Yttrium	Y	39	22

The REEs have many differing properties and many of the REEs are not especially rare, several being more common in the earth's crust than copper. In day to day practice, the REEs are divided into two groups: Light Rare Earth Elements ("**LREE**"s), those having an atomic number of 63 or less, and Heavy Rare Earth Elements ("**HREE**"s), those metals with a greater atomic number. The elements with low atomic numbers are generally more abundant in the earth's crust than those with higher atomic numbers, and those with even atomic numbers are 2-7 times more abundant than the adjacent rare earth elements with odd atomic numbers. Although yttrium is the lightest of the group, it is usually included with the HREEs to which it associates because it is chemically and physically similar to the heavier elements.

On a global basis, REEs are found in a wide variety of minerals and geological environments including oil-field brines; however, the most economically interesting deposits occur in carbonatites and felsic intrusive rocks (typically alkaline granites). These elements are included in a series of 'high field strength elements'

[5] that are commonly enriched in alkaline igneous settings. This enrichment can be due to fractional crystallization of magma or hydrothermal alteration of the granite body. The Arabian Shield contains one of the largest fields of alkali granites in the world. Within the Shield, these granites constitute about 2.3% of the total plutonic rock assemblage. Together with some aluminous granites, the alkali granites are collectively associated with high levels of Nb, Ta, Th, Sn, W, F, Mo, Zr, Y and REE mineralization. This has been documented by a series of workers including Drysdall and others (1984) and Qadhi (1990). Forty-nine major, and more than a dozen minor, alkaline and peralkaline granite plutons are concentrated in the Midyan and Hijaz Terranes of the Arabian Shield, as well as in the Nabitah Orogenic Belt. However, for unknown reasons, very few alkali granite plutons are defined in the southern part of the Arabian Shield, a trend that continues southwards into Yemen.

Throughout the Arabian Shield, the alkaline granites are the last (youngest) major intrusive phase. The so-called alkali granites are relatively uncommon in comparison to other varieties of granite, and are the result of the progressive evolution of granitic magma compositions over time. In the Saudi Shield, alkali granites were emplaced over a period of approximately 180 Ma (686–518 Ma), however all but four occurrences formed during the late Proterozoic between 630 Ma and 565 Ma. A major part of the alkaline/peralkaline granites show marked enrichment in Nb, Ta, Th, Zr, Y and REEs. The REE mineral occurrences in the KSA are associated with a class of plutonic rocks that are sodic-alkalic granites enriched in high-field-strength elements such as Ti, Y, Zr, Nb, Hf and Ta. Some are enriched in thorium and rare earth elements (REEs).

Nearly all commercial REE production has come from less than 10 minerals, although the metals occur in significant amounts in many minerals. The recovery of the metals from a potentially economic REE resource is strongly influenced by its REE mineralogy. In the past, producing deposits were limited to those in which (1) REE-bearing minerals were relatively easy to concentrate because of coarse grain size or other attributes; or, (2) REEs were hosted in rocks or minerals that were easily broken down or leached, such as the carbonate bastnäesite. Those deposits in which the REEs are found in minerals that are difficult to dissociate, such as the silicate mineral allanite constitute much less favourable deposits. Placer monazite, once an important source of REEs, has been largely abandoned because of its high thorium content. While thorium was once stockpiled by the USA as a strategic metal, the current stockpile is sufficient to supply global demand for a great many years, and so it is no longer accumulated and treated more like an environmentally undesirable waste product. Recently, REEs absorbed on clay minerals in laterite have become important sources of HREEs in China.

Four major REE deposits have been identified to date in the Kingdom (Table 69) and WGM understands that the Saudi Geological Survey is drilling several others that are less well defined. Although none of these

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[5] '*High field strength elements*' is a technical term used for elements that are characterized by large ionic valences (or high charges), and these include such elements as zirconium, niobium, hafnium, the rare earth elements, thorium and tantalum.

is well explored, it is clear that the Quriyyah (Ghurayyah) deposit is by far the largest resource of high field strength elements in the country, especially Ta, Nb and potentially REEs. It may be one of the largest undeveloped resources in the world. The size of this deposit is constrained only by the volume of the Quriyyah intrusion. However, the average grade of its REE mineralization is very low and the deposit could not be developed based on REE content alone. Tertiary Minerals, the operator of the Quriyyah project, announced an Inferred Resource estimate of "nearly 400 million tonnes" grading 245 ppm (0.024%) Ta_2O_5, 2,840 ppm (0.28%) Nb_2O_5, 8,915 ppm (0.89%) ZrO_2 and 1,270 ppm (0.13%) Y_2O_3 (Tertiary Minerals Plc website).

Notwithstanding the size of Quriyyah, Sirw Al Buhayr and potentially Jabal Sayid are notably enriched in the HREEs compared to the LREEs. Although these deposits are much smaller, WGM believes that significant potential may exist for the discovery of new mineralized bodies with additional drilling.

Table 69
Estimate of Tonnage and Grade of REE Deposits in Saudi Arabia

Location	Tonnes (millions)	Depth (m)	Nb	Ta	Sn	La	Ce	Y	Th	Zr
			---------- (ppm) ----------							
Major Deposits and Prospects										
Sirw Al Buhayr	6.4	85	3,405	175	381	19	137	5,216	693	37,300
Umm al Birak	6.6	150	1,663	121	84	371	800	311	46	5,129
Jabal Sayid	23.0	100	1,290	82	199	587	1,301	4,151	834	>17,000
Jabal Humayra	17.9	100	1,731	146	194	2,593	3,432	1,592	263	13,267
Other Prospects										
Al Quriyyah	440	250	2,256	212	290	61	144	1,326	399	8,578

None of the aforementioned occurrences have been demonstrated to be economically viable and none of the estimates is compliant with current regulatory standards..

As can be seen from the foregoing table, the disseminated intrusion-hosted deposits are the largest in respect to tonnage however this gold mineralization is typically lower grade than the vein-type deposits. In the disseminated deposits, mineralization occurs as discrete Nb, Ta and REE-minerals and REE-bearing minerals within the framework of the major rock-forming minerals of the host granite, or as disseminated mineral components of hydrothermal alteration zones within the granite. The physical size and geometry of the disseminated deposits favours open-pit mining whereas only near-surface portions of the vein-type deposits can be mined without resorting to selective underground mining techniques. It is worth noting that many of the disseminated deposits also contain vein stockworks that may possibly be selectively mined at higher grades.

3.4.2 DISTRIBUTION OF DEPOSITS

WGM's initial assessment of the Saudi Mineral Occurrence Database (MODS) identified only two (2) REE occurrences: Wadi At Tawilah (MODS 2794) formerly known as Mowasse' and Jibal Al Qarain (3156), formerly known as Jabal Ba'Ghna. In the most recent version of the MODS, and Umm al Birak (2841) has been reclassified as a niobium prospect with associated tin, zirconium and tantalum. The classification of Jabal Humayra (2842), formerly Jabal Hamra, has been confused by classifying it as a lanthanum prospect with associated cerium, niobium, zirconium, thorium and tin. Similarly, Sirw Al Buhayr-NE (1635), formerly Jabal Tawlah, has been reclassified as a niobium occurrence with associated yttrium and zirconium.

Although certain mineral commodities (metals) can be explored for by following various types of structural zones or linear "belts", the nature of the REE association with granites (and carbonatites as well) precludes this approach. As plutonic rocks, the hosts may cluster or be otherwise restricted in distribution, but they do not occur in belts. The alkali granite plutons tend to be isolated bodies. The REE-bearing rocks do have particular physical, geochemical and radiometric signatures that distinguish them from country rocks. The typical host rocks for REM mineralization in the Arabian-Nubian Shield are young, post-tectonic intrusions, and they generally have a strong, positive topographic expression – they rise above the ground often to heights of 100 m or more above the surrounding wadis. As such, the use of high-resolution satellite imagery is a viable means of identifying intrusions that may be prospective for REEs if they have not already been sampled (many have not). These intrusions will also be well exposed for airborne geophysical surveying. In general, the favoured alkali granites are anomalously radioactive due to the presence of minerals containing U, Th and certain REEs. In turn, these features allow geologists to target individual bodies to ascertain REE potential. It must be remembered, however, that the most favourable intrusions are highly fractionated, and the granite bodies may be zoned in such a manner that only one of the zones has true REE potential – therefore all phases of the granite must be systematically mapped and sampled.

3.4.3 PROSPECTIVE REE AND RELATED OCCURRENCES

3.4.3.1 Geology

As of 2009, the Mineral Occurrence Database System ("**MODS**") of the Saudi Geological Survey listed 22 mineral occurrences where REEs were the primary commodity. In addition, the MODS listed 6 occurrences where the major associated minerals contained or included REEs. The current 2014 version of the MODS lists 14 REE occurrences and a single yttrium occurrence. In addition, there are five niobium occurrences that list yttrium as an associated metal. These occurrences are summarized in Table 70 from the most northerly to the most southerly.

Table 70
REE-Y-Nb-Ta Records in the MODS for Saudi Arabia

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Potential Ranking *	Geometry
				Longitude	Latitude			
2796	Wadi Hagiyah	Wadi Marshah	La + Sn-Zr	35.3333330	28.7666670	Al Bad	Undefined	undefined
2794	Wadi At Tawilah	Mowasse'	REE	35.1534720	28.5663890	Al Bad	Low	undefined
1635	Sirw Al Buhayr-NE	**Jabal Tawlah**	Nb + Y-Zr	35.3917780	28.2407780	Al Bad	Med	dd
0765	Al Quriyyah	**Ghurayyah**	Nb + Zr-Y-Ta-U-F	35.7973890	27.9145000	Al Muwaylih	High	dd
2653	Shaib Aba Al Mulayh	Hail Area	Nb	41.7990560	27.5801110	Hail	Undefined	undefined
3156	Jibal Al Qarain	Jabal Ba'Ghna	REE	41.0683610	26.9333890	Halaban	VL	dd
4028	Jibal Aba Ad Dud	Jabal Aba Ad Dud	Ce + Sn-Nb-Ta	38.5588890	26.1077780	Al Ayn	VL	undefined
3682	Jibal Aba Ad Dud	Jabal Aba Ad Dud	Ce + Nb-Th	38.5580280	26.1015560	Al Ayn	VL	dd
2842	Jabal Humayra	**Jabal Hamra**	La + Ce-Nb	38.6152500	26.0896670	Al Ayn	VL	dd, mass bed
4029	Jabal Humayra-S	Hamra-SE	Ce + Sn-Zn	38.5957500	26.0525000	Al Ayn	VL	dd
2733	Aban Al Ahamr-Jabal Mirqid	Ahmar-SE	Nb + Y-F	42.7336110	25.4161110	Al Rass	Low	undefined
0358	Jabal Sayid-SE	**Jabal Sayid-SE (Sa'id)**	Nb	40.9696670	23.8195830	Al Mahd	Undefined	dd, veins
0356	Jibal Ash Sharar-W	Jabal Sayid-SE	Nb	40.9676940	23.7782500	Al Mahd	Low	dd, veins
2841	Umm Al Birak	**Umm Al Birak**	Nb + Sn-Zr-Ta-Th-Y	39.2083890	23.3905830	Ar Rayis	Med	dd, bx, v
4030	Jabal Bani Yub	Jabal Al Yoob	Ce + Y-Th-Sn	39.0978330	23.3207780	Ar Rayis	VL	undefined
2084	Jabal Sabha	Jabal Sabhah	Nb	44.6472220	23.2833330	Halaban	Undefined	dd, lenses
2316	Jabal Sabha-W	Jabal Sabhah	Nb	44.5722220	23.2680560	Halaban	Undefined	lenses, veins
2259	Jibal Al Aqir	Jabal Abu Gobaaq-NE	Y	43.3843890	23.1398060	Al Khasrah	VL	dd
1622	Jabal Sahah	Jabal Sahah	Nb + Zr-Y	44.8266670	22.1461110	Al Raqmiah	VL	dd
2820	Hidab Ad Dirayn	North Huqban Altered granite	Ce + Sn-Nb-Ta	43.9675560	21.9968060	Halaban	Undefined	dd
2819	Hidab Al Qarain	Huqban granite District	Ce + Sn-Nb-Ta	43.9146940	21.8644720	Halaban	Low	dd
2802	Jabal Waqt Specialised Dikes	Jabal Waqt Specialised dykes	Ce + Li-F	42.8624170	20.5506390	Bishah	Low	undefined
2799	Jabal Yala	Jabal Yala	Ce + Sn-Zr-F	42.8112780	20.1159170	Bishah	Low	massive
2797	Jabal Libd	Libt Specialised granite	Ce + Mo-Li-F	42.6008330	19.7137500	Bishah	Med	undefined
1235	B'ir Kurrath	Karath Well	Nb + Ta-Be	42.7333330	18.9500000	Abha	VL	dd
0620	Al Hadba	Al Hadba	Ce	43.2503610	18.6171390	Abha	Low	lenses

NOTES: (1) Ranking according to MODS: VL = Very Low; Med = Medium. (2) dd = disseminated; v = veins; bx = breccia; mass = massive
(3) The five bolded names highlight Ghurayyah and the four deposits originally recognized as prominent REE prospects or Nb-Ta-Zr prospects.

The major REE deposits, prospects and occurrences in the Arabian Shield are summarized in Table 71 based largely on historical exploration prior to 2001 (Orris and Grauch, 2002). Although the SGS has drilled some of these prospects, there has been very little material change in respect to estimated resources which in any case are not compliant with existing regulatory standards such as Canada's National Instrument 43-101 ("**NI 43-101**") or Australia's JORC Code.

Table 71
Summary of REE Deposits, Prospects and Occurrences in the Arabian Shield, Saudi Arabia

Name	Location	References	Status[1]	Resources	REE Minerals	Associated Minerals / Metals	Gangue Minerals
Alkalic Igneous Types							
Jabal Humayra (MODS 2842)	26°04'N 38°36'E	Drysdall and others, 1984; Laval, 1992	Occ	18. Mt @ 0.21% Nb_2O_5, 0.18% Y_2O_3, 1.78% ZrO_2, 0.8% REO	monazite, bastnäesite	zircon, uraninite, Nb, Ta, Sn, Th, hematite	quartz, microcline
Jibal Ash Sharar-W (MODS 0356)	23°49'N 40°56'E	Drysdall and others, 1984	Dep	23 Mt (to 100 m below surface) @ 0.6% REE+Y	brookite, allanite, pyrochlore	fluorite, zircon, thorite, Th-uraninite, ilmenorutile, anatase, sphalerite, hem, Nb, Ta, Sn	quartz, albite, microcline, tour, aegirine, arfvedsonite
Sirw Al Buhayr-NE (MODS 1635)	28°14'N 35°23'E	Drysdall and others, 1984; Laval, 1992	Occ	6.4 Mt @ 0.42% Nb_2O_5, 0.62% Y_2O_3, 5.0% ZrO_2	pyrochlore, monazite	zircon, sphalerite, Nb, Ta, Sn, Th	albite, quartz, microcline, mica
Jabal Abu ad Dud (MODS 3682)	26°06'N 38°34'E	Al Nakhebi	Pro	none	Cerium, Lanthanum	niobium, thorium,	Quartz
Umm al Birak (MODS 2841)	23°22'N 39°13'E	Drysdall and others, 1984	Pro	6.6 Mt @ 0.14% REE+Y	monazite, bastnäesite, pyrochlore	zircon, fluorite, scheelite, thorite(?), ceriopyrochlore, albite, microcline, aegirine, biotite, arfvedsonite, quartz	Uncertain
Important Deposits with Associated REEs							
Al Quriyyah (MODS 0765)	27°55'N 35°48'E	Drysdall and others, 1984	Dep	440 Mt @ 0.15% REE+Y	aeschynite (Y), xenotime, monazite, samarskite, pyrochlore	zircon, fluorite, cassiterite, columbite-tantalite, uraninite, thorite, ilmenorutile, galena, sphalerite	mica, quartz, microcline, albite, chlorite, arfvedsonite, aegirine

Note 1: Dep = REE deposit with estimated (noncompliant) resources; Pro = a major REE occurrence without sufficient work to define resources; Occ = a lesser REE occurrence based on very limited sampling which may or may not be representative of the mineralization.

As stated in the foregoing section, REE mineralization occurs only in the Arabian Shield and occurs at four well documented sites: Jabal Humayra (MODS 2842), formerly Jabal Hamra, Jabal Sayid-SE (0358) formerly Jabal Sa'id, Sirw Al Buhayr-NE (1635) formerly Jabal Tawlah and Umm al Birak (2841). More recent exploration activity has added Jibal Aba Ad Dud (MODS 3682 and 4028) to the select list, however information on this prospects is lacking in the available literature. The most advanced REE projects are associated with late Precambrian, post-tectonic alkali granites located in the north-western Arabian shield. These bodies evolved from alkalic magmas formed by high-temperature, dry melting of island-arc crust. Mineralization is accompanied by enrichment in Nb, Ta, Sn, REEs, Y, Th and Zr.

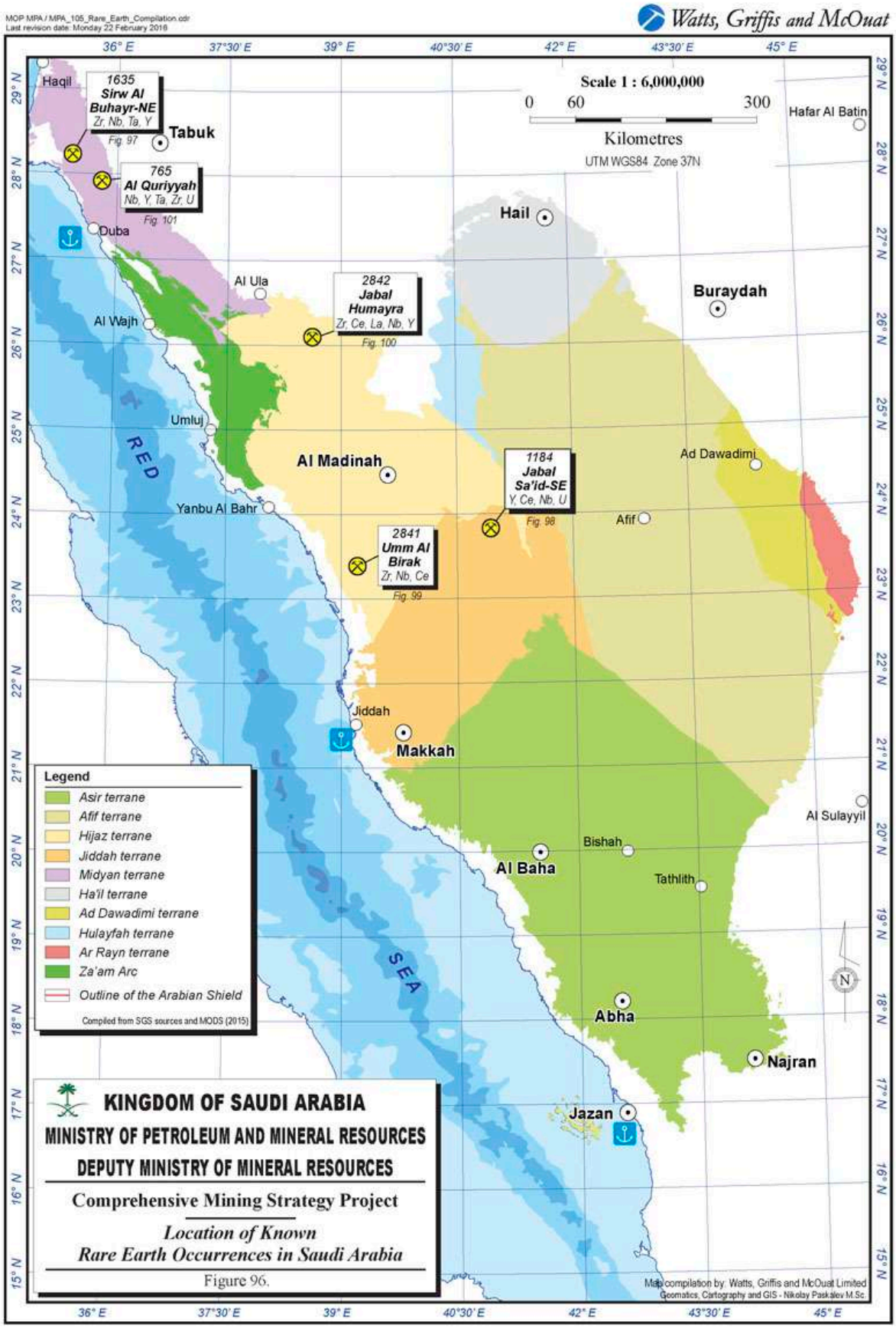
According to Drysdall et al (1984), it is possible to distinguish two basic types of mineralization hosted in felsic plutons that may be economically significant.

1) The first type is hydrothermal in origin, related to the introduction of evolved residual fluids enriched in granitophile elements and volatiles. It is distinguished by high Fe_{total}:alkali ratios and is potassic rather than sodic. They are represented by the Jabal Sayid-SE (Jabal Sa'id) aplite-pegmatite, the Jabal Humayra (Jabal Hamra) silexite and minor pegmatites associated with alkali granites. The REE concentrations and balances reflect the composition of the evolved fluids.
2) The second type is characterized by major oxide abundances approximating those of typical alkali granites and alteration is generally deuteric and sodic in composition. They are represented by the Sirw Al Buhayr-NE (Jabal Tawlah) and Umm al Birak intrusions. The Al Quriyyah (Ghurayyah) Deposit, within which REEs are a relatively minor component, also occurs in a sodic alkali granite. In this model, the total REE contents in the mineralization are thought to be determined by the REE concentrations in the parent magma and the degree to which fractionation occurs during emplacement.

The mineralized granites show chondrite-normalized REE patterns with pronounced negative Eu anomalies, however, the overall patterns are quite different from one to another. Well fractionated REE trends with negative slopes showing lower HREEs than LREEs are noted for Jabal Humayra and the Umm al Birak microgranites. The REE trendline for Al Quriyyah is U-shaped and asymmetrical. Sirw Al Buhayr's trend shows strong enrichment in HREEs and a pattern that is broken only by the negative Eu anomaly.

The locations of the major REE prospects/deposits in the KSA is shown in Figure 96.

The mineral resources of most of the Saudi deposits range from approximately 6.4 and 6.6 Mt in the case of Sirw Al Buhayr and Umm al Birak, respectively, to about 18 Mt and 23 Mt in the Jabal Humayra and Jabal Sayid deposits. The largest is the 440 Mt Al Quriyyah deposit. Sirw Al Buhayr has the highest average grades for niobium (3,400 ppm), yttrium (5,200 ppm), zirconium (37,000 ppm) and tin (380 ppm). Ghurayyah contains the highest average tantalum grades at 200 ppm, and Jabal Sa'id carries the highest average thorium contents (830 ppm, respectively). Jabal Humayra is relatively enriched in LREEs with 2,600 ppm La and 3,400 ppm Ce. LREEs are also irregularly enriched at Jabal Sa'id which carries 600 ppm La and 1,300 ppm Ce. Strong HREE and Y enrichment occurs at Sirw Al Buhayr, Al Quriyyah and Jabal Sayid. Nb is present in columbite-tantalite or pyrochlore. REEs are concentrated in monazite, bastnäesite and synchysite. Thorium is present in thorite and allanite, and zircon is abundant in all the deposits.


MOP MPA / MPA_105_Rare_Earth_Compilation.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
Scale 1 : 6,000,000
0 60 300
Kilometres
UTM WGS84 Zone 37N
1635 Sirw Al Buhayr-NE Zr, Nb, Ta, Y Fig. 97
765 Al Quriyyah Nb, Y, Ta, Zr, U Fig. 101
2842 Jabal Humayra Zr, Ce, La, Nb, Y Fig. 100
1184 Jabal Sa'id-SE Y, Ce, Nb, U Fig. 98
2841 Umm Al Birak Zr, Nb, Ce Fig. 99
Haqil
Tabuk
Duba
Al Ula
Al Wajh
Umluj
Yanbu Al Bahr
Hail
Buraydah
Al Madinah
Ad Dawadimi
Afif
Hafar Al Batin
Jiddah
Makkah
Al Sulayyil
Bishah
Al Baha
Tathlith
Abha
Najran
Jazan
RED SEA
Legend
Asir terrane
Afif terrane
Hijaz terrane
Jiddah terrane
Midyan terrane
Ha'il terrane
Ad Dawadimi terrane
Hulayfah terrane
Ar Rayn terrane
Za'am Arc
Outline of the Arabian Shield
Compiled from SGS sources and MODS (2015)
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Location of Known Rare Earth Occurrences in Saudi Arabia
Figure 96.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
36° E 37°30' E 39° E 40°30' E 42° E 43°30' E 45° E
29° N 28° N 27° N 26° N 25° N 24° N 23° N 22° N 21° N 20° N 19° N 18° N 17° N 16° N 15° N

3.4.3.2 Prospects and Deposits

Sirw Al Buhayr (MODS 1635 – formerly Jabal Tawlah)

The Sirw Al Buhayr REE-enriched granite was discovered in 1964 as a result of its highly radioactive thorium-bearing alkali microgranite. A prospecting program specifically designed to locate further mineralization of this type within an area centered on the original discovery started in 1977. Data from airborne magnetometer-scintillometer surveys in 1962 and 1965-66 were reinterpreted by the DGMR and WGM (Drysdall and Douch, 1986). Follow-up geological mapping, geochemical sampling and ground spectrometer surveying was completed by WGM which identified a prominent radiometric anomaly centered on Sirw Al Buhayr. Additional exploration resulted in the discovery of a felsic intrusion with disseminated mineralization thought to be similar to that of Al Quriyyah (WGM-Lalande 1978). Three inclined diamond drill holes, JT 1, 2 and 3 with an aggregate length of 636 m were completed at that time.

Based on surface mapping and sampling data, the three holes drilled by WGM and 45 drill core samples, Douch and Drysdall (1982) reported resources totalling 6.4 Mt to a depth of 65 m below surface. The average grade was estimated at 3,405 ppm Nb, 175 ppm Ta, 381 ppm Sn, 5,216 ppm Y, >20,000 ppm Zr, 693 ppm Th and 4,747 ppm Zn. Most REE grades were not reported, but average Ce and La were low at 137 ppm and 19 ppm, respectively. "Extreme enrichment" in HREEs was noted. The resources do not comply with any existing regulatory standard and must be considered hypothetical. Recent drilling carried out by the SGS comprised six diamond cored holes totalling 1,500.4 m that generated 1,091 samples. The first four holes failed to intersect mineralization exceeding 1% total REE content although many samples assayed above 5,000 ppm. The last two holes, JTAW-C005 and 'C006 intersected multiple zones exceeding 1% combined REEs (Table 72). The results align with earlier data. At this time, WGM lacks sufficient information to determine whether these results enlarge the mineralized zone or merely confirm what is inferred from previous drilling. The enrichment in HREEs is interesting as are the tantalum and zirconium values, and these distinguish this prospect from others in the Kingdom.

Table 72
Summary of Selected SGS Drilling at Sirw Al Buhayr (Jabal Tawlah)

Hole	From	To	Width	LREE	HREE+Y	REE_{TOT}	Nb	Ta	Zr	Th
	(metres)			---------- (ppm) ----------						
JTAW-C005	12.15	12.85	0.7	2,457	11,731	14,188	1,533	134	5,203	25
	23.15	31.15	8.0	55	13,371	13,426	4,217	214	18,961	1,729
	35.15	37.15	2.0	47	15,369	15,416	2,644	167	12,892	1,023
	39.15	47.15	8.0	32	12,103	12,134	4,387	244	22,238	1,098
	59.3	60.3	13.0	261	18,839	19,100	8,816	365	31,653	2,107
JTAW-C006	30.8	31.8	1.0	26	12,835	12,862	3,943	283	32,338	1,307
	38.8	41.8	3.0	38	11,075	11,113	4,202	208	23,602	1,164
	50.8	54.8	4.0	33	9,966	9,999	4,040	210	23,105	1,067
	57	62.2	5.2	186	12,981	13,167	6,066	257	23,362	1,601
	67.2	71.2	4.0	269	15,846	16,115	2,259	108	25,907	1,110

WGM met with SGS geologists in Jeddah and was informed that a new resource estimate had been made based on the recent drilling at Sirw Al Buhayr (Jabal Tawlah). While this estimate at a US $30.00 per kilogram REE cut-off was not considered as compliant with international standards, it was thought to be indicative of the resource potential of the granite. The SGS estimated that the deposit contained 8.1 Mt averaging 0.02% LREEs, 0.58% HREEs + Y_2O_3, 0.29% Nb_2O_5, 156 ppm Ta, 1.2% ZrO, 619 ppm Th and 278 ppm Sn.

The Sirw Al Buhayr deposit occurs in a composite leucocratic microgranite and microsyenite-albite sill that has a maximum thickness of 50-80 m and a strike length of 320 m (Figure 97). The body dips 45-50° SSW. Located only 5 km southeast of the Jabal az Zuhd alkali granite complex, the sill intrudes greenschist grade metavolcanic and metasedimentary rocks. It is itself intruded by dikes of calc-alkaline granite, typically biotite monzogranite-diorite and basalt.

The microgranite comprising the upper parts of the sill contains quartz bodies, possibly due to silicification, separated by felted albite replacements and granular microcline with minor sericite. Cataclastic textures are common throughout. This fracturing may have allowed for pervasive porphyry-style mineralization. Zircon forms up to 5% of the rock volume, sometimes with sphalerite. Fe-oxides are common. The trace element and REE composition of the Sirw Al Buhayr microgranite and microsyenite are shown in Table 73 (Drysdall and Douch).

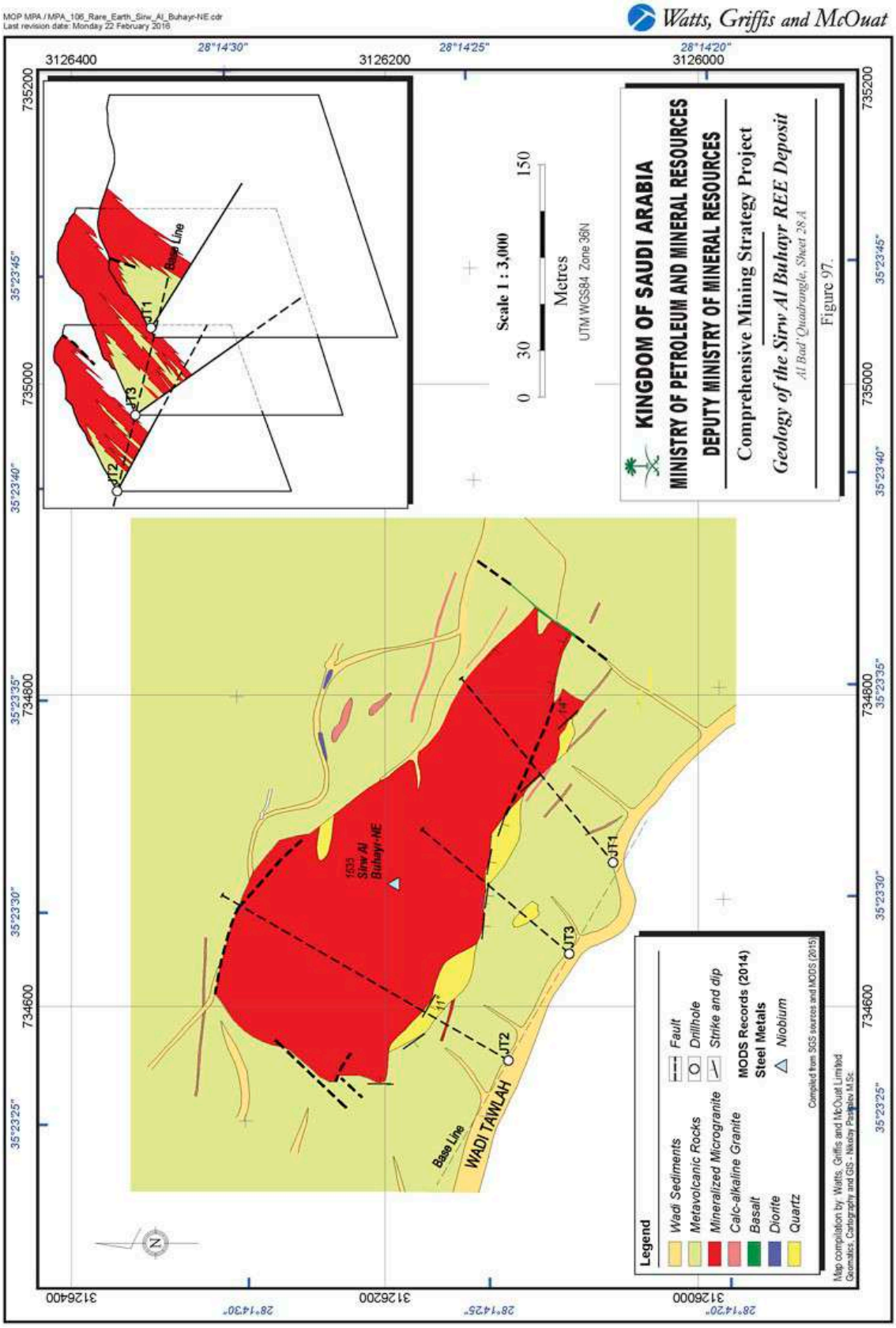
Table 73
Average trace Element and REE Compositions for Jabal Tawlah Granites

Element	Microgranite	Microsyenite
Trace Elements (in ppm except for F)		
Nb	1,110	3,266
Ta	312	148
Th	823	559
F	1.02%	0.96%
Zn	7,968	6,460
Zr	31,800	15,790
Rare-earth elements (in ppm)		
La	4.0	16
Ce	30	43
Pr	2.0	5.1
Nd	12	19
Sm	24	48
Eu	1.4	2.2
Gd	89	132
Dy	607	910
Ho	178	264
Er	699	996
Yb	991	1,066
Lu	135	134
Y	4,638	10,921

The main economically interesting metals at Sirw Al Buhayr include Nb, Ta, Sn, Y, Th, and Zr. Visually, the major minerals are zircon, pyrochlore and lesser sphalerite and cassiterite. Microprobe analysis identified four Y- and/or HREE-bearing minerals: gagarinite [$NaCaY(F,C1)_6$], fergusonite $(Y,Er,Ce,Fe)(Nb,Ta,Ti)O_4$, xenotime ($YPO_4$) and yttrian fluorite $(Ca,Y)(F,O)_2$. Gagarinite, a F-rich mineral containing 22.3% to 32.3% Y, is present as small white crystals in places intergrown with yttrian fluorite and feldspar. Xenotime, which at Jabal Tawlah resembles zircon, contains 36% to 41% Y, and rare fergusonite containing approximately 29% Nb and 18% Y. White yttrian fluorite, present in veinlets, was found to contain 15% Y. The predominant Nb-bearing mineral is columbite which contains about 56% Nb. The principal Th-bearing mineral is dark red-brown thorite. Jabal Tawlah zircons contain relatively high percentages of HfO_2 and lower than average contents of Y_2O_3.

Jabal az Zuhd, the nearest plutonic complex situated 5 km to the NW, consists predominantly of coarse-grained alkali granite, but includes large rafts of finer-grained aegirine augite-arfvedsonite microgranite characterized by numerous small patches with pegmatitic, graphic and miarolitic textures. It is possible that it and the Sirw Al Buhayr sill are genetically related which potentially offers a larger exploration target than Tawlah alone.

Of the intrusions studied in detail, only Sirw Al Buhayr, Jabal Sayid and Al Quriyyah are significantly enriched in HREEs. According to Drysdall and Douch, the normalized profile for Sirw Al Buhayr shows an unusual steep positive slope reflecting extreme enrichment in HREE and depletion in LREE, a feature also seen at Jabal Sayid and to a lesser extent at Al Quriyyah. Sirw Al Buhayr is viewed by WGM as being one of the more interesting deposits from the standpoint of both exploration potential and economic viability given its REE budget. Additional systematic diamond core drilling is needed to fully investigate this deposit.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Geology of the Sirw Al Buhayr REE Deposit
Al Bat'Quadrangle, Sheet 28.A
Figure 97.
Scale 1 : 3,000
0 30 150
Metres
UTM WGS84 Zone 36N
Base Line
JT1
JT2
JT3
WADI TAWLAH
105 Sirw Al Buhayr-NE
Legend
Wadi Sediments
Metavolcanic Rocks
Mineralized Microgranite
Calc-alkaline Granite
Basalt
Diorite
Quartz
Fault
Drillhole
Strike and dip
MODS Records (2014)
Steel Metals
Niobium
Compiled from SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pasgalev M.Sc
3126400
3126200
3126000
735200
735000
734800
734600
28°14'30"
28°14'25"
28°14'20"
35°23'45"
35°23'40"
35°23'35"
35°23'30"
35°23'25"

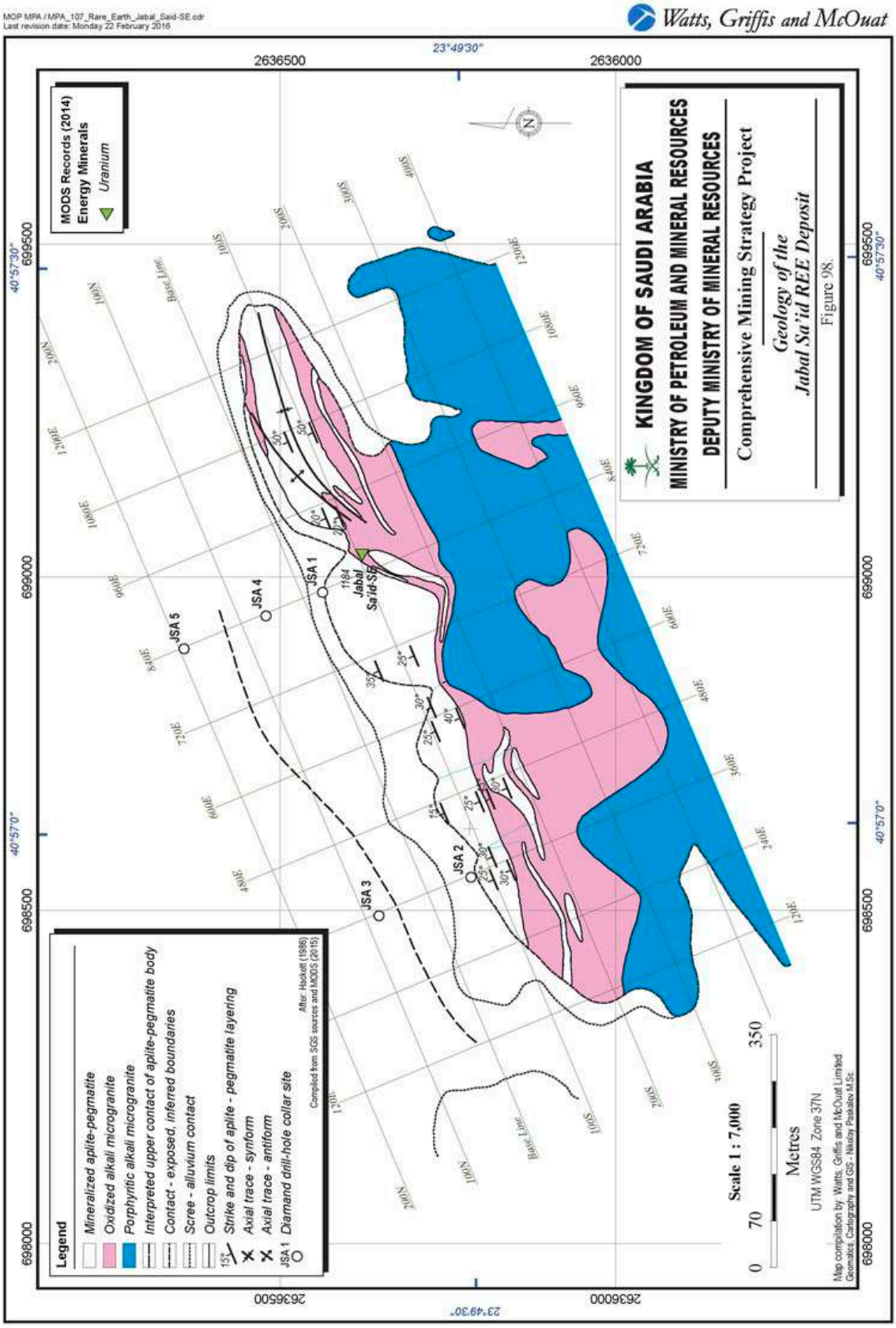
Jabal Sayid (MODS 1184 – formerly Jabal Sa'id)

Mineralization at Jabal Sayid occurs in an aplite-pegmatite zone which locally is prominently layered and as much as 150 m thick (Figure 98). The host rocks extend 2.4 km along the northern flank of the Ash Sharar alkalic complex. REE minerals are concentrated in the apical area of the complex within the contact zone between altered alkali microgranite and metavolcanic country rocks. The microgranite contains bipyramidal quartz phenocrysts up to 3 mm in size. The matrix is albite, microcline, quartz, acicular aegirine, and irregular prismatic crystals of riebeckitic arfvedsonite sieved with small laths of albite and granules of hematite. The host rocks are mainly quartz-microcline-albite aplite, but layers and pockets of quartz-microcline pegmatite are also present. These rocks locally occur in outcrop where they contain an oxidized pyribole and/or fluorite. Emplacement of the Jabal Sayid rocks appears to have been somewhat passive as evidenced by a general lack of fracturing and brecciation.

To a depth of only 100 m, the Mineral Resources at Jabal Sayid are reportedly 23 Mt with an average grade of 4,151 ppm Y, >17,000 ppm Zr, 1,301 ppm Ce, 587 ppm La, 1,290 ppm Nb, 199 ppm Sn and 82 ppm Ta. Thorium content is relatively high at 834 ppm. Mineralization occurs as disseminated zircon, thorite, bastnäesite, synchysite-(Y), monazite, thorian uraninite, pyrochlore, ilmenorutile, anatase, brookite and sphalerite. A marked decrease in grade is present down the dip of the internal banded structure of the aplite-pegmatite zone.

The REE mineralization at Jabal Sayid is contained within a distinctive and well-defined lithological unit: the aplite-pegmatite zone. This is clearly a plus from the standpoint of developing a geological model that is easily recognized in the field. The source of the mineralization is thought to be from hydrothermal fluids circulating in fracture systems within the granite. These fluids were responsible for the observed alteration as well as enrichment in Fe_2O_3 and depletion of Al_2O_3 and Na_2O. Those same fluids were segregated into the residual magmas that formed the pegmatite. The fact that grades appears to be decreasing with depth is a negative, however this interpretation was based on only two drill holes and 84 drill core samples and so this conclusion must be considered as very tentative.

As a REE project, the Jabal Sayid deposit offers several advantages over Al Quriyyah and some other deposits. Firstly, it is less dependent on Nb and Ta because it contains significantly higher REE, Y and Zr values. To this extent, the aplite-pegmatite zone is a well defined geological target. Its radiometric profile is also higher than most granites and this may allow rapid areal assessment for targets that are similar to Jabal Sayid. This deposit is favoured by WGM as one of the more economically interesting rare earth projects which is relatively under-explored. Clearly a systematic drilling program is needed.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Last revision date: Monday 22 February 2016
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Comprehensive Mining Strategy Project
Geology of the
Jabal Sa'id REE Deposit
Figure 98.
MODS Records (2014)
Energy Minerals
Uranium
Legend
Mineralized aplite-pegmatite
Oxidized alkali microgranite
Porphyritic alkali microgranite
Interpreted upper contact of aplite-pegmatite body
Contact - exposed, inferred boundaries
Scree - alluvium contact
Outcrop limits
Strike and dip of aplite - pegmatite layering
Axial trace - synform
Axial trace - antiform
JSA 1 Diamond drill-hole collar site
After Hackett (1986)
Compiled from SGS sources and MODS (2015)
JSA 1
JSA 2
JSA 3
JSA 4
JSA 5
1184
Jabal
Sa'id-SE
Scale 1 : 7,000
0 70 350
Metres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc
2636500
2636000
23°49'30"
40°57'30"
699500
699000
698500
698000
40°57'0"

Umm al Birak (MODS 2841)

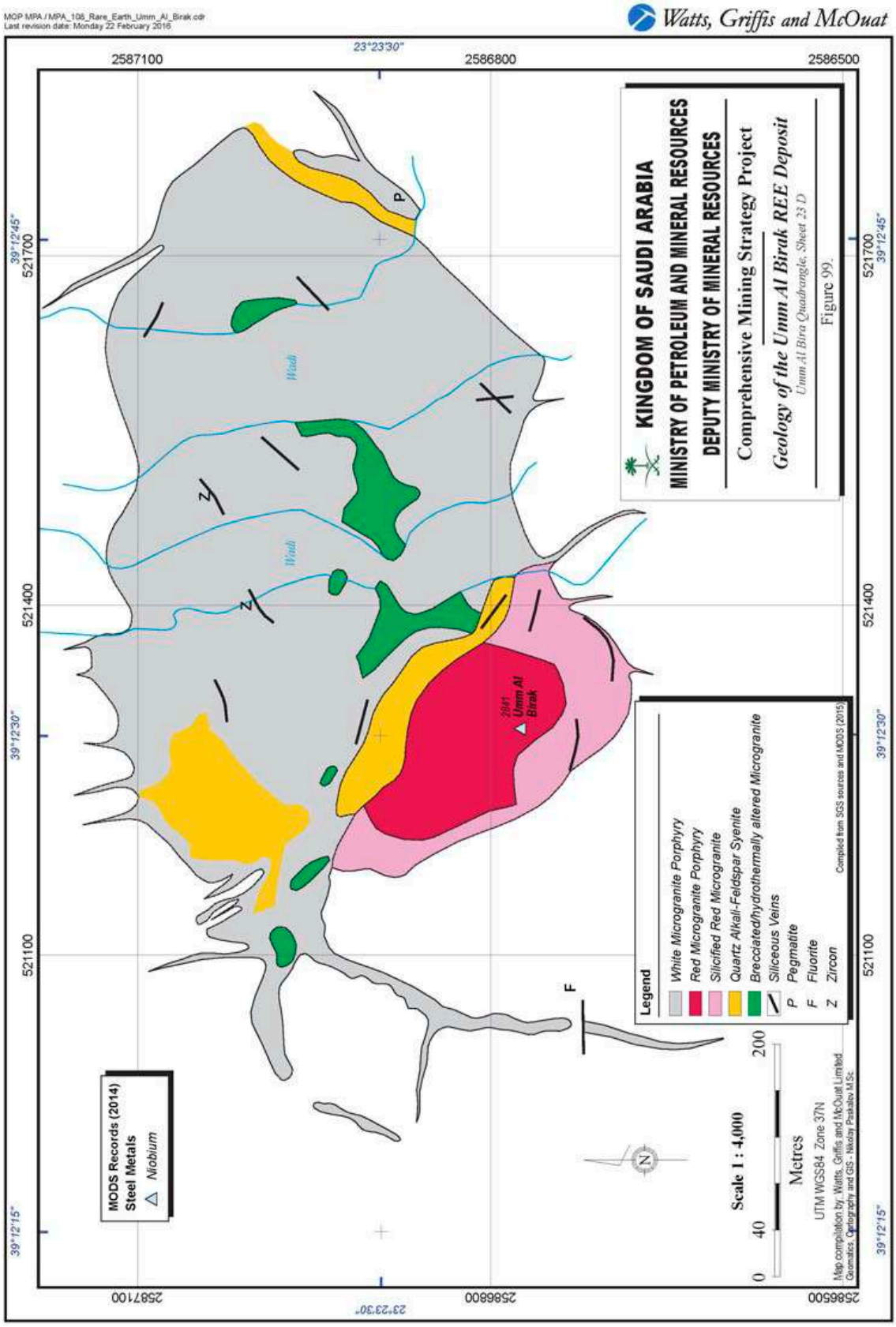
The microgranite stock that hosts the Umm al Birak prospect measures approximately 700 m by 400 m (Figure 99). The pluton was emplaced into metavolcanic rocks about 10 km east of the Jabal Subh and Ulub alkali granites to which it may be genetically related. The rocks at Umm al Birak include porphyritic aegirine arfvedsonite microgranite, similar to that found at Jabal Sayid. It is aplitic and potassic in composition, carrying biotite as well as phenocrysts of quartz and alkali feldspar. The matrix contains albite, microcline, aegirine and arfvedsonite (or biotite). Accessory zircon, fluorite and opaque minerals are common. Forceful injection of the pluton is indicated by brecciation of its margins and evidence of marginal flow foliations. The stress related to emplacement may have induced sufficient permeability to have allowed for pervasive mineralization over large areas, an important consideration to be investigated with a future drilling program.

Based solely on 30 surface samples, the mineral resources at Umm al Birak were estimated to total 6.6 Mt to a depth of 150 m. The average grade of this resource is 5,129 ppm Zr, 1,663 ppm Nb, 121 ppm Ta, 800 ppm Ce, 371 ppm La, 311 ppm Y and 46 ppm Th. Given the complete lack of drilling at the time of and in support of the resource estimate, there is no possibility that this estimate complies with existing regulatory guidelines or best practices standards. The mineralization comprises disseminated Nb, Ta, Sn, REE, Y, Th and Zr minerals such as zircon, monazite, bastnäesite, pyrochlore, scheelite, thorite and chalcopyrite. While all rocks are to some degree mineralized, the highest grades are found within a biotite-bearing phase of the intrusion.

Recent work by the SGS has included 8 surface samples and 9 diamond drill holes (2,141 m). Surface samples averaged 2,009 ppm LREEs and 598 ppm HREEs plus yttrium for a average total REE content of 2,607 ppm. Average niobium and tantalum contents were 939 ppm and 51 ppm respectively. Zirconium contents averaged 3,373 ppm. thorium content was 50 ppm, respectively. These results were generally in line with previously reported assays. Most of the SGS drill holes intersected zones of mineralization exceeding 1% combined rare earth metals + yttrium as summarized in Table 74. The grades are somewhat higher than indicated from previous surface sampling, and some of the widths are substantial, for example in hole C005. Although total REE contents are somewhat comparable to Sirw Al Buhayr (Jabal Tawlah), the balance of rare earths at Umm al Birak favours the light rare earths. Zirconium and niobium contents are also lower, however some strong enrichment in tantalum is seen in holes C001 and C002.

During a meeting with SGS geologists in Jeddah, WGM was informed that a new resource estimate had been made based on the recent drilling. While this estimate at a US $30.00 per kilogram REE cut-off was not considered as compliant with international standards, it was thought to be indicative of the resource potential of the granite. The SGS estimated that the deposit contained 6.3 Mt averaging 4,189 ppm LREEs, 1,803 ppm HREEs, 1,129 ppm Y, 1,643 ppm Nb, 75 ppm Ta and 5,414 ppm Zr (personal communication).

Figure 99: Geology of the Umm al Birak REE Deposit



The earlier exploration suggested that the Umm al Birak intrusion had similarities with Al Quriyyah in that it is relatively lower grade and more or less mineralized across all rock types. In nearly all respects the grades based solely on surface sampling were lower than Al Quriyyah although Umm al Birak is significantly richer in Ce (800 ppm versus 144 ppm). Unfortunately, the deposit is very small and the distribution of REEs favours the lower valued LREEs, and this has been reinforced with the recent drilling. Despite local enrichments seen in drill core samples, the associated metals including niobium and tantalum are of insufficient concentration to be economically recoverable. Although the deposit is not drilled off, WGM believes that the exploration for REE in the Kingdom is better served by other HREE-rich targets such as Sirw Al Buhayr.

Table 74
Summary of Selected SGS Drilling at Umm al Birak

Hole	From	To	Width	LREE	HREE+Y	REE_{TOT}	Nb	Ta	Zr	Th
	(metres)			(ppm)						
UBR-CO01	11.95	12.20	0.25	108,237	2,924	111,161	6,212	634	47	1,077
	214.40	215.40	1.00	8,632	1,520	10,152	1,957	835	73	73
UBR-CO02	105.70	106.90	1.20	7,722	2,768	10,490	20,784	2,223	75	425
	153.00	154.00	1.00	10,211	2,140	12,351	4,811	1,611	75	598
	161.50	162.50	1.00	10,688	5,880	16,568	9,733	1,353	114	104
UBR-CO03	41.10	41.60	0.50	13,692	5,591	19,283	1,342	39	9,394	229
	153.00	154.00	1.00	22,429	1,975	24,404	2,935	237	5,017	115
	227.00	230.00	3.00	10,576	1,554	12,130	1,287	69	748	75
UBR-CO04	157.20	158.40	1.20	28,032	4,809	32,841	2,242	73	13,426	1,276
UBR-CO05	76.00	77.00	1.00	8,640	4,114	12,754	232	1	6,909	179
	173.65	185.20	11.55	8,069	3,913	11,982	44	<5	1,048	80
UBR-CO06	183.65	184.65	1.00	32,026	4,462	36,488	1,989	135	4,579	846
	221.80	228.80	7.00	9,173	2,430	11,603	1,390	108	703	224
UBR-CO08	46.35	47.35	1.00	11,081	3,948	15,029	750	6	11,843	261
	57.00	58.00	1.00	10,565	5,308	15,873	963	61	1,852	140
	162.15	163.00	0.85	21,490	16,393	37,883	1,345	37	5,695	141
UBR-CO09	114.50	115.50	1.00	12,809	6,181	18,990	308	<1	7,582	324

Jabal Humayra (MODS 2842 – formerly Hamra)

The Jabal Humayra REE mineralization was first studied during the early 1980 by the USGS. A collection of samples was analysed top characterize the geochemical nature of the host granite and the composition of the mineralization (Douch and Jackson,1983, 1986). The Jabal Humayra REE mineralization is hosted within an epizonal intrusive complex consisting of alkali feldspar granite and alkali feldspar syenite. The granites were emplaced into metavolcanic and metasedimentary rocks of the Matran Formation as shown

in Figure 100. The rocks of the two plutons are chemically indistinguishable - both are enriched in Th, Nb, Y, Ta, Hf, Zr and REEs (Qadha, 2007). The quartz syenite pluton, which accounts for the greatest part of Jabal Humayra, is a 1.3 km by 5 km, north-trending body that has a relief of about 250 m above the wadi level. It is situated 4 km east of the Jabal Aba ad Dud alkali granites to which it is thought to be genetically related. Chemically, the rocks are metaluminous to peralkaline. The rocks are massive and fine to medium-grained, and are relatively homogenous compared to other REE-bearing alkalic granites. The pluton is reported to be anomalously radioactive throughout with total count rates between 1000 and 3000 c.p.s, measured on a DISA 400A differential spectrometer (Jackson and Douch, 1986).

Based solely on the analysis of bedrock samples, the USGS estimated that the mineralization in the Jabal Humayra silexite totalled 9.74 Mt averaging in excess of 6,000 ppm REE_{total} (Douch and Jackson, 1983, 1986). A second estimate, which appears more recently in a presentation by Monitor Company Group LP (2010) is based on the same suite of 30 samples and indicates that the deposit contains 17.9 Mt of mineralization at the same grade as reported previously: 13,267 ppm (1.3%) Zr, 2,593 ppm La, 3,432 ppm Ce and 1,592 ppm Y. The Nb content is 1,731 ppm while Ta averages 146 ppm. thorium is 263 ppm, respectively. On the basis of the REE contents in original samples, Jabal Humayra has the highest grades of the four best-known REE deposits in the Kingdom in respect to the LREEs, and it contains the second highest Y and Zr grades together with modest Nb and Ta. These resource estimates are based solely on surface samples and neither are thought to be supportable in any real sense. The estimates should probably be considered as simply "blue-sky potential" to be realized is all exploration variables render positive results. More recent work by the SGS resulted in the drilling of 9 diamond drill holes totalling 2,089 m. Only four of the holes intersected zones containing more than 1% combined REEs (Table 75). In the remaining five drill holes, the 1st and 8th holes contained few samples that exceeded 1,000 ppm total REEs. No sample in the 2nd or second hole exceeded 260 ppm. The 4th hole contained a range of values, mostly between 500 ppm and 2,000 ppm with a maximum assay of 3,303 ppm. The 7th hole contained wide intervals between 1,000 and 3,000 ppm which may be the tail of one of the zones reported in the following table.

Table 75
Summary of Selected SGS Drilling at Jabal Humayra (formerly Al Hamra)

Hole	From	To	Width	LREE	HREE+Y	REE_{TOT}	Nb	Ta	Zr	Th
	(metres)			(ppm)						
JHR-CO03	193.45	206.45	13.00	11555	2733	14288	3415	150	10887	496
	217.25	219.05	1.80	9315	2133	11448	4096	146	11263	405
	225.75	232.90	7.15	10278	2557	12835	2715	135	9906	357
JHR-CO05	37.60	38.45	0.85	7488	2783	10271	2260	151	22845	209
	127.40	134.10	6.70	11899	2991	14889	3008	144	14603	1077
JHR-CO06	138.75	165.90	27.15	9532	2120	11652	3781	112	8694	549
	222.90	232.00	9.10	10632	2417	13049	2404	105	8481	538
JHR-CO09	218.40	219.30	0.90	7622	2468	10090	2052	110	9231	732

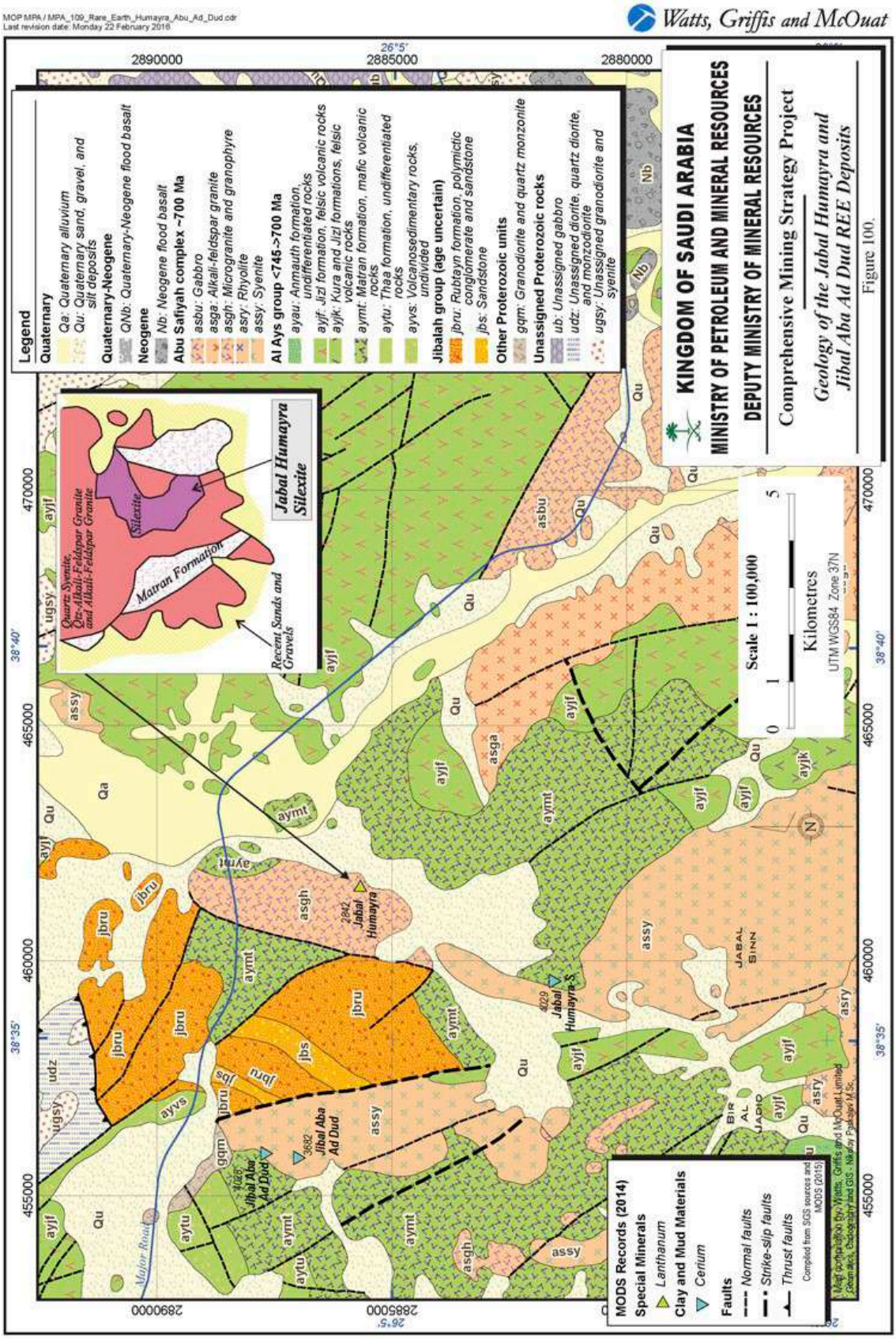
On the basis of its new drilling, the SGS estimated that the Jabal Humayra deposit contained 16.1 Mt with an average grade of 0.63% LREOs, 0.19% HREOs, 0.12% Y_2O_3, 0.21% Nb, 0.01% Ta_2O_5, 1.10% ZrO_2. This estimate, like the other SGS estimates, is based on too little data to be compliant with existing regulatory standards, however the composition does parallel previous estimates of the make-up of this deposit.

Most of the Jabal Humayra (Jabal Hamra) pluton consists of reddish quartz alkali-feldspar syenite. Although coarse grained, alkali-feldspar granite predominates in the northern part, some phases of the syenite in the south show a variable degree of deformation and hydrothermal alteration. The geochemistry of the rocks is shown in Table 76.

Table 76
Trace and Rare Earth Element Composition of Al Humayra Rocks

Element (metal)	Silexite			Quartz-Alkali Feldspar Granite	Alkali-Feldspar Granite		Pegmatite
	(all values reported in ppm)						
Trace Elements							
Nb	1,659	5,055	856	55	54	238	501
Pb	399	(300) [1]	(20)	(<I0)	(<I0)	(<I0)	(20)
Sn[2]	(I00)	294	92	15	18	39	13
Ta[2]	-	315	77	-	-	-	-
Th[2]	-	522	153	5	I0	30	47
Zn	789	1,288	185	-	-	-	-
Zr	15,597	15,250	7,350	239	249	2,379	3,947
Rare-earth elements [3]							
La	2,000	4,098	946	31	26	207	365
Ce	3,922	8,588	2,271	77	65	487	867
Pr	560	758	160	11	-	45	64
Nd	1,535	2,796	767	46	-	206	304
Sm	287	530	153	I0	-	44	64
Eu	33	54	17	0.9	-	5.3	9.2
Gd	240	442	129	8	-	41	62
Dy	212	382	107	7	-	45	62
Ho	47	65	22	I	-	9	14
Er	126	192	66	4	-	31	42
Yb	96	141	55	4	-	28	38
Lu	13	18	8	0.6	-	4	5
Y	1,581	1,749	479	13	14	126	387

NOTES:
1 analytical data in parentheses () is semi-quantitative.
2 analytical determinations are by XRF.
3 analytical determinations for REEs and trace elements are by ICP.


MOP MPA / MPA_109_Rare_Earth_Humayra_Abu_Ad_Dud.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Jabal Humayra and Jibal Aba Ad Dud REE Deposits
Figure 100.
Legend
Quaternary
Qa: Quaternary alluvium
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Neogene
Nb: Neogene flood basalt
Abu Safiyah complex ~700 Ma
asbu: Gabbro
asga: Alkali-feldspar granite
asgh: Microgranite and granophyre
asry: Rhyolite
assy: Syenite
Al Ays group <745->700 Ma
ayau: Anmauth formation, undifferentiated rocks
ayjf: Jizl formation, felsic volcanic rocks
ayjk: Kura and Jizl formations, felsic volcanic rocks
aymt: Matran formation, mafic volcanic rocks
aytu: Thaa formation, undifferentiated rocks
ayvs: Volcanosedimentary rocks, undivided
Jibalah group (age uncertain)
jbru: Rubtayn formation, polymictic conglomerate and sandstone
jbs: Sandstone
Other Proterozoic units
ggm: Granodiorite and quartz monzonite
Unassigned Proterozoic rocks
ub: Unassigned gabbro
udz: Unassigned diorite, quartz diorite, and monzodiorite
ugsy: Unassigned granodiorite and syenite
Jabal Humayra Silexite
Quartz Syenite, Qtz-Alkali-Feldspar Granite and Alkali-Feldspar Granite
Silexite
Matran Formation
Recent Sands and Gravels
Scale 1 : 100,000
Kilometres
UTM WGS84 Zone 37N
MODS Records (2014)
Special Minerals
Lanthanum
Clay and Mud Materials
Cerium
Faults
Normal faults
Strike-slip faults
Thrust faults
Compiled from SGS sources and MODS (2015)
Jabal Humayra
Jabal Humayra S.
Jibal Aba Ad Dud
Major Road
JABAL SINN
BIR AL JADID
2890000
2885000
2880000
455000
460000
465000
470000
38°35'
38°40'
26°5'

The granite has undergone pervasive cataclasis and is silicified to the extent that it resembles a porphyritic rhyolite. These rocks form the Jabal Humayra silexite, the most important host to mineralization, a crescent-shaped zone 300 m long and 100 m wide rising 160 m above the level of the local wadi. Contacts with the quartz alkali-feldspar syenite are strongly sheared and brecciated. Fractured phenocrysts of quartz and rarer microcline occur in a fine-grained matrix of secondary quartz with scattered quartz fragments and pseudomorphed remnants of original feldspar and ferromagnesian minerals. Quartz forms elongated interstitial masses up to 1 cm long, and small, anhedral crystals distributed along feldspar boundaries. Minor minerals include opaque oxides or pyrite and secondary sericite, carbonate and epidote. Iron oxides are present throughout as irregular-shaped masses or are finely disseminated.

The pluton has very low CaO, TiO_2, MgO, FeO and MnO contents. Mineralization occurs in highly altered, fracture-controlled zones along the margins of the granites. The altered rocks are characterized by higher TiO_2, Fe_2O_3, SiO_2 and lower Al_2O_3, CaO, Na_2O than the unaltered rocks. Mineralization occurs as disseminated Nb, Ta, Sn, REE, Y, Th and Zr minerals, predominantly as monazite and bastnäesite comprising 1-2% of the silexite, with lesser uraninite and pyrochlore. Accessory minerals include zircon, fluorite and allanite. As shown in the previous table, a wide range is noted in total REE contents (804–15,579 ppm) as well as associated metals such as Ta (6–194 ppm), Nb (51-3,483 ppm), Hf (13–368 ppm), Zr (394–14,887 ppm) and Th (16–572 ppm).

Data on the Al Humayra deposit indicates that the altered rocks and the rare metal enrichment are the products of hydrothermal-metasomatic alteration of the quartz alkali feldspar syenite and the alkali feldspar granite. REE mineralization is thought to have been derived through partial melting of depleted crust followed by fractional crystallization of feldspars, ferromagnesian minerals and the evolution of a REE-enriched fluid. The REE-bearing fluid transported these elements as fluoride complexes, and their subsequent deposition was the result of mixing with externally derived Fe-rich fluids which scavenged fluoride and caused REE precipitation.

Douch and Jackson noted that the Humayra silexite is a silicified phase of the quartz-alkali-feldspar granite and that, with increasing SiO_2, it shows an inverse relationship between Na_2O and K_2O as well as between FeO_2 and Al_2O_3. The authors also noted increasing Y, Nb, Zr, Sn and REEs with increasing silicification. On-going crystallization of feldspar through the earlier phases of quartz alkali-feldspar syenite and subsequent alkali-feldspar granite is thought to have resulted in a high-silica magma enriched in volatiles and REEs. Fractures, shears and breccias zones controlled the emplacement of this highly fractionated silexite. LREEs were probably transported as chlorine complexes and these were precipitated and trapped within the silexite in contrast to HREEs which have an affinity for F^-. The relative scarcity of fluorite at Jabal Humayra suggests that the REE-fluorine complexes probably escaped through the roof of the pluton.

The Jabal Humayra silexite is presently the only known example of such mineralization related to a quartz alkali-feldspar syenite precursor. As such, it may represent a unique deposit. If so, then it may not

represent a useful model for REE exploration in the Arabian Shield. However, the silexite is also well mineralized with REEs compared to other evolved granites in the Kingdom. With approximately 0.6% REE_{total}, it would be wrong to dismiss this model as not being useful. In fact, additional exploration is warranted in the Jabal Humayra area to determine if other bodies of silexite are present, however its potential may be impaired by its comparatively low content of HREEs.

Jabal Abu ad Dud

The Jabal Abu ad Dud granite is located situated 4 km west of the Jabal Humayra alkali granites. The two areas thought to be genetically related as both are metaluminous to peralkaline. The Jabal Abu ad Dud pluton forms a north-trending elongated pluton of reddish to brick red, homogenous, medium to coarse-grained alkali-feldspar granite. The level of alteration is similar to that at Jabal Humayra with varying degrees of shearing and deformation, and the oxidation of mafic minerals imparting a reddish brown colouration to the rock. Quartz content ranges from 10% to 30%. Jabal Abu ad Dud shows very similar REE patterns to Jabal Humayra. As at Jabal Humayra, the rocks locally, most prominently in the northern part which is also anomalously radioactive. Two phases of mineralization are recognized, one of which is associated with adularia development.

The SGS recently completed an exploration program at Jabal Abu ad Dud that included litho-geochemical surveying, geological mapping and an 11-hole diamond drilling program totalling 5,666.5 m. Most of the drill holes were in excess of 400 m in length; WGM understands that several holes were abandoned prematurely. The drilling discovered two separate zones, East and West, however in general the assays results were lower than expected. Most of the drill holes intersected total REE + yttrium contents of 100 to 1,000 ppm over wide intervals with maximum values of 1,300 ppm to 5,900 ppm and generally only a few such values per hole. The two best intersections were in holes DOS-CO07 and DOS-CO08, the first producing a 9.8 m section from 259.2-269.0 m that averaged 2,021 ppm total REEs + Y. The second hole produced a 6.15 m section from 26.00 to 33.15 m that averaged 3,826 ppm total REEs + Y. The SGS made separate mineral resource estimates for the two zones as follows *(personal communication)*:

Zone	Tonnes (M)	HREO	LREO	TREO	Nb_2O_5	Ta_2O_5	Y_2O_3
East	81.6	0.11%	0.25%	0.36%	0.06%	40 ppm	0.07%
West	47.7	0.04%	0.11%	0.15%	0.03%	30 ppm	0.03%

Given the drill hole assays reported by the SGS, the grade of the estimated resources seems to be optimistic and is perhaps leveraged on narrow higher grade intervals. There are, however, few intersections that total in excess of 3,600 ppm total REEs after yttrium is removed – only 3 drill holes of the 11 would meet this standard. There seems to be a disconnect between the grades reported in the drill holes and the estimated tonnages that might be present at such grades.

Jabal Libd and Wadi Miryash

The Jabal Libd area (MODS 2797), formerly Libt, is located in the Ranyan granite belt, a collection of approximately 40 late-Proterozoic granites in near the towns of Ranyah, Junaynah and Bishah. Jabal Miryash is separated from Jabal Libd by a narrow wadi approximately 1 km wide. This group of alkaline to peralkaline intrusions is more or less aligned along the Junaynah Fault and cut off by a Najd Fault in the north (Ramsay, 1982). Early regional wadi sediment geochemical surveying by the USGS identified anomalies in various lithophile elements such as Mo, Sn, Be as well as Cu, Pb and Zn. During 1982, a helicopter-borne spectrometer survey with a 500-metre flight line spacing was flown over the Jabal Libd area to assess its REE potential. Anomalies were ranked in accordance with several known prospects including the Umm al Birak and Al Humayra prospects. Four anomalies were identified as high priority: Jabal Libd, Jabal Biyah (2734), Sirat Bishah (1346) and Jabal Dummah (2801). After completing a program of ground follow-up, including 1:20,000 scale geological mapping, prospecting with a scintillometer and bedrock sampling, the DGMR concluded there was little potential for economically interesting mineralization. Based on this initial work, Jabal Libd was found to have a few weak geochemical anomalies (F, Zr, Sn, Li, W, Be, B, Pb, Zn, Ta, Sn, Ce, Y, U, Th and Mo) associated with a number of intrusions. The anomaly at Jabal Biyah was a greisen zone in F-Bi-Li-Sn enriched granite with brannerite-bearing pegmatites and quartz-fluorite veins. The Sirat Bishah and Jabal Dummah granites were found to be aluminous, not the more favourable alkaline variety, and locally enriched in Li, Sn and F. More detailed exploration revealed that Jabal Libd contained radioactive aplite dikes that were enriched in F with Nb contents as high as 704 ppm and up to 2,585 ppm Zr. At the time of WGM's review in 1989-1992, the rocks at Jabal Libd had been analysed for Ce and La, but had not been analysed for many of the more valuable REEs. The Wadi Miryash prospect was not known at that time.

The SGS has recently carried out an exploration program at Jabal Libt to better assess the potential of an area approximately 10 km in length. This work has included detailed geological mapping and complete coverage by lithogeochemical sampling which detected good Nb and Zr anomalies in surface samples. The SGS carried out a follow-up 15-hole (5,343 m) diamond drilling program to test the mineralized zone. This generated 5,363 core samples that were analysed. The drilling resulted in the initial delineation of a narrow albitized structural zone, striking approximately N-S and dipping approximately 45°. The structure is thought to be part of, or related to, the Nabitah Fault Zone. The results of the drilling program are not presently available to WGM.

During the most recent follow-up exploration, the SGS also sampled the Wadi Miryash area and discovered yttrium anomalies. The nature of the follow-up sampling is not known to WGM, however as part of the overall program the SGS drilled 12 diamond drill holes totalling 4,671 m and generating 5,729 samples. WGM reviewed the analytical data files generated from the core samples. Most samples contained between 100 and 600 ppm total REE content plus yttrium. Some holes favoured the lower end of the spectrum at 100-300 ppm and some the higher end 200-600 ppm. Peak values varied from hole to hole, and generally the higher the background values, the higher the maximum REE content in any given hole. Half the holes had peak values that were less than 1,400 ppm. The best mineralized hole was JMR CO09 in which the range of background values was as high as 1,000 ppm and the maximum value was 5,023 ppm. Totalling REEs and Y, the best intersection was 3,820 ppm over 3.0 m.

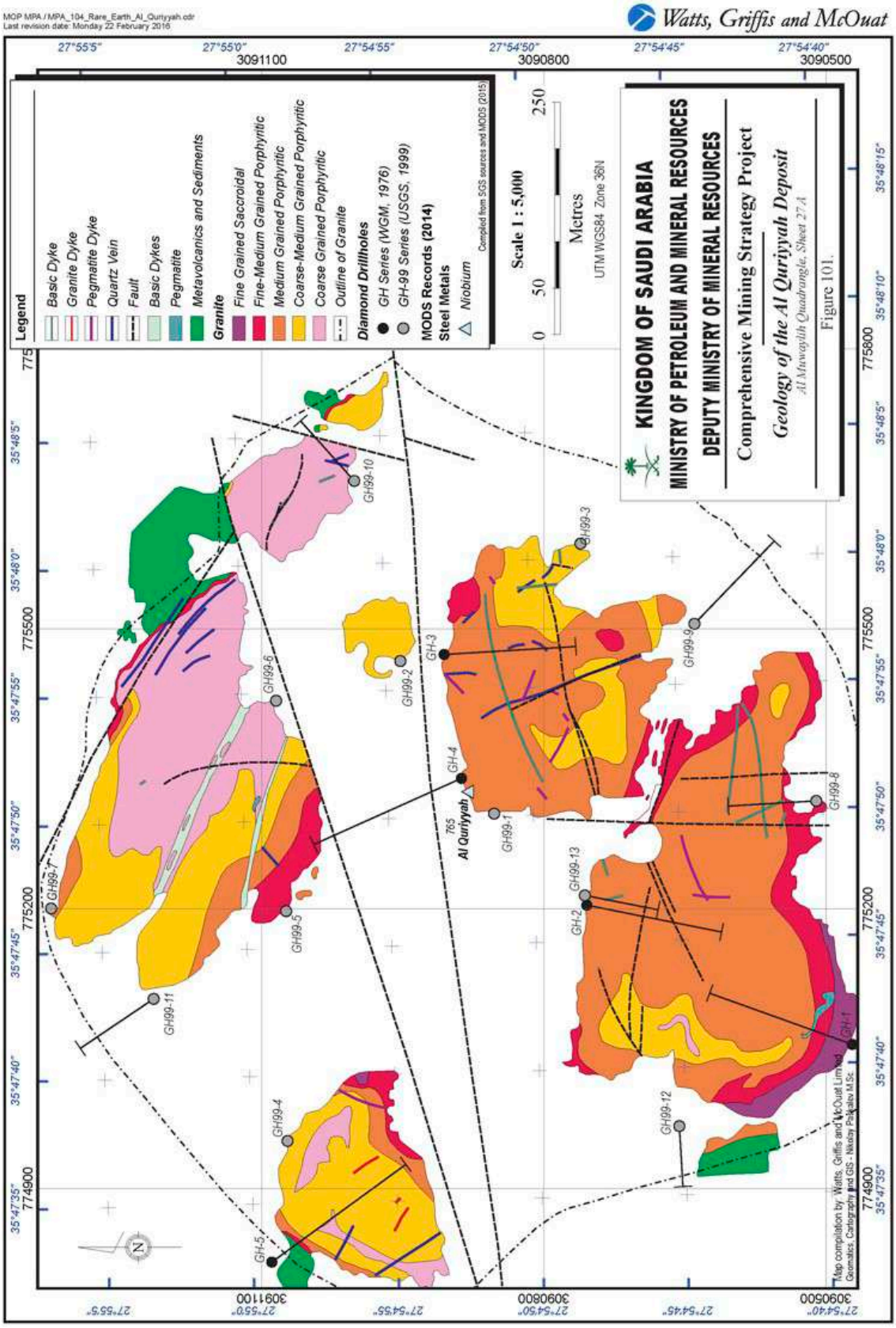
Al Quriyyah (MODS 0765 – also known as Ghurayyah)

The Al Quriyyah deposit is predominantly enriched in Zr (8,915 ppm), Nb (2,840 ppm), Ta (245 ppm) and U (140 ppm). Because of its size, approximately 400 Mt, it does include a very large, very low grade REE (yttrium) resource at 1,270 ppm. It is, however, most of all a zirconium deposit with associated yttrium and niobium and not a rare earth deposit. Al Quriyyah occurs in an alkali microgranite stock which is approximately 900 m in diameter with steeply dipping contacts intruding metavolcanics and metasediments (Figure 101). The Al Quriyyah pluton is situated about 3 km east of the shallowly dipping eastern contact of the Jabal Dabbagh alkali granite complex. The Al Quriyyah wall rocks show little or no alteration. The granite is leucocratic with variable proportions of euhedral phenocrysts of quartz and microcline, both containing laths of albite and laths of sodic amphibole with remnant pyroxene. Mafic minerals are typically chloritized and are enclosed in a matrix of albite laths with minor mica and fluorite in which zircon and other REE-minerals occur as interstitial aggregates of grains, generally less than 1 mm in diameter. Alteration is not strong, perhaps due to Al Quriyyah's passive emplacement and general lack of strong brecciation or cataclasis.

Disseminated Zr, Nb, Y, Ta, Sn, U and Th minerals occur in the rock matrix, and the grade is thought to vary inversely with the proportion and size of phenocrysts. The main economic minerals are zircon, columbite-tantalite, pyrochlore, samarskite, aeschynite-(Y), xenotime, monazite, uraninite, cassiterite, thorite, ilmenorutile, galena, sphalerite, etc. Importantly, the Al Quriyyah deposit, like Sirw Al Buhayr, is enriched in HREEs compared to LREEs, albeit at rather low concentrations.

Tertiary Minerals Plc. refers to Al Quriyyah as "*a world-class deposit containing valuable tantalum, niobium, rare-earths, zirconium and yttrium*". Tertiary's news release places the Mineral Resources at nearly 400 million tonnes grading 245 ppm (0.024%) Ta_2O_5, 2,840 ppm (0.28%) Nb_2O_5, 8,915 ppm (0.89%) ZrO_2 and 1,270 ppm (0.13%) Y_2O_3. For reasons that have not been explained. In referring to the deposit as "world-class", Tertiary has ignored some basic facts:

1) Brazil controls the global niobium market and its deposits are 10X the grade of Al Quriyyah;
2) the Australians mine zirconium beach-sand deposits that are 10X the grade of Al Quriyyah; and,
3) Rwandan tantalum production is 50% of total global supplies currently about 1,200 t/yr from weathered granites that do not require crushing and further processing – cut off grades are approximately 150 ppm which is higher than the average grade of Al Quriyyah. The huge Greenbushes tantalum mine in Australia, currently on care and maintenance has the capacity to produce 1 Mlbs of Ta2O5 per year, so the existing market is considered to be well serviced.


MOP MPA / MPA_104_Rare_Earth_Al_Quriyyah.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
Legend
Basic Dyke
Granite Dyke
Pegmatite Dyke
Quartz Vein
Fault
Basic Dykes
Pegmatite
Metavolcanics and Sediments
Granite
Fine Grained Saccroidal
Fine-Medium Grained Porphyritic
Medium Grained Porphyritic
Coarse-Medium Grained Porphyritic
Coarse Grained Porphyritic
Outline of Granite
Diamond Drillholes
GH Series (WGM, 1976)
GH-99 Series (USGS, 1999)
MODS Records (2014)
Steel Metals
Niobium
Compiled from SGS sources and MODS (2015)
Scale 1 : 5,000
0 50 250
Metres
UTM WGS84 Zone 36N
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Al Quriyyah Deposit
Al Muwayilih Quadrangle, Sheet 27.A
Figure 101.
765
Al Quriyyah
GH-1
GH-2
GH-3
GH-4
GH-5
GH99-1
GH99-2
GH99-3
GH99-4
GH99-5
GH99-6
GH99-7
GH99-8
GH99-9
GH99-10
GH99-11
GH99-12
GH99-13
N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pavlyalev M.Sc.

Initial metallurgical test work supported a scoping study completed in 2003 for the development of the deposit. The study included financial modelling of a number of alternative processing flow sheets using a conceptual mining rate of 1.52 Mt of ore per annum over an initial 20-year mine life. Costs have been estimated to an accuracy of +/- 30%. The four main flow sheets were all economically attractive. It is worth noting that the Ta price in 2003 was approximately US $40/pound versus approximately $55 per pound ($122/kg) for tantalum scrap currently as of the date of this report. Each flowsheet produced pre-tax Internal Rates of Return (IRR) in excess of 25% and Net Present Values (NPV) in the range $55-285 million using discount rates between 10 and 20%. In addition to other studies, including environmental impact assessments, on-going metallurgical test work evaluated the use of hydrometallurgical separation of the metals following flotation and magnetic separation of ore after crushing/grinding. Further processing of niobium into ferro-niobium remains the preferred route for this metal.

At present according to the Tertiary Minerals Plc website, work on the project has been suspended pending the re-issue of an exploration license over the deposit in the names of Tertiary (Middle East) Ltd - a wholly-owned subsidiary of the Company (50%), AH Algosaibi Bros Co (25%), and Al Nahla Trading & Contracting Co (25%). This suspension has been in effect for more than three years.

WGM believes that the uniformity of mineralization in the Al Quriyyah deposit is strong evidence that it is a porphyry-style deposit. The drilling to date has outlined a substantial resource.

Al Quriyyah is often mentioned as a rare metal deposit, however with the exception of yttrium, the REE content is too low to make a significant contribution to project economics. As conceived by Tertiary Minerals at this time, the project relies heavily on Nb and Ta. Since the Tertiary scoping study, the global production of niobium has gone into surplus and production from Al Quriyyah would only contribute further to the supply imbalance. Tantalum fabricators are increasing the use of scrap to satisfy their demands and so the future is difficult to predict for this metal. It is worth noting that the world's consumption of new tantalum metal, excluding secondary sources such as scrap, is approximately 2,000 tonnes per year of which concentrates are approximately 1,200 t. The Greenbushes and Wodgina Mines in Western Australia, operated by Global Advanced Metals, exploit two of the world's largest hard rock tantalum deposits through open cut and underground mining. The combined operation has the capacity to produce about 2.4 million pounds of tantalum pentoxide (Ta_2O_5) per annum as a co-product of lithium production, equivalent to 890 t of Ta metal. The Rose Ta-Li Project in the James Bay Area of Quebec, Canada, a project currently suspended, has fully diluted reserves of 24 Mt averaging 108 ppm Ta and 4,132 ppm Li and the capacity to produce 1,600 t per year of Ta_2O_5 (GENIVAR Inc. and others, 2011). Many other deposits have been outlined in recent years. The Toongi deposit, 20 km south of Dubbo in New South Wales, Australia has been drilled out to a depth of 55 m to provide a Measured Resource of 35.7 Mt grading 0.03% Ta_2O_5, and between 55 and 100 m for an Inferred Resource of 37.5 Mt grading 0.03% Ta_2O_5. According to the Gippsland Limited company website (http://www.gippslandltd.com/), the Abu Dabbab Ta-Sn deposit in the Central Eastern Desert in Egypt has a total Mineral Resource of 44.5 million tonnes grading 250 ppm Ta_2O_5 and 0.09% Sn, and in addition to this, Mineral Reserves are estimated at 33.2 Mt at 252 ppm Ta_2O_5 and 0.131% SnO_2. Clearly, there is no shortage of tantalum resources or production capacity, and additional supplies are available if

market conditions are favourable. The contribution of zirconium to project economics is not well discussed in the available literature.

Al Quriyyah does offer a viable exploration model insofar as it is relatively enriched in the HREEs, however, its average content is very low compared to other major international deposits. As a result, it may only be commercially viable if it is possible to recover all of the contained metal in a marketable form. In this respect, however, the importance of Al Quriyyah's elevated yttrium content (1,270 ppm) cannot be ignored. WGM believes that Al Quriyyah's development requires a partnership with a company needing several of the metals and willing to engage in a long-term production off-take agreement.

Other Potential REE-Ta-Nb Sources

Reconnaissance exploration in the Arabian Shield during the 1970s and 1980s identified several evolved alkaline to peralkaline granitic complexes. Between December 1981 and March 1982, Minatome completed 28,519 line-kilometres of airborne spectrometer surveying in the Adqan al Hajun area on the border between the southern and eastern segments of the Afif Terrane. Radiometric anomalies in peralkaline to alkaline granites and felsic volcanic rocks were modest. Nevertheless, the DGMR initiated follow-up work on some of the more radioactive granites, many of which were found to contain anomalous REEs. It is uncertain how much of the follow-up work, if any, focused on REE mineralization.

Although the reports by the USGS and others report the results of samples analyzed for thorium, tin, tungsten, molybdenum and base metals, many of the prospects in Tables 70 and 77 lack any record of being assayed for the entire REE group. These granites have potential for REE mineralization in highly fractionated rocks and pegmatites, a local analogue being the Umm al Birak granite, which (as noted) may not be a useful model. However, each REE prospect should be assessed based on its own merits, and having a complete suite of REE analyses is fundamental to this. As mentioned previously, there are many prospects that appear to have received little or no attention after the initial discovery mainly, we believe, due to the depressed REE markets that existed through most of the 1990s and lasted until quite recently.

The following table summarizes potential sources of REEs for which there is little information in the available literature (Table 77).

Table 77
Summary of Minor REE Prospects and Occurrences in the Arabian Shield, Saudi Arabia

Name	Location	References	Host Rocks	Economic Metals	Comments
Sirat Bishah (MODS 1346)	29°56'N 42°40'E	BRGM open file report BRGM-OF-07-6	granite, quartz vein, gossan, pegmatite	Be, F, Li, Nb	in MODS as a beryllium occurrence
Ratama (MODS 2792)	29°05'N 35°20'E	DMMR report DGMR-OF-02-19	alaskite, granite, pegmatite	Sn, Ta, Nb, Y	in MODS as a tin occurrence
Wadi Marshah (MODS 2796)	28°46'N 35°20'E	DMMR report DGMR-OF-02-19	alkali granite	La, Zr, Zn, W	
Mowasse (MODS 2794)	28°34'N 35°09'E	DGMR-OF-02-19	quartz syenite	REEs	no specific metals given in database
Wadi Ghannah (MODS 3315)	28°21'N 35°23'E	DGMR Report #517, new DMMR report in preparation	granite	Zr, La, Nb	in MODS as a zirconium occurrence
Rawa (MODS 2795)	28°20'N 35°28'E	DMMR report DGMR-OF-02-19	granite, quartz vein	Sn, Be, F, Y	in MODS as a tin occurrence
Naqayn (MODS 3360)	27°37.8'N 41°40.3'E	USGS report in progress by Last and Kellogg	not specified	Th, Nb, REE	
Hail (MODS 2653)	27°35'N 41°48'E	In report GM-40	dacite, granite	Nb, REE	
Qufar (MODS 3361)	27°27.7'N 41°36'E	BRGM open file report BRGM-OF-03-46	not specified	Th, Nb, REE	
Jabal Baghna (MODS 3158)	26°56'N 41°04'E	BRGM open file report BRGM-OF-02-40	peralkaline granite	REEs	no specific metals given in database
Ahmar South (MODS 2733)	25°25'N 42°44'E	Cole and others (1981); updated by C.W. Smith USGS (09/85).	peralkalic granite and pegmatite	Nb, La, Y, F	classified in MODS as a fluorite occurrence
Jabal Al Yoob (MODS 4030)	23°19'N 39°05'E	Report in progress in 1417C	alkali granite	Ce, La, Sn, Y	mineral occurrence
Jabal Abu Gobaaq (MODS 2259)	23°08.4'N 43°23'E	reports 78-JED-2 and Riofinex reference RF-OF-01-3 (Last).	rhyolitic tuff	Y	unusual that no associated metals are reported
Al Malah Ring	22/43D quadrangle	Abdulhay and Douch (1987)	peraluminous biotite monzogranite	REE	anomalous Be, La, Mo, Nb, Sn, W, F
Al Munkhalah Ring	22/43D quadrangle	Abdulhay and Douch (1987)	peralkalic biotite syenogranite	REE	anomalous La, Nb, W, Mo
Jabal Al Hawshah (MODS 4954)	22°35'N 44°43'E	Riofinex report # RF-OF-05-7	pegmatite, monzonite.	Be, Bi, Nb, Sn	In MODS as a beryl prospect – WGM believes could have REE potential
Dahul (MODS 2822, 2823)	22°14'N 43°46'E	Ramsay (1982)	metaluminous monzogranite	Mo, Sn, Ta, Th, W, U, Zn	anomalous Be, Li, Sn, Th, U, B, Ce, F, La, Mo, Pb, Ta, Y, Zn
Jabal Sahah (MODS 1622)	22°08.8'N 44°49.6'E	Reports SG JED 66A9 and BRGM-OF-06-13	granite	Nb, Y, Zr	
Huqban (MODS 2819, 2820)	22°01'N 43°58'E	Ramsay (1982) Abdulhay and Douch (1987), WGM 1992a, b	peraluminous biotite granite	Sn, REE, U, W	radioactive, REE, fluorite veinlets, anomalous Be, La, Nb, Sn, W, Y, F, Li
West Huqban Dikes (MODS 2821)	21°51.5'N 43°49'E	DMMR report DGMR-OF-02-20	aplite, pegmatite	Li, Nb, Sn	in MODS as a lithium occurrence
Demar Abiad (MODS 4037)	21°13.7'N 44°09.7'E	Jackson and Al Yazidi (1985)	peraluminous monzogranite to syenogranite	Sn, W	anomalous K_2O, F, Li, Nb, Y; depleted Ba, Sr, Zr
Jabal Waqt (MODS 2802)	20°33'N 42°52'E	Last (?)	trachyte and rhyolite	Ce, F, La, Li	probably a Riofinex or USGS report
Jabal Yala (MODS 2799)	20°05'N 42°48'E	USGS-TR-12 (Last); DGMR-OF-02-19.	alkali granite	Ce, F, Li, Nb	
Libt (MODS 2797)	19°43'N 42°36'E	USGS report USGS-TR-11 (Last); DMMR report DGMR-OF-02-19	granite, aplite, greisen, pegmatite	Ce, F, Li, Mo	mineral occurrence
Hadbah (MODS 0620)	18°37'N 43°15'E	Riofinex reports RF-78-3, RF-80-8	pegmatite, gabbro, granite	Ce	unusual that no associated metals are reported

Very few of the occurrences in Table 77 are classified as being predominantly REE-bearing. Most of the available information indicates a prevalence of LREE-enriched granites, nevertheless, evidence from elsewhere in the Arabian Shield indicates a moderate range of LREE:HREE ratios with some being relatively HREE-enriched. These would be preferred exploration targets as discussed elsewhere in this report. In its 1989 - 1992 review of mineral exploration in the Eastern Shield, WGM recommended that many of the REE occurrences be explored utilizing remote sensing studies followed by on-site prospecting and detailed geological mapping (WGM, 1992b). WGM recommended the use of high-resolution satellite imagery to find and locate the presence of late faults and fracture systems within these evolved granites, the intersections of which might create focal points for mineralization in the most highly fractionated phases of the intrusions. WGM also recommended mapping to cover an area of 3,000 to 4,000 km^2**.** Late-stage pegmatites, aplites and other associated rocks were identified as potential hosts for REE mineralization. In areas of shallow surficial cover WGM recommended trenching across satellite lineaments. In areas of deeper alluvial cover, geochemical sampling was recommended to test for REE anomalies (as well as Sn, W, Mo, Cu, Pb, Zn).

Current and foreseeable market conditions dictate that those deposits that are enriched in HREEs versus LREEs will be more economically interesting both in respect to the marketability of product and commodity price. Certain geochemical indicators, such as fluorine, and certain geological settings are known to be more favourable for HREEs, however, it is also clear that the REE balance is also affected by the origin and composition of the original magma, the amount of crustal contamination, the degree of fractionation and local geological conditions. Notwithstanding these preferences, which extend to granites favoured for Nb and Ta potential, most of the world's REE production is derived from carbonatites.

The presence of carbonatites in the Arabian Shield in Saudi Arabia is not well documented, if at all. Substantial evidence exists that many carbonatites are linked spatially and temporally with large igneous provinces, often referred to as "LIPs". These are generally represented by high volume - short duration, intraplate, magmatic events consisting mainly of flood basalts and their feeder systems of dykes, sills and layered intrusions. According to Ernst and Bell (2010) the LIP-carbonatite association is illustrated by the 66 Ma Deccan flood basalt province (India) with which the Amba Dongar, Sarnu-Dandali (Barmer) and Mundwara carbonatites and alkali rocks are associated. Other examples include the 130 Ma Paraná-Etendeka LIP, the 250 Ma Siberian LIP with the Maimecha-Kotui carbonatites and the +/-370 Ma Kola Alkaline Province which is coeval with basaltic magmatism widespread in parts of the East European craton. Other associations are found in the major Proterozoic and Archean shield areas of the world such as in the Superior Province in Canada and the Kaapvaal craton in South Africa. As a result of the prevalence of flood basalts in the Arabian-Nubian Shield one might expect to find a significant number of carbonatites in Saudi Arabia.

Miocene to Quaternary carbonatites are known to occur along the East African Rift. Mantle-derived carbonatite dikes that contain monazite and apatite have been positively identified in Yemen (Le Bas et al, 2004) and carbonatite-affiliated magmas are recognized in Jordan (Shaw et al, 2007). Intrusive carbonatites (dolomitites) have been found in the Sinai of Egypt, although they are distinctively low in

REEs, U, Th and other associated elements (Azer et al, 2010). REE-bearing carbonatites, kimberlites and aillikite lamprophyres have been discovered in the Batain Nappes area in eastern and northern Oman (Nasir and Klemd, 1998). The aeschynite-group Ce-bearing minerals of the Wadi Sal carbonatite generally show high REE contents of 33 to 43 wt.% which is close to that of the mineralization from Bayan Obo, China (Nasir et al, 2009). Carbonatites also occur in the Uyaynah area, United Arab Emirates (Woolley and others, 1991), within a tectonic window beneath the Semail Ophiolite Complex at the northern end of the Oman Mountains. The carbonatites form conformable layers up to 10 m thick, and one distinct group of rocks contains primary calcic amphibole and biotite with Nb-titanite, strontian barite, albite and REE (Ce)-bearing allanite and rare Ce-monazite (Woolley and others). The Uyaynah carbonatites have higher incompatible element abundances than average intrusive carbonatites and are notably rich in REEs (up to 2.6 wt%). It is clear from this that the presence of carbonatites in the Kingdom is a subject that needs to be studied. If identified in the Kingdom, the REE potential of these rocks needs to be assessed given that the world's largest REE resources are found in such bodies of rock.

3.4.3.3 Recommendations

To reduce the risk in bringing a new REE project on-stream, the SGS must firstly ensure that its investments in REE projects are targeted towards those projects which offer the greatest potential to be economically viable based on technical factors and market acceptance. Low-grade projects that require bulk mining of large tonnages are thought to be less desirable because they require large investments in capital equipment, and the profitability of such projects typically requires a high degree of metal recovery for all commodities - this is not easy to accomplish. WGM believes that the most favourable projects will involve a combination of the following characteristics:

1) higher grading, lower tonnage REE production containing in excess of 1% total REEs plus Y;
2) HREEs + Y relatively enriched comprising at least 50% of the total REEs (HREE/LREE ≥1.0);
3) mineralization that is amenable to simple metallurgical processing to recover REEs and by-products to a concentrate, such as that hosted in some carbonatites; or,
4) mineralization that satisfies a niche demand by a REE consumer in the global market and one with which the KSA can arrange a take-off agreement.

3.4.3.4 Economic Viability

During the last 15-20 years, the demand for rare earth metals has been satisfied by producers in China that have accounted for approximately 97% of global production. During the commodity boom that existed up until the financial crisis in 2008, a considerable amount of global concern existed in respect to the ability of manufacturers to access sufficient rare earth metal to satisfy production requirements. To some degree, these fears may have been fed by venture capital firms and mining analysts seeking to advance the interests of their client companies that were exploring for REE deposits, however at the time China's reduction in REE exports in order to satisfy its own growing domestic needs certainly fed into these

concerns. It is interesting that, at the time of this "REE crisis", the Australian Government's review of national mineral activities for 2009 did not mention even one REE project despite the fact that two of Australia's deposits were advancing towards production at that time: Arafura Resources' Nolans Project (56 Mt at 2.6% combined rare earth oxides[6]) and Lynas Corporation's Mount Weld Deposit (33.1 Mt at 8.5% rare earth oxides[7]). The search for REEs was energized by ever-increasing demands for these metals in a wide variety of applications ranging from 'high-tech' electronics to high-strength magnets used in motors and generators to more everyday uses such as in the field of ceramics. In order to understand the viability of the mineralization found in the KSA, one must understand the current status of the REE markets and how REE projects in Saudi Arabia compare to other similar projects globally. The rapid drop in REE prices during 2011 is evident in Table 78.

Table 78
Rare Earth Oxide Prices, 99% Grade FOB China
August, 2011 versus December, 2011

Element	Units	August, 2011	December, 2011	Percent Decline
Lanthanum	US $/kg	$165	$21	68%
Cerium	US $/kg	$125	$25	80%
Praseodymium	US $/kg	$240	$135	44%
Neodymium	US $/kg	$320	$182	43%
Samarium	US $/kg	$125	$23	82%
Europium	US $/kg	$5,300	$2,990	44%
Gadolinium	US $/kg	$195	$88	55%
Terbium	US $/kg	$4,200	$2,440	42%
Dysprosium	US $/kg	$2,400	$1,740	29%
Yttrium	US $/kg	$175	$62	65%

During 2010, the Monitor Company Group, L.P. ("**Monitor Group**") carried out a comprehensive review of the potential REE, Ta and Nb industries that might be developed in the Kingdom of Saudi Arabia based on the estimated mineral resources contained in the four major deposits discussed in the foregoing sections and Al Quriyyah. The study, which was carried out for the National Industry Cluster Development Program ("**NICDP**"), does not challenge the credibility of the resource estimates, nor does it contain a discussion of how additional production from the Kingdom would affect existing markets. At the time of the study, considerable fear existed of REE supply shortfalls which must be considered when assessing the validity of the study. Shortly afterwards, market dynamics rapidly changed to an over-supply situation, certainly for the more abundant light REEs and also for niobium. The authors of the study assumed that the Kingdom

[6] Arafura Resources Website, 10 January, 2016
[7] Lynas Corporation, 5 October 2015 news release

could substantiate and develop the REE resources, and would then develop mid-stream and down-stream manufacturing (fabrication) based on the exploitation of its domestic deposits to produce:

- tantalum super alloys for aerospace applications;
- cemented carbide cutting tools for the oil and gas industry and for vehicle manufacturing;
- tantalum mill products for the chemical processing industry and the aerospace industry;
- niobium alloy superconductor wire for use in superconducting magnets in MRI machines; and,
- nickel metal hydrate (NiMH) batteries using lanthanum for use in hybrid vehicles.

Given that the downstream is predicated on developing the domestic supply chain, WGM believes the approach to the study is somewhat flawed given that the known Saudi deposits are generally too low grade to be competitive – that is, infrastructure and production costs will place Saudi miners at an great disadvantage. Jabal Tawlah (Sirw Al Buhayr) and Al Quriyyah (Ghurayyah) were identified as the more attractive deposits based on the aforementioned resources, however as noted, these estimates were based on very limited sampling and do not comply with any existing reporting standard. The Monitor Group does flag concerns relating to the idiosyncratic market and the small size of the market as reasons why planners may wish to focus economic development plans elsewhere (Monitor, 2010). As a key aspect to any decision to proceed, the Monitor Group also emphasized the need for an appropriate partner to develop the project and an end-market producer which to develop an off-take agreement. The linking of mineral producers (miners) and mineral consumers (refiners and fabricators) is not unusual in many resource industries that are characterized by relatively small production volumes and highly specialized requirements.

In assessing mineral processing needs, any development of REE production will compel the Kingdom to have a dedicated facility, the engineering of which will be dependent on the mineralogy of the deposit, the balance of the various rare earth metals in the deposit, as well as the nature of the host rocks and the marketable product. In such an evaluation, it is important to first identify a market for the REE products, and open a dialogue regarding the form and amount of REE off-takes. In the event that a REE deposit was developed, the project owner will need to evaluate processing options with the purchaser to determine the optimum point on the value chain beyond which continuing capital investment produces diminishing returns while still satisfying the client's specifications. The cost of building a plant suitable for the production of a rare earth mineral concentrate is a relatively low-cost approach compared to the construction of a refinery for the production of rare earth metal or high-purity rare earth oxides. These refineries are extremely expensive to build and must contend with restrictive environmental guidelines which impact the disposal of processing wastes. At this time, there are very few refineries outside of China, and the only new facility is located in Malaysia, and owned and operated by Lynas for processing of its ore from the Mt. Weld Mine. There is no excess international refining capacity.

Nearly all of the world's REE production at this time comes from carbonatites. Although they are low in the HREEs, they are large open-pitable deposits that are relatively easy to mine and process compared to granite-hosted deposits. The Mount Weld Mine in Australia entered production as a deposit that had sufficient resources, and especially grade, to be a success despite its somewhat remote location (Table 79). This deposit represents a key competitor in a resource space with very few participants.

Table 79
Mount Weld Mine – Western Australia Mineral Resource Classifications *

Deposit	Classification	Tonnes	% REO $_{total}$	%REO $_{(less\ Y)}$	ppm Y_2O_3
Central Lanthanide Deposit	Measured	3,550,000	14.4	14.3	820
	Indicated	1,440,000	8.2	8.1	960
	Measured & Indicated	4,990,000	12.6	12.5	860
	Inferred	4,884,000	8.4	8.5	1,120
Duncan Deposit	Measured	3,650,000	5.5	5.2	2,700
	Indicated	3,560,000	4.1	3.9	2,460
	Measured & Indicated	7,210,000	4.8	4.6	2581
	Inferred	410,000	4.3	4.1	2,360
Total	Measured	7,200,000	9.8	9.7	1,770
	Indicated	5,000,000	5.3	5.1	2,020
	Measured & Indicated	12,200,000	8.0	7.8	1872
	Inferred	5,290,000	8.3	8.2	1,210

* all data from Lynas Corporation website, 4 November, 2011 and presented in compliance with National Instrument 43-101 standards.

It is worth noting that there are few granite-hosted deposits currently in production anywhere in the world despite some having significantly higher grades and greater tonnages than the KSA prospects. Some examples of granite-hosted deposits are given in Table 80.

Table 80
Summary of Selected Granite-Hosted REE Deposits

Name	Location	Resources	Production
Lovozero Massif	Kola Peninsula, Russia	7.1 Mt containing 2-3% loparite which is 37% to 40% TiO_2, 29% to 33% REOs and 7.5% to 9.8% Nb_2O_5 and Ta_2O_5.	5,000–8,000 t/annum of loparite concentrate
Pajarito Mountain	New Mexico, USA	2.4 Mt grading 0.18% Y_2O_3 and 1.2% Z	Not in production
Strange Lake	Labrador, Canada	114.8 million tonnes grading 1.97% ZrO_2, 0.21% Nb_2O_5, 0.053% HfO_2, 0.082% BeO and 0.73% F	Not in production
Nechalacho	Northwest Territories, Canada	88.46 Mt averaging 1.26% LREEs and 0.27% HREEs classified as Indicated Resources and 223.24 Mt averaging 1.11% LREEs and 0.19% HREEs classified as Inferred Resources	Not in production

As a stand-alone source of REEs, the Gara El Hamra deposit may offer a local (Egyptian) analogue as to what might be thought of as an economically interesting deposit. It is hosted in an alkaline granite-syenite complex which intrudes Cretaceous Nubian sandstone. It is therefore younger that the rocks of the Arabian Shield which has been the focus of REE exploration in the KSA. The complex is distinguished by anomalous radioactivity (Th reach up to 1.93%) as well as high concentrations of the rare elements: Y, HREE, Th, Zr, Nb, and Be coincide with these hydrothermally altered zones (Abdalla, 2006). Average REE compositions for the Gara El Hamra peralkaline complex are as follows in Table 81.

Table 81
Average Composition for Selected Elements and REEs, Gara El Hamra Complex

Element	Fresh Syenite	Altered Syenite	Peralkaline Granite
LREEs			
La	18.2	427.8	13.8
Ce	46.0	1,592.5	25.8
Pr	8.2	232.5	2.8
Nd	39.3	1,170	18.9
Sm	44.2	637.5	17.8
HREEs			
Eu	2.2	166	1.7
Gd	127	1,860	81.9
Tb	50.1	602.5	17.9
Dy	662.5	4,875	238
Ho	202.3	1,157.5	119.5
Er	676.3	3,525	323
Tm	82	540	45.7
Yb	710.5	2,591	384.5
Lu	126.8	342.8	94
Y	180	28,937	142
$REE_{TOTAL\ -Y}$	2,796	19,720	1,420
$LREE_{TOTAL\ -Y}$	157	4,226	82.0
$HREE_{TOTAL\ -Y}$	2,616	15,494	1,323.0
HREE/LREE (-Y)	0.06	3.70	0.06

As can be seen in the foregoing table, both the syenite and peralkaline granite are significantly enriched in REEs with contents of 2,796 and 1,420 ppm respectively, most of which is HREEs. These total REE contents, excluding yttrium, are increased to 19,720 ppm (1.97%) in the altered syenite (7.1x enrichment). The HREE is also increased to 15,494 ppm in the altered syenite (5.9x enrichment). In addition to this, the altered phase carries 2.9% yttrium. Although much higher grading, the mineralization at Gara El Hamra is similar to the hydrothermal mineralization associated with alkali granite-syenite elsewhere, for example Jabal Hamra and Jabal Sa'id in Saudi Arabia. The REE-bearing minerals occur as interstitial grains or as fracture fillings and small veinlets. The gangue minerals are mainly barite, calcite, and fluorite. The REE mineral content is directly proportional to the degree of alteration, ranging between 2 and 50% of the rock volume. The principal ore minerals are xenotime, thorite, zircon, parasite, bastnäesite and pyrochlore. Other economic minerals include relatively rare grains of gittinsite, gadolinite and gagarinite. The fact that this granite is much younger than the Arabian Shield therefore suggests REE potential beyond the strict

margins of the shield although it is uncertain whether comparable geological terrane exists in the Kingdom. This needs to be investigated by the SGS.

Faced with the realities of low grade, low market price and limited market opportunities that most of the deposits face, it is difficult to see how the Kingdom can develop a niobium, tantalum or REE-based industry given its current known resources. In respect to tonnage and grade, there is no single deposit or cluster of deposits that has sufficient resources to act as a catalyst to development. That is not to say that continuing exploration might not identify such a deposit, and further exploration is encouraged, focusing on HREE enriched granite-hosted prospects and the search for REE-bearing carbonatites.

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3.5 PORPHYRY COPPER DEPOSITS

3.5.1 METALLOGENIC MODEL AND EXISTING MINES / MAJOR DEPOSITS

According to the USGS, porphyry copper deposits result from a complex interaction of geological factors that produce many deposit sub-types (Cu-Mo, Cu-Mo-Au and Cu-Au) which can only be summarized in the most general terms. A working definition of a porphyry copper deposit is a deposit in which copper-bearing sulfides are localized in a network of fracture-controlled stockwork veinlets and as disseminated grains in the adjacent altered rock matrix. The host rocks are silicic to intermediate intrusions which are shallowly emplaced, upright-vertical cylindrical stocks and (or) complexes of dikes and commonly porphyritic. The plutons are emplaced in magmatic arcs above subduction zones. Alteration and ore mineralization occurs at a depth of 1 to 4 km, and the fluids responsible are genetically related to the magma reservoirs that were emplaced into the crust at a depth of 6-8 km. Porphyry deposit formation is commonly preceded by a genetically related intrusive rock complex in which the porphyry-hosting components are a late-stage component. Zones of phyllic-argillic and marginal propylitic alteration overlap or surround a potassic alteration assemblage within which mineralization occurs. Copper may also be introduced during overprinting phyllic-argillic alteration events. The copper occurs predominantly in chalcopyrite and to a lesser extent bornite and enargite in hypogene portions of porphyry copper deposits. In addition to mineralized plutonic rocks, ore minerals may occur as disseminations and in stockworks of veins in adjacent hydrothermally altered country rocks.

Porphyry copper deposits occur in continental magmatic arcs along convergent plate-margin boundaries or in island-arc environments. The deposits are commonly associated with subduction-related volcanic centers which may be associated with post-collisional volcanism of the type that characterizes some of the terrane boundaries within the Arabian Shield. Permissive magmatic-arc environments may be transpressional or transtensional. Complex structures seen on surface commonly merge into major basement faults. The localization of individual volcanic centers may reflect local tectonic strain developments, while chains of volcanic centers may reflect more regional-scale structures at depth. These factors are important when exploring for porphyry copper deposits and trying to identify areas of potential within magmatic arcs.

Porphyry copper deposits result from the condensation of residual fluids derived from a crystallizing magma reservoir in the shallow crust most likely at depths of 8–10 km or more. The compositions of the shallow intrusions that host porphyry copper deposits indicate that the deep melt reservoirs from which both the shallow intrusions and the ore fluids were derived may be compositionally calc-alkaline, alkali-calcic, or alkaline.

Porphyry copper deposits are structurally controlled insofar as the intrusive complexes which host them tend to be developed along major arc-parallel structures and often in the vicinity of intersecting arc-normal faults, however evidence for such structures can be difficult to recognize. Deposits form in areas of shallow

magmatism within subduction-related tectonic environments. Deposits only form when and where structurally controlled permeability is tightly constrained by regional structure.

Sulphide minerals are zoned, increasing from irregular zones with <1% in the central part of the deposit, through a surrounding zone with 1–4% pyrite to an outer zone with approximately 4%. The highest chalcopyrite content tends to be in the zone with intermediate amounts of pyrite. From this zone, chalcopyrite content decreases inwards whereas moderate amounts of chalcopyrite continue outwards with up to 0.4% Cu. The zoning can be concentric from the center outwards from a deep low-grade core (<0.5% sulfides including pyrite, chalcopyrite, bornite, and molybdenite).

Deposit-scale geochemical studies show that the major metals and associated elements are related to alteration zones within deposits. The main associations are Cu-Mo-Au ± Ag-As and Ba-Zn-Pb-Sb-Ag-As-Te ± Bi. Fe-sulphide and Cu, Mo, Au and Sn concentrations are highest in ore-bearing rock. Ag and As are also anomalous in ore zones, however they also occur with Ba, Zn, Pb and Sb in overlying subeconomic, altered rocks and with As, Te and Bi can be anomalous in rocks lateral to ore zones. Sulfur anomalies broadly outline mineralization and are often highest in pyritic propylitic alteration zones. Gold is an important by-product in many porphyry copper deposits, but the details of its occurrence are not well understood. Gold is predominantly found in association with bornite; and, in bornite-rich ores, the gold is within the sulfide mineral structure and present as small grains of native gold. In chalcopyrite-rich ores, gold mainly occurs as small grains within the copper sulfide.

Singer and others (2008) tabulated the dimensions for selected porphyry copper deposits worldwide, including the area of hydrothermal alteration, orebodies and sulphide-bearing rock. The median size of the longest axis of alteration surrounding a porphyry copper deposit is 4–5 km, while the median size area of alteration is 7-8 km^2. The vertical extent of ore is dependent upon the lower copper cut-off grade. In general, the vertical dimension is in excess of 1,000 m and can be greater in the case of major deposits such as at Bingham, Utah (1.4 km). The deposits are typically semicircular to elliptical in plan view, and the ore-grade zone typically has an altered, but low-grade core which in some deposits is a barren late-stage intrusion.

The exploration for porphyry copper districts can take advantage of certain geophysical characteristics. The deposits are commonly associated with arc-normal or transverse faults cutting across the predominant structural trend, and therefore deposits may coincide with similarly oriented magnetic anomalies transverse to the predominant structural grain. The mineralized zones may appear as magnetic highs associated with annular or open-ring magnetic lows. Magnetite is variable across the alteration zone and the typical magnetic profile can be quite irregular depending on how the alteration is zoned. Clay alteration and stockwork veins, commonly with a higher water content, generally have a lower resistivity than barren parts of the host stock and surrounding rocks. The presence of disseminated mineralization means that ore zones usually exhibit well developed polarization anomalies from IP surveying, however the strongest anomalies may come from zones containing abundant pyrite in altered rocks rather than areas of less IP-active clay chalcopyrite, and bornite. Spectral IP has been used to classify different alteration zones and

to distinguish noneconomic sulfides such as pyrite from chalcopyrite and bornite. Resistivity and IP anomaly strengths correlate inversely with resistivity of the host rock and the thickness of any cover. Porphyry copper deposits almost always appear as moderate gravity lows, especially if the host rock is igneous or metamorphic. Radiometric methods do not always provide useful information other than differentiating felsic intrusions form country rocks as a general mapping tool. Potassium channel anomalies may be present if alteration if significant and potassically altered parts of the porphyry system are exposed. Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) multispectral data have been used to regionally map potassic, phyllic, argillic and propylitic alteration halos of porphyry copper deposits as they contain distinct spectral absorption features that can be mapped using multispectral and hyperspectral remote sensing data. This has been done with some success in Iran, Afghanistan and Kazakhstan. Siliceous, phyllic, argillic and propylitic rocks have been mapped using ASTER data and a matched filtering algorithm incorporating image spectra at the Reko Diq porphyry copper deposit in Pakistan.

3.5.2 DISTRIBUTION OF DEPOSITS

Mineral occurrences that might be classified as porphyry copper deposits are relatively rare in the KSA. Early in the exploration of the shield, Cole (1985) described the Mibari copper occurrence in such a manner as to invoke parallels with this model. Mibari is located in the Al Khaymah area of the Aban al Ahmar Quadrangle. It is located about 830 km northeast of Jeddah and 60 km ENE of the Sukhaybrah Mine. The only other known porphyry-type copper prospect is located at Suwaj, a new SGS project located near the eastern margin of the Arabian Shield at a site about 84 km SSW of Ad Dawadimi and 64 Km west of Ar Ruwaidhah, a small town on the Jeddah-Riyadh highway. The closest town is Halaban, located about 40 km to the south-southeast. The Suwaj project covers a series of copper prospects previously discovered in 1969 and explored periodically during the early 1970s, then known as the Jabal Intaq sites and recorded in the MODS as indices 2298-2311, inclusive. The sites have only recently been re-examined by the SGS.

The two known porphyry copper prospects do not conform to the concept of a mineral belt, however this is not the same as saying they do not occur in a recognizable geological feature that may define a belt. Neither prospect is sufficiently explored that its structural geology is known with any certainty. Only continued exploration over a period of time will reveal whether these are unique or one-of-a-kind deposits or are members of a class of deposits that define a regional-scale belt.

In respect to the geological model, there is nothing known at this time that would create a link between Mibari and Suwaj as each seems to be associated with a unique geological setting. Mibari is spatially associated with structures that developed during the suturing of the Afif and Hail Terranes. Suwaj is located in the Ad Dawadimi Terrain near the Al Amar Fault Zone along which the Ar Rayn Terrane is sutured to the Ad Dawadimi Terrane.

The Musaynah copper-gold prospect (MODS 0951) is located approximately 150 km west of Mibari, and 32 km SSW of the town of Al Hulayfah As Sufla. This area has several individual MODS indices all with variations on the name Wadi Musayha'ah (0923, 0924, 0930-938, 0951-0954, 0875, 0884). Very little work has been done in this area recently, however this appears to be an extension of a zone favourable for porphyry copper-type mineralization that flanks the northern margin of the Afif Terrane, and extending to the east beyond the Mibari area. The earliest work in the area comprised 30 km^2 of geologic mapping carried out in 1966 during which 447 surface samples were collected for analysis (Delfour, 1968). Grab samples of mineralized material returned values of up to 2.5% Cu and 9.6 g Au/t. At that time, ground geophysical surveying (mag, EM, SP and IP) was also completed. The area was flown as part of an extensive regional airborne geophysical (INPUT and magnetometer) survey in 1967. That year, the BRGM excavated 290 m of trenches and completed a geochemical soil sampling survey. During the 1967-68 exploration program, 10 drill holes were completed totalling 2,640 m. One of the drill holes at Musayna'ah North produced an intersection of 69.73 m averaging 0.42% Cu.

The SGS made a metallogenic investigation of the Musaynah prospect in 1998 in follow-up to previous work by the USGS and the BRGM and described a large area of ancient copper workings covering a 1 km by 7 km area. The mineralization at these localities consists of disseminations and stringers of pyrite-magnetite-chalcopyrite ± sphalerite. In addition, quartz-carbonate veins containing the same mineral assemblage cut the host rocks at various orientations. Some of these were worked by the ancient miners in andesite, rhyolite and rhyolitic tuff, and are overprinted by potassic and hematite alteration. Silicification is also mmentioned in the MODS. The country rocks are described as andesite, chert, conglomerate, jasper, marble, rhyolite and tuffite. The exploration to date is reported as surface and dump sampling, some trenching and channel sampling, and a limited diamond drilling program at the MODS 0951 location. Only the Musayniat-S2 (0930) site is classified in the MODS in accordance with a geological model: Porphyry Cu (Transition model from Fe-oxides (Cu, Au) deposits.

3.5.3 PROSPECTIVE MINERAL BELTS AND PORPHYRY COPPER OCCURRENCES

3.5.3.1 The Mibari Prospect

Previous Exploration and Status

The initial exploration of Mibari commenced during 1981 when the copper-bearing stockwork was discovered by the USGS during reconnaissance level mapping of the region. In 1984, the USGS carried out widespread bedrock sampling in the Al Khaymah area which included 30 samples from Mibari. The low level of copper mineralization detected at Mibari resulted in a general lack of further interest until a re-assessment of the area by the BRGM in 1996. The following year, the BRGM carried out 1:5,000 scale prospect mapping and collected 65 rock samples on six profile lines across the mineralized zone. The type of mineralization discovered at Mibari was recognized as being new to the Kingdom, however the grades were found to be low in respect to what was thought to be viability thresholds. Notwithstanding this, however, the BRGM completed a 10-month follow-up exploration program initially comprising topographic

surveying over a 2.5 km^2 area, 1:2,500 scale geological mapping, additional lithogeochemical sampling with petrographic studies on 25 samples, excavating four trenches (1,735 m) and magnetometer and spectrometer radiometric surveying. This work was followed by the completion of 114 shallow reverse circulation boreholes with an average length of only 13 m (1,486 m total) and 4 shallow inclined diamond drill holes averaging 107.8 m (431 m total). From this work, it was concluded that the overall grade of the Mibari mineralization was 0.12% Cu and 0.18 g Au/t which was insufficient to have any economic potential. The BRGM stated "The Mibari Prospect has no economic potential and no further work is warranted". WGM has no record of any work being completed at Mibari following that of the BRGM.

Geology

In 1985, Cole described the Mibari mineral occurrences in the following manner:

> The Mibari locality (MODS 3944) coincides with a complex braided fracture zone at the south end of a south-trending splay of the Ata fault system, 6.5 km east of the Al Khaymah occurrence on the north bank of Wadi ar Rumah. The host rocks are blocks of Dhiran meta-andesite that -are irregularly intruded by fine-grained, orange-pink, microporphyritic granodiorite granophyre of the Suwaj suite. The granophyre is riddled with stockwork veinlets of gray quartz that contain chalcocite, sparse pyrite, and variable amounts of orthoclase. Secondary hematite and copper minerals are common. The veinlets are exposed for a distance of about 2 km along a N. 70° W. trend that follows the irregular trace of later fractures. These fractures are thin, coated with epidote and chlorite, display irregular slickenside lineations, and locally contain some redeposited copper minerals. Spot and composite rock samples collected by Smith and Samater (1985) contain variable amounts of copper (300 to about 10,000 ppm), minor zinc, and local amounts of molybdenum (100 ppm maximum). Precious metals are characteristically present in amounts less than 1-2 ppm.
>
> The Mibari South occurrence (MODS 3943) is located on the south bank of Wadi ar Rumah, on a southwestward continuation of the Mibari trend, but no cataclastic zone is present. Mibari South consists of two subparallel trenches (30 and 40 m long) along thin veins that trend N. 65-85° W. The host rocks are poorly exposed, but include Suwaj diorite and irregular inclusions of Dhiran meta-andesite. The veins are chiefly fractured quartz and calcite and contain small gossanous pods and masses that are stained by secondary copper minerals. Smith and Samater (1985) report a maximum value of about 1.6 percent copper and 500 ppm zinc for gossanous material.

Based on the most recent exploration by the BRGM, Mibari has been described as poorly mineralized, containing only sparse fine grains of pyrite and chalcopyrite associated with small gold inclusions, and lacking a consistently mineralized stockwork system (Jaques and others, 1999). Nevertheless, low-grade copper mineralization was encountered in several areas, for example 0.15% Cu and 0.34 g Au/t over 92 m in a surface trench and 0.30% Cu and 0.50 g Au/t over 24 m in a reverse circulation drill hole. In a more general sense, the tenor of the Mibari mineralization overall was estimated at 0.12% Cu and 0.18 g Au/t which was approximately half of the target copper grade and one third of the targeted gold grade exploration managers had hoped to achieve even though volumes were considered to be favourable. Especially noted was the lack of a zoned hydrothermal alteration system, particularly the phyllic alteration zone and a potassically altered core related to a late stage core complex.

Recommendations

At Mibari, the aforementioned conclusions by the BRGM were based entirely on a reconnaissance-level approach to exploration. While there is nothing wrong with this approach, the resulting evidence must be interpreted in a proper context. In this case, the surface work was probably sufficient in terms of bedrock sampling and mapping to characterize the appropriate geological model. However, none of the surveys explored the vertical dimension of the mineralization. Induced polarization ("**IP**") surveying is the method of choice for exploring porphyry-style mineralization at depth before drilling. Depending on the resolution required by exploration geologists, IP surveying can provide useful data to depths in excess of 400 m. In the case of large volume models, such as porphyry copper deposits, IP surveying is extremely useful in selected targets for drilling. It is especially notable that no such work was completed at Mibari before the BRGM drilling program. Further to this, porphyry copper deposits and the alteration systems within which they occur can have vertical ranges in excess of 1.5 km, and even small systems are rarely less than 1,000 m. Within this range, alteration and mineralization styles and intensities can vary markedly. It is also notable that the vast majority of the BRGM RC drill holes were about 10 m in length and the longest holes were 24 m. The diamond drill holes were angled at -45^{o} and -50^{o} with hole lengths of 39.4 m, 124.2 m, 153.1 m and 114.0 m which translates into a maximum vertical range of sampling of approximately 28 m, 87 m, 107 m and 80 m, respectively. It would be a huge exaggeration to say that the drilling did more than scratch the surface of what could be a very large mineralized system, yet the BRGM was emphatic in its conclusions. A large effort was devoted to statistical analysis of analytical data, however this effort would have been better spent on acquiring more informative data. In WGM's opinion, the BRGM's exploration did not meet industry best practices standards and its conclusions were inappropriate. Mibari remains a very interesting prospect that warrants additional systematic exploration beginning with a re-assessment of the geology, geochemistry and geophysics followed by detailed IP surveying using a dipole-dipole electrode configuration on 100-200 m profile lines with equipment suitable for surveying to depths of 250 m. Typically this would require a dipole separation ('a' spacing) of 60-70 m with readings for n=1 to n=6. All anomalies should be investigated by varying the dipole spread to provide greater near-surface resolution. Larger anomalies may be traced deeper by increasing the 'a' spacing. All anomalies must be tested with a diamond core drill and all drill core should be sampled from collar to the bottom of the hole. Copper mineralization can have a wide range of mineral types, some of which may not be clearly evident. At the very least, every second metre should be sampled outside of zones that shown good evidence for mineralization. All samples should be analysed for copper using a robust digestion, such as a 3-acid digestion (usually hydrochloric, nitric and perchloric), and finished with a high-precision instrumental determination such as ICP. All gold assays must be by the fire assay method, preferably with a 50-gram charge.

3.5.3.2 The Musayna'ah Prospect

Previous Exploration, Geology and Status

The area of the Musayna'ah copper-gold prospect (MODS 0923, 0924, 0930-938, 0951-0954, 0875, 0884) has been subject to very little exploration during the last 20-30 years despite some very encouraging early results. The initial work in the area comprised 30 km^2 of geologic mapping carried out in 1966 during which 447 surface samples were collected for analysis (Delfour, 1968). Grab samples of mineralized material returned values of up to 2.5% Cu and 9.6 g Au/t. At that time, ground geophysical surveying (mag, EM, SP and IP) was also completed. The area was flown as part of an extensive regional airborne geophysical (INPUT and magnetometer) survey in 1967. That year, the BRGM excavated 290 m of trenches and completed a geochemical soil sampling survey. During the 1967-68 exploration program, 10 drill holes were completed totalling 2,640 m. One of the drill holes at Musayna'ah North produced an intersection of 69.73 m averaging 0.42% Cu (WGM, 1992).

The SGS made a metallogenic investigation of the prospect in 1998 in follow-up to previous work by the USGS and the BRGM and described a large area of ancient copper workings covering a 1 km by 7 km area. The mineralization at these localities consists of disseminations and stringers of pyrite-magnetite-chalcopyrite ± sphalerite. In addition, quartz-carbonate veins containing the same mineral assemblage cut the host rocks at various orientations. Some of these were worked by the ancient miners. The host rocks are described as andesite, rhyolite and rhyolitic tuff which are overprinted by potassic and hematite alteration. Silicification is also mmentioned in the MODS. The country rocks are described as andesite, chert, conglomerate, jasper, marble, rhyolite and tuffite. The exploration to date is reported as surface and dump sampling, some trenching and channel sampling, and a limited diamond drilling program at the MODS 0951 location. Only the Musayniat-S2 (0930) site is classified in the MODS in accordance with a geological model: Porphyry Cu (Transition model from Fe-oxides (Cu, Au) deposits.

Recommendations

Like at Mibari, most of the previous work was reconnaissance-level which in this area quickly focused on the Musayna'ah North prospect for drill-testing. Despite a highly encouraging intersection that proved the geological model, it is notable that there has been no follow-up drilling, and none of the surrounding prospects have been drill-tested. Induced polarization ("**IP**") surveying should be carried out over the region to define the sub-surface. This would entail surveying an area of 30-40 km^2 which could be accomplished with 150-200 line-kilometres of surveying if a 200-metre profile spacing was used. The area is relatively flat and the surveying could likely be completed in 2-3 months even if a dipole-dipole array was used with a 50-metre a-spacing for readings from n=1-6. This would give high-quality data sufficient for the design of drilling programs. In is certain that with a previous intersection of nearly 70 m averaging close to 0.5% Cu, that additional targets will be generated for diamond core drilling. All anomalies must be tested with a diamond core drill and all drill cores should be sampled from collar to the bottom of the hole. Copper

mineralization can have a wide range of mineral types, some of which may not be clearly evident. At the very least, every second metre should be sampled outside of zones that shown good evidence for mineralization. All samples should be analysed for copper using a robust digestion, such as a 3-acid digestion (usually hydrochloric, nitric and perchloric), and finished with a high-precision instrumental determination such as ICP. All gold assays must be by the fire assay method, preferably with a 50-gram charge.

3.5.3.3 The Suwaj Prospect

Previous Exploration and Status

Suwaj is a new prospect now being explored by the SGS near the eastern margin of the Arabian Shield. At this time, there is no MODS index specifically for the Suwaj prospect, however the project is located near the centre of a 23-kilometre long NNW-SSE trend in which there are 14 copper occurrences (MODS 2298-2311) with variations of the name Shaib Ad Dad or Shaib Umm Habiyah. These were previously referred to as Jabal Hentag West, and before that as the Jabal Intaq sites as summarized in Table 82.

Table 82

Name and Location of Porphyry Copper Occurrences in the Suwaj Project Area

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Ranking	Geometry
				Longitude	Latitude			
2298	Shaib Abu Hasak	Jabal Hentag-W	Copper	44.0033330	23.9127780	Halaban	Low	dd, v
2299	Shaib Umm Habiyah-W	Jabal Hentag-W	Copper	44.0752780	23.8969440	Halaban	Low	dd, v
2300	Shaib Ad Dob-NW	Jabal Hentag-W	Copper	44.0929720	23.8867500	Halaban	Low	dd, v
2301	Shaib Umm Habiyah-E	Jabal Hentag-W	Copper	44.1019170	23.8825560	Halaban	Low	dd, v
2302	Shaib Ad Dab-SE	Jabal Hentag-W	Copper	44.0925000	23.8575000	Halaban	Low	dd, v
2303	Shaib Ad Dab-SE 1	Jabal Hentag-W	Copper	44.1018330	23.8610560	Halaban	Low	dd, v
2304	Shaib Ad Dab-SE 3	Jabal Hentag-W	Copper	44.1101670	23.8590560	Halaban	Low	dd, v
2305	Shaib Ad Dab-SE 4	Jabal Hentag-W	Copper	44.1178890	23.8544170	Halaban	Low	dd, v
2306	Shaib Abu Salam-N	Jabal Hentag-W	Copper	44.1225000	23.8050830	Halaban	Low	dd, v
2307	As Sahamiyah	Jabal Hentag-W	Copper	44.0983330	23.7882220	Halaban	Low	dd, v
2308	Shaib Abu Salam-S	Jabal Hentag-W	Copper	44.1358330	23.7611110	Halaban	Low	dd, v
2309	Nufayyid Qaradan	Jabal Hentag-W	Copper	44.1515560	23.7335280	Halaban	Low	dd, v
2310	Rawdat Qararah Al Gharbiyah	Jabal Hentag-S	Copper	44.0905560	23.7302780	Halaban	Low	dd, v
2311	Jabal Al Ghuthayra	Jabal Hentag-W	Copper	44.0437780	23.7290830	Halaban	Low	dd, v

The copper occurrences in the Jabal Hentag Area were discovered by the BRGM in 1969 during regional reconnaissance geological mapping at 1:100,000 scale (Bois, 1971). Numerous ancient workings are present in the area. The occurrences consist of malachite and chrysocolla in quartz-filled fractures in diorite, granodiorite and ultramafic rocks. It is very strange that the BRGM did not report taking any

samples, suggesting that the mineralization was viewed as unimportant, or somewhat of a curiosity. During 1981, the USGS evaluated data collected during various regional magnetometer surveys carried out during the 1960s and 70s and noted the presence of various magnetic lows. The USGS pointed out the fact that such lows can result from local alteration around porphyry copper deposits that has destroyed the original magnetic minerals of the host pluton. The USGS commented "Geologists mapping areas within the Arabian Shield should be aware of the possible significance of the alteration associated with local magnetic lows within magnetic plutons" (Griscom, 1983). There is no other reference to work in this area at the time of WGM's major review in 1989-1992. There is no reference to follow-up work after the WGM review until recent activities by the SGS. A group of 227 bedrock samples was collected from an area of approximately 35 hectares (0.35 km^2) during 2011 under the Wadi Al Ghuthayra Project, and analysed for gold, rare earth metals and major oxides. Analytical techniques are not disclosed in the data file available to WGM, and given the low gold results reported, it is almost certain that the method did not include conventional fire assaying. Copper values ranged from 56 to 11,629 ppm, averaging 1,939 ppm. No sample carried more than trace levels of gold (< 0.02 ppm) and the highest silver value was 5.9 ppm, with the population averaging only 0.32 ppm Ag. Lead values ranged from 2 ppm to 22 ppm and zinc ranged from 13 ppm to 151 ppm. The average lead and zinc values were 12 ppm and 42 ppm, respectively. The highest total REE content was less than 70 ppm, and niobium, lithium, tantalum values were all low. The maximum thorium and zirconium values were 4 ppm and 37 ppm, respectively. In general copper contents correlate weakly with molybdenum, lithium, scandium, some of the rare earth metals and thorium. The program could be considered a success because it confirmed the widespread presence of copper mineralization. Exploration work by the SGS re-commenced during 2015 in an area approximately 5.7 km northeast of the Wadi Al Ghuthayra Project sampling. The renewed work has included surface sampling of copper occurrences and geochemical analysis, geological reconnaissance mapping and prospecting of a 1,050 km^2 area, petrographic studies of representative samples and development of an overall systematic plan for on-going exploration. The SGS plan for 2016 includes the following work programs:

- a trenching program involving the excavation of 1,500 m of trenches to expose bedrock for systematic sampling;
- the acquisition of satellite imagery for remote sensing analysis;
- detailed geological mapping of surface exposures and trenches with detailed chip-channel sampling;
- an AMT geophysical survey totaling 30 line-kilometres of surveying;
- data compilation and interpretation; and,
- reconnaissance diamond core drilling towards the end of the year.

Geological Setting and Mineralization

The Suwaj project is in the area of the former Jabal Hentag prospects and occurrences where hydrothermal copper mineralization occurs in siliceous veins along fractures within diorite and granodiorite, as well as in an ophiolite complex. The main area of mineralization centred on the Shaib Abu Hasak ancient workings

(MODS 2298) are in ultramafic rocks intruded by numerous dikes of microdiorite/andesite and by quartz veins. Mineralization, consisting of visible pyrite and minor galena is associated with siliceous fracture zones, and the rocks are hematized and silicified. Five samples of dump material collected by Bois (1971) were analyzed for Au, Ag, Cu, Pb, and Zn and maximum values of 2 g Au/t and 5 g Ag/t were obtained. The other surrounding prospects are hosted in a variety of setting including calc-alkaline granodiorite, diorite, andesite, metabasalt, conglomerate and sandstone. The results of work on the other prospects are not reported. Sampling by the SGS during 2011 in the Wadi Al Ghuthayra Project area resulted in evidence of copper mineralization over an area measuring approximately 600 m by 600 m. Only one sample exceeded 1% Cu however 14 samples exceeded 3,000 ppm and the average value was 1,939 ppm. The new work by the SGS on the Suwaj Batholith has identified several phases of intrusive activity including a younger porphyritic phase which is felsic to intermediate in composition, locally brecciated and affected by late stage hydrothermal activity that has resulted in copper mineralization. The late stage intrusion, which is as much as 500 m wide, is thought to have evolved from the parent magma and been emplaced along a NNW-trending fault system that has been traced for 8 km. The SGS recognizes that the mineralization and alteration patterns are in agreement with a porphyry copper model, and the remaining questions concern the present level of erosion in respect to the mineralizing system.

Recommendations

Although the area has consistently yielded positive geochemical results from surface samples, only early reconnaissance-level exploration has been undertaken. Despite quite a long history of work, there is no detailed geological map for review in the available literature. A re-examination of the area is certainly warranted to determine the relationship of the mineralization to lithology and major structural features. For the most part, the work program currently proposed by the SGS is well planned and the 2-year timetable is realistic, provided the outcome is to identify the nature of the target, but not necessarily to precisely outline or define the target. In other words, 6 months of drilling (say, 5,000 to 10,000 m) is inadequate to delineate the mineralized zone, but it will give an indication of the magnitude of the mineralized zone and the general nature and grade (“tenor”) of the mineralization.

In detail, the proposed trenching program of 1,500 m may not be sufficient if the estimated target area is 6-8 km long and as much as 2 km wide even through outcrop is limited due to alluvial and eolian sand cover. WGM recommends increasing the trenching to at least 5,000 m which would be 20 trenches, each 250 m in length, on profiles every 300 m. Of course, if the intent is to only explore in the central part of the copper anomaly, then 1,500 m may be sufficient, however there is the risk that out-lying areas will not be explored. The trenches must be mapped in detail at no less than 1:2,500 scale. All bedrock samples, and future drill core samples, must be analyzed with an industry standard method. In digesting the samples, a fairly robust digestion should be used to ensure that all sulphide minerals are digested. A standard aqua regia digestion may not be good enough. A 3-acid digestion would be better. ICP can be used as the instrumental finish. All samples should be analysed for major oxides (whole rock) to detect alteration trends. All samples should be analysed for gold by the fire assay method, preferably using a 50-gram charge. Some attention

should be given to petrographic and mineralogical work on typical rock types and mineralization to properly characterize and classify the mineralization.

During the trenching program it would be appropriate, as the SGS has noted, to carry out geophysical surveying. AMT surveying has been proposed to explore the deeper sections of the porphyry system. With clear evidence of mineralization on surface, it seems illogical to explore the deep sections of the deposit before the shallower features are fully understood. Conventional systematic approaches to exploration inform us that information should be gathered as cost-effectively as possible, dictating that shallow drilling targets (<300 m) should be developed before deeper targets (>300 m). Any interpretation of geophysical data at depth would be vastly improved if the geophysical model closer to surface was developed first. The proposed AMT surveying has the capability of characterizing the size and various features of polarizable mineral deposits, such as porphyry copper deposits, that are concealed beneath thick overburden or cover rocks. The method can differentiate between rocks that have distinct differences in resistivity and metallic mineral contents, that is between ore-bodies and the country rocks that hosts them. AMT has very good depth penetrating capabilities depending on the EM frequencies used. The problem with AMT is that it has limited ability to resolve or define specific targets for drilling, especially the near surface area which is likely to contain the most easily tested drill targets. In any event, some follow-up induced polarization ("**IP**") surveying will be necessary to define specific targets, and especially near-surface targets. In keeping with the concept of conventional exploration, it must also be said that IP surveying is the surveying technique of choice for porphyry copper deposits, and especially for identifying drill targets between surface and approximately 400 m depth. WGM's geophysicist and other geophysicists we have consulted with concur that it would be more appropriate to carry out an IP survey first because AMT will probably not provide the resolution needed to select targets for drilling at a useful depth. The proposed AMT survey is planned over a 30-day period, however the actual amount of work planned (30 line-kilometers) should require no more than 5 days to complete.

In simple terms, WGM is surprised that IP surveying isn't mentioned in the SGS proposal. Magnetometer surveying is also missing. Although an airborne survey was carried out in the late 1960 or early 1970s, there is a need for a detailed grid-based ground (or airborne) magnetometer survey using profile lines no more than 100 m apart with 25-metre stations. The entire area of interest should be surveyed to provide data that can be used as a geological mapping tool and to be modeled to generate a 3-D view of the subsurface in respect to the location of plutons and the presence of major structures. Both IP and magnetometer surveying should be carried out before any consideration is given to AMT surveying. The interpretation of AMT data will benefit greatly if detailed near-surface geophysical data is available.

Detailed near-surface information at depths down to 500-800 m can also be generated by using 3D induced polarization surveying. While this provides excellent data quality and resolution, it is a costly survey to carry out. WGM is not aware of a contractor in the Kingdom with this capability.

In any event, the SGS must resist testing deep geophysical targets before it has adequately explored the near-surface zone. With evidence of copper mineralization on surface, the focus must be on developing

targets that can be tested in a cost-effective manner. In terms of a successful outcome, the chances of success increase with shorter holes because 5 shorter holes can be drilled for the cost of two long holes. If the drilling program produces less than optimum results, then the consequences may be a project that is more difficult to promote. If an orebody, or portions of an orebody, cannot be found in the area shallower than 300-500 m, then the economic viability demands increase sharply below this depth. Knowing that mineralization extends to surface, as has been demonstrated many times, favours detailed geophysical surveying to define drill targets in this upper zone. AMT can be used later to investigate the deeper roots of a mineralized zone after you have defined its precise location.

The SGS has the ability and equipment needed for magnetometer and IP surveying, however, WGM is uncertain regarding the technical specifications of the IP equipment and the experience level of its operators. These equipment specifications need to be critically reviewed to ensure that the transmitter and generator are suitably paired and have the ability to generate sufficient power output (signal strength) to penetrate overburden and get into bedrock. The IP electrodes must be appropriate, and from reviewing several previous surveys that were negatively impacted by noise, WGM concluded that the electrodes used previously by the SGS were not appropriate, and the operators did not recognize the problems with the survey at the time the readings were being taken. In general electrode pots are better than stainless steel spikes for the reading electrodes as they can minimize noise.

3.5.4 Economic Viability of Porphyry Copper Occurrences

There are no porphyry copper prospects in the KSA that are sufficiently advanced to be assessed as a deposit and certainly none that have any economically significant mineral resources attributed to them. There is geological risk in exploring for such deposits because none have been found in the Arabian Shield to date that would meet any test of economic viability. The Mibari “deposit”, as defined at this time, is much too low grade, however its geological model is valid and its level of exploration at this time is extremely shallow. Therefore it must be concluded that viable, under-explored models do exist in the Kingdom. The lack of a successful porphyry copper project in Saudi Arabia means that explorers are deprived of a local analogue by which to learn and gauge other projects in respect to probability of success. Given what is known at the moment concerning the assembly of the Arabian-Nubian Shield, it is known that subduction zones existed and with subduction zones comes the possibility of porphyry-type deposits. Therefore, it is not unreasonable to believe that continuing exploration should result in the discovery of a deposit somewhere in the Arabian Shield, but there is a general lack of knowledge concerning what features, especially size and grade, that such a deposit would have. Current work has focused on two prospects in the eastern Shield and these settings present themselves as logical targets for on-going exploration. Any further discussion of economic viability at this time is meaningless without some physical data on which to base such analysis.

3.5.4 REFERENCES

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3.6 CHROMIUM DEPOSITS

3.6.1 LOCATION, DISTRIBUTION OF DEPOSITS AND HISTORY

Major chromium deposits in the KSA are associated with the Al Ays Complex, a series of ultramafic rocks comprising a circular-shaped arrangement approximately 25 km in diameter and located about 200 km northwest of Madinah. A total of 491 identified chromite occurrences are located in an area encompassing 830 km^2 in the Jabal al Wasq and Wadi Malahat areas of the complex Chevremont and Vaillant (1983). These include in-situ bedrock chromite occurrences (schlieren, pseudo-stratiform bodies and pods) and secondary (eluvial and alluvial) occurrences. These have an average density approximately one occurrence per 2 km^2. The outlines of four areas containing 260 reported occurrences, not all of which have MODS indices, are shown in Figure 102 and summarized in Table 83. The major chromite occurrences in the Arabian Shield are identified in Table 84 by cluster area. The location co-ordinates provided are for the mid-point of the cluster.

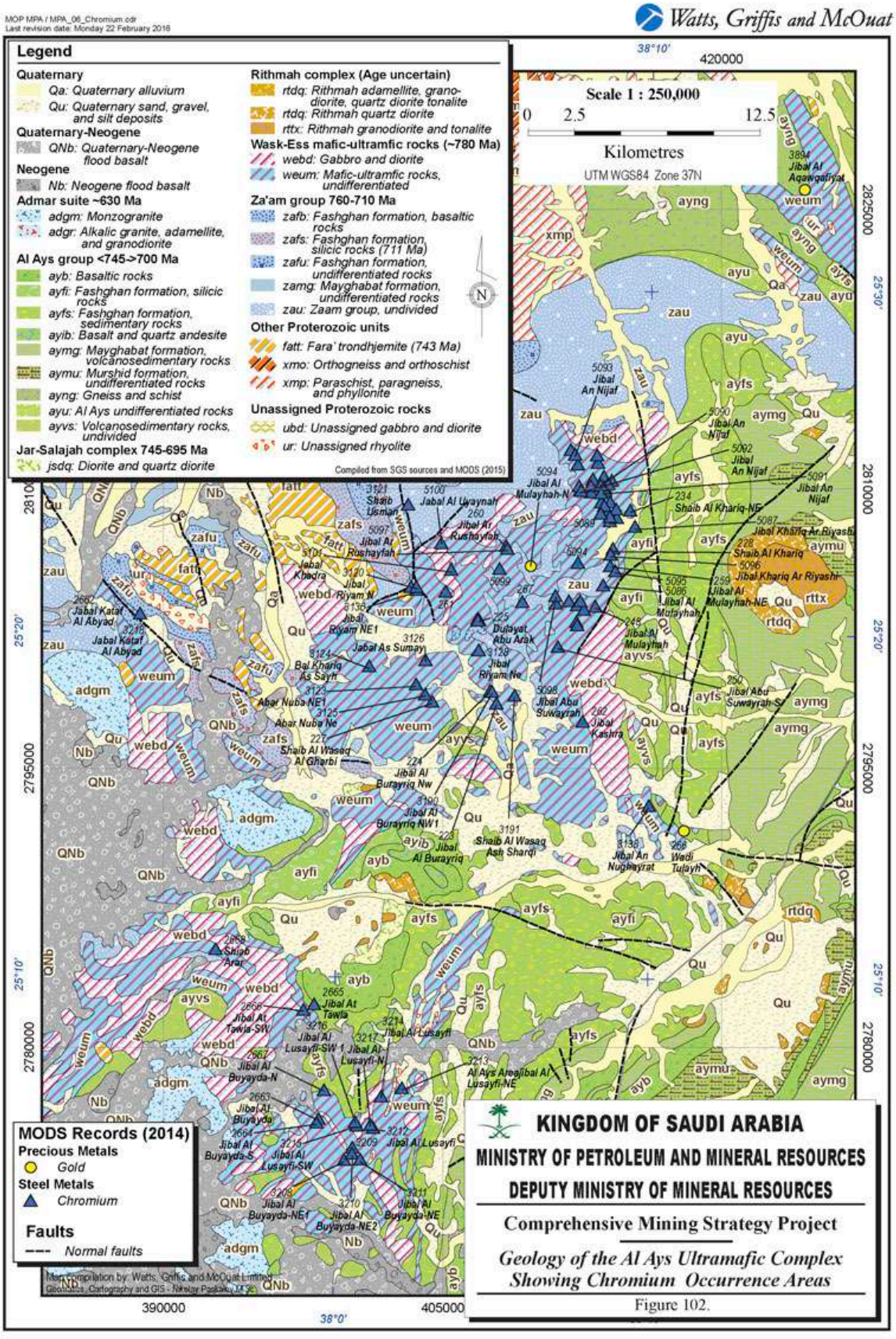
Table 83
Summary of Chromite Occurrences in the Al Ays Complex

Location	Area (km^2)	Number of Occurrences	Chromium Content		Largest Body (lens)		
			Cr2O3 (%)	Cr/Fe Ratio	Tonnes	Cr_2O_3 (%)	Cr/Fe Ratio
1	40	57	34.5	1.95	2,000	43.0	2.1
2	37	46	54	2.40	4,000	58.0	2.7
2W	80	112	47.7	2.73	<1,000	---	---
3	20	45	55	2.70	350	36.8	2.1

Table 84
Name and Location of Major Chromium Occurrences, Arabian Shield

Name	Prospect Area	Centre Location		Potential Ranking *	MODS	New Name	Old Name	Cent
		Longitude	Latitude					Longitu
					Halaban Area			
rayriq	Jabal Wasq	38.0831	25.3032	Med	2315	Shaib Abu Jiss	Halaban	44.3497
h Sharqi, J. Riyam NE	Jabal Wasq / Jabal Rayan	38.0850	25.3140	VL	**Jabal at Tays Area**			
, Jabal As Sumay	Jabal Khashm An Na'Bun	38.0467	25.3079	VL	0132	Jabal At Tays	Jabal At Tays	44.9917
bu Arak	J. Rayan, J. Jimamah, W. Osman	38.0750	25.3398	VL	**Bi'r Tuluhah Area**			
wayrah, J. Al Mulayhah	Jabal Abu Swera	38.1199	25.3443	VL	0182, 0178, 0179, 0180, 0181	B'ir Tuluhah	B'ir Tuluhah	40.8191
ra	Jibal Kashrah	38.1311	25.2908	VL	**Jabal Nuf Area**			
han Ne	Jabal Jimama-N	38.0575	25.3533	VL	2175	Jibal Nuf	Jabal Nuf-N	41.9667
dra	Jabal Khadra	38.0603	25.3642	Low	3028	Jabal Nuf-E	Jabal Nuf-E	41.9792
m	Jabal Rayan (Raian)	38.0409	25.3551	VL	**Jabal al Juhfah Area**			
aynah	Jibal Al Uyaynah	38.0550	25.3769	Low	0369	Shaib Ad Dahmul	Jabal Al Juhfah-SE	40.9974
ushayfah	Jibal Ar Rushayfah, Jabal Abu Swera	38.0887	25.3717	Low to VL	0370	Jibal Marurah	Jabal Al Juhfah-SE	40.9503
han	Wadi Osman	38.0372	25.3954	VL	**Jabal Sakharah-Jabal al Himdaniyah Area**			
As Sayh	Jabal Khashm An Na'Bun	38.0169	25.3169	VL	1363, 0451	J. Sakharah, J. al Himdaniyah	J. Sakharah, J. al Himdaniyah	41.2576
ulayhah	Jibal Al Mulayhah, Jabal Abu Swera	38.1368	25.3557	Low to VL				
hariq	J. Gharig, W. Gharig, Shaib Al Khariq	38.1481	25.3857	Low to VL	**Additional Individual Occurrences**			
					0183	Jibal Huwaymidat	Jabal Samrah Tuluha	40.7990
ijaf	Jibal An Nijaf (Jabal Negaf)	38.1377	25.4058	Low to VL	3155	Buqaya Ash Ashamaliyah	Buqaya Jasperoid	42.9168
					0767	Sinfan Al Amshat	Wadi Umm Ghaza	44.9753
					2285	Ashal Al Hamd	Jabal Smakh-W	45.2094
ughayrat	Jabal Al Wasq	38.1667	25.2500	VL	4711	Shaib Al Khuthuth	Jabal Ghurrab-SE	42.4639
wla	Jabal Taholah	37.9861	25.1514	VL	1345	Wadi An Nujharah-S	Wadi Aqiq	41.5903
f Al Abyad	Wadi Magra	37.8944	25.3417	VL - uncertain	0627	Jash	Jash	43.4667
sayfi	West of Wadi Sahiffi	38.0208	25.0997	VL	2650	Al Hamdah	Serpentinite	43.6665
yayda	Wadi al Marra, Wadi ad Dub	38.0022	25.0890	VL				

o MODS: VL = Very Low; Med = Medium, VH = Very High; (2) Place names are sometimes abbreviated: J. = Jabal, W. = Wadi.


MOP MPA / MPA_06_Chromium.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
Legend
Quaternary
Qa: Quaternary alluvium
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
Neogene
Nb: Neogene flood basalt
Admar suite ~630 Ma
adgm: Monzogranite
adgr: Alkalic granite, adamellite, and granodiorite
Al Ays group <745->700 Ma
ayb: Basaltic rocks
ayfi: Fashghan formation, silicic rocks
ayfs: Fashghan formation, sedimentary rocks
ayib: Basalt and quartz andesite
aymg: Mayghabat formation, volcanosedimentary rocks
aymu: Murshid formation, undifferentiated rocks
ayng: Gneiss and schist
ayu: Al Ays undifferentiated rocks
ayvs: Volcanosedimentary rocks, undivided
Jar-Salajah complex 745-695 Ma
jsdq: Diorite and quartz diorite
Rithmah complex (Age uncertain)
rtdq: Rithmah adamellite, granodiorite, quartz diorite tonalite
rtdq: Rithmah quartz diorite
rttx: Rithmah granodiorite and tonalite
Wask-Ess mafic-ultramfic rocks (~780 Ma)
webd: Gabbro and diorite
weum: Mafic-ultramfic rocks, undifferentiated
Za'am group 760-710 Ma
zafb: Fashghan formation, basaltic rocks
zafs: Fashghan formation, silicic rocks (711 Ma)
zafu: Fashghan formation, undifferentiated rocks
zamg: Mayghabat formation, undifferentiated rocks
zau: Zaam group, undivided
Other Proterozoic units
fatt: Fara' trondhjemite (743 Ma)
xmo: Orthogneiss and orthoschist
xmp: Paraschist, paragneiss, and phyllonite
Unassigned Proterozoic rocks
ubd: Unassigned gabbro and diorite
ur: Unassigned rhyolite
Compiled from SGS sources and MODS (2015)
Scale 1 : 250,000
0 2.5 12.5
Kilometres
UTM WGS84 Zone 37N
38°10'
420000
390000
405000
38°0'
2825000
2810000
2795000
2780000
25°30'
25°20'
25°10'
MODS Records (2014)
Precious Metals
Gold
Steel Metals
Chromium
Faults
Normal faults
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pasiakov, 2015
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Al Ays Ultramafic Complex Showing Chromium Occurrence Areas
Figure 102.

During the early 1960s, the SGS (then known as the DGMR) carried out 1:60,000 and 1:50,000 scale reconnaissance geological mapping of the Al Ays Complex. At the same time, airborne geophysical surveying (radiometric and magnetometer) was being completed on the region by Hunting. Given the anomalous magnetic profile over the complex, follow-up ground geophysical surveying was completed in 1965-66 followed by additional geological mapping by the USGS and the BRGM. During the next 15 years, additional prospecting and regional mapping was completed however the chromite occurrences did not receive significant attention during the period. Modern exploration was initiated with a geological mapping and resampling program during 1981. Additional magnetometer surveys were completed to identify targets for drilling and 18 percussion holes totalling 1,617 m of drilling were completed

A second area of chromite occurrences is hosted in the Wadi al Hwanet - Jabal Iss Complex, located about 300 km northwest of Al Madinah and 200 km inland from the Red Sea coast. It is located about 120 km NNW of the Al Ays complex and is generally thought of as being part of the same belt of ultramafic rocks, but displaced in a left-handed manner along Najd faults. Smaller but similar bodies of ultramafic rock remain between the two major complexes. The chromite bodies in the Wadi al Hwanet-Jabal Iss Complex have not been studied in the same detail as those of the Al Ays complex. Regional scale, 1:50,000 geological mapping was completed by the BRGM during the late 1970s, and the identified chromite occurrences tend to be widely scattered (as of the early 1990's none were assigned a MODS index), and not as regular in occurrence as in the Al Ays Complex. Initial work on the complex included geologic mapping at 1:100,000 scale by BRGM in 1974 and evidence of chromite was discovered the following year and reported by Chevremont and Johan (1982b). Prospecting and 1:20,000 scale geological mapping were carried out by the BRGM during 1976-78, and a single 300.2 m diamond drill hole was completed during 1979 in the Wadi al Hwanet part of the complex to test the massive, chromite-bearing, serpentinized dunite beneath the harzburgite unit and "to provide more petrologic and structural data" (Chevremont and Johan). The hole failed to intersect economically interesting chromite and intersected only harzburgite and several layers of serpentinized olivine and chrome spinel. From this time onwards, the BRGM focused its exploration on the search for base metals in the Jabal ash Shizm area a short distance to the north.

Minor chromite occurrences were found during reconnaissance mapping within the Halaban quadrangle. The BRGM noted lenses of chromite within mafic and ultramafic rocks of the Urd Group which were mapped and sampled during 1966-67. The Jabal Thys chromite occurrence (MODS 0132) is composed of four pods of iron-rich chromite with dimensions of up to 15 m by 6 m. The occurrences were mapped and sampled, and returned average assays of 34.3% Cr_20_3.

3.6.2 GEOLOGY

Al Ays is a layered intrusive complex mainly composed of harzburgite, dunite, serpentinite, and gabbro. Chromite occurs as relatively numerous lens-like bodies in a sequence of rocks that, from bottom to top, consists of: (1) Harzburgite with some chromite lenses; (2) an intermediate dunite horizon containing most of the chromite lenses; and, (3) an uppermost dunite-wehrlite unit containing layers of "rodingitized" gabbro.

In the Jabal al Wasq area, elongated chromite lenses are essentially stratiform in respect to magmatic layering and are located in the intermediate dunite north of the harzburgite unit. Chromite bodies have undergone post-consolidation tectonic redistribution by boudinaging. Within the chromite lenses cataclastic textures are widespread and the rocks have been recemented by serpentine containing minor inclusions of nickel arsenides and sulfides including millerite, bravoite and pentlandite (Chevremont and Vaillant, 1983).

The country rocks of the Wadi al Hwanet Jabal Iss Complex are composed of mafic, intermediate, and felsic metavolcanic rocks, as well as undifferentiated metasedimentary schists which are unconformably overlain by sedimentary strata of the Al Ays Group (Chevremont and Johan, 1982b). The geologic setting is thus very similar to that of the Al Ays complex. The Wadi al Hwanet-Jabal Iss complex is composed of serpentinized dunite and less serpentinized, cumulate-textured harzburgite with minor orthopyroxenite and wehrlite. The harzburgite is the more evolved unit and its central position in the complex is attributed to folding of the complex into a south-dipping, overturned syncline. Interestingly, the harzburgite of the Al Ays Complex is considered to be the least evolved of that sequence. If the same relationship is true of the Wadi al Hwanet-Jabal Iss complex, then the harzburgite may occupy the core of an anticlinal fold. As chromite is stratigraphically positioned, the orientation of “tops” is important from and exploration perspective. At surface, the chromite lenses have an average length of 1-2 m (maximum 10 m) and an average thickness of one metre (maximum 1.5 m). The analysis of eleven massive chromite samples gave Cr_2O_5 contents of 43.7-61.5%, and Cr/Fe ratios of 2.34-4.27. The Cr contents of the massive chromites from the north part of the complex (57.5-61.5% Cr_2O_5 and Cr/Fe of 3.61-4.27) are higher than those in the southern part of the complex.

The Jabal Thys chromite occurrence (MODS 0132) is composed of four pods of iron-rich chromite with dimensions of up to 15 m by 6 m. The occurrences were mapped and sampled, and returned average assays of 34.3% Cr_20_3 with a Cr/Fe ratio of 2.16. The host rocks have been deformed by late stage faulting which has resulted in localized asbestos development in serpentinite. Within similar Urd Group rocks, lenses of massive chromite up to 4 x 1 m are hosted in serpentinite 15 km south of Halaban. These lenses average 44.0% Cr_20_3 with a Cr/Fe ratio of 2.25. Due to the small size of the occurrences, no further exploration has been done to provide greater insight to the geology of these occurrences (Delfour and others, 1982).

3.6.3 RECOMMENDATIONS

Although the Cr_2O_3 content and Cr/Fe ratios shown for some deposits in Tables 83 and 85 may appear to be of potential economic interest (Areas 2, 2W and 3) when considered according to USGS economic criteria presented by Mosier and others (2012), most of the occurrences are very small. The largest lens (JL1), containing about 4,000 t of chromite mineralization, is within the Al Ays ultramafic complex. The chromite occurrences are in the range of what may be acceptable as metallurgical grade (46-55% Cr_20_3) however the high Cr/Fe ratios of 2.4 to 2.73 limit their marketability as shown in the specifications listed in Table 72. An important limiting factor is, of course, the potential tonnages of individual and aggregate lenses. Although gravimetric surveys outlined weak (0.1-0.25 mgal) anomalies, no potentially large, non-outcropping bodies of chromite were outlined. The drilling program demonstrated that even the larger lenses, such as JL1 which is approximately 15 m long by 7 m wide extending to a depth of 15 m, abruptly pinch out about 15 m below surface. If these lenses repeated in a fashion such that multiple chromite bodies co-existed, a small pit might be envisioned for exploitation purposes, however this is not the case – the bodies are usually some distance apart. The chromite lenses do not contain other base metals, such as nickel or precious metals such as platinum group elements ("**PGE**"s), in sufficient quantities to enhance the economic potential.

Table 85
Specifications for Chromite Ore

Use type	Cr_2O_3 (%)	Cr/Fe (ratio)	Al_2O_3 (%)	Impurities (maximum)	Comments
Metallurgical grade A	>64	>2.5	low	4–9.5% C, 3.0% Si, 0.06% S, 0.03% P	Lump ore, nonfriable
Metallurgical grade B	56-64	1.8-2.5	low	4–6% C, 8–14% Si, 0.04% S, 0.03% P	Lump ore, nonfriable
Metallurgical grade C	46-55	<1.8	low	6–8% C, 6% Si, 0.04% S, 0.03% P	Lump ore, nonfriable
Refractory	30-40	2.0-2.5	22-34	12% Fe, 5.5% CaO, 1% MgO	>57% Cr_2O_3 + Al_2O_3, hard, dense, nonfriable lump ore
Chemical	40-46	1.5-2.0	low	5% SiO_2 , Low Mg	Fine-grained, friable ore preferred

Note: compiled by the USGS from DeYoung and others (1984), Harben (2004) and U.S. Business and Defense Services Administration (1962)

Although the ultramafic complexes may not be mapped in sufficient detail to show every aspect of the geology, and the mode of emplacement of the complexes may not yet be fully resolved, the evidence from more than 400 known occurrences strongly suggests that any future chromite discoveries will be more or less the same as what has been discovered to date. Nevertheless, continuing exploration of layered ultramafic bodies is recommended in the Al Ays Complex because of the potential for commercially viable PGE mineralization which should be systematically assessed even though podiform chromite deposits are typically very low in PGEs.

Global experience, as enunciated by the USGS, has not developed an effective means of exploring for chromite deposits (Mosier et al). Most operating mines are significantly larger than the Saudi deposits. The very largest Saudi deposit (4,000 tonnes) situated in location 2 might have been viable as a small operation, however its iron content is unacceptable. According to the USGS commodity summary for 2015, global chromite resources are greater than 12 billion tons of shipping-grade chromite. This resource base, largely concentrated in Kazakhstan and southern Africa, will satisfy world demand for centuries. WGM concludes that the exploitation of these chromite bodies might only be carried out by an individual operator with a small vehicle that allows localized access. In reality, the cost of exploitation on this scale, and the cost of moving the ore to a point of sale (a port) would rapidly overtake the value of the chromite mined. As such, WGM foresees no commercial chromite operation in the KSA until such time as a major deposit is discovered. Based on the results of exploration to date, that appears to be unlikely, and even more unlikely that a Saudi deposit could satisfy steel industry demands in excess of 100,000 tonnes per year of chromium concentrate.

3.6.4 REFERENCES

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Mosier, D.L., Singer, D.A., Moring, B.C. and Galloway, J.P., 2012, **Podiform Chromite Deposits—Database and Grade and Tonnage Models**, US Geological Survey Scientific Investigations Report 2012–5157, 45 pages.

3.7 PORPHYRY OR VEIN-TYPE SN-W-MO DEPOSITS

3.7.1 METALLOGENIC MODEL

This discussion is focused on mineralization of tin, tungsten and/or molybdenum related to granitic rocks, but does not include porphyry-type copper-molybdenum occurrences.

There are no major deposits of tin, tungsten or molybdenum within the Kingdom. In fact, there are only three deposits with any estimated resources, and these have probably been drilled with insufficient density or quality control protocols to be considered compliant with modern industry guidelines for estimating and reporting Mineral Resources and Mineral Reserves. The known deposits are outlined in Table 86.

Table 86.
Summary of Tin, Tungsten, Molybdenum Deposits In Saudi Arabia

MODS	Deposit	Deposit Type	Mineral Resources	Grade	Notes
2688/89	Bi'r At Tawilah N / SE*	Veins	0.265 Mt	0.69% WO_3, 0.13% Sn, 26 g/t Ag	Drilled in 1985
0960	Bid Al Jamalah	Disseminated, stockwork veinlets	10 Mt	0.117% WO_3, 0.012% Sn	
4216	Al Hajrah (Silsilah)	Dissemination,, veins	1.5 Mt	0.2% Sn	Drilled 1983-4

Note: *See section 3.7.3.3 for discussion of Bi'r At Tawilah-SE1

In general, tin, tungsten and molybdenum are not well known in the Precambrian shield areas in Africa or the Middle East. Notable exceptions, however, include: tin (-tungsten) deposits of the large-scale granitoid province of the Kibaran in the Congo Basin, now only mined by artisanal and small-scale miners from alluvial deposits; and the Jos Plateau in Nigeria, where significant commercial production of tin, niobium and tungsten, associated with Jurassic-aged granitic ring complexes ("Younger granites"), ceased some 30-40 years ago, and is now restricted to artisanal and small-scale extraction. Elliott (1983) noted that tin-bearing granites of the Kingdom may be similar to granites in the eastern desert of Egypt and associated with small deposits of tin, tungsten, tin-tungsten, tin-tantalum, and tantalum. For example, tin is a noteworthy potential by-product metal at Abu Dabbab, a large, apo-granite-hosted tantalum-tin deposit in the Nubian Shield. Abu Dabbab's mineral resources have been recently (2015) been estimated at 30 Mt grading 255 g/t Ta_2O_5 and 0.109% Sn; in addition, adjacent alluvial deposits contain an inferred 759 tonnes of tin metal.

In the Kingdom, all of the significant mineralization of tin, tungsten or molybdenum is related to post-orogenic granitic rocks. According to Jackson (1985), stockwork tungsten mineralization at Bid Al Jamalah (formerly Baid Al Jimalah) and disseminated tin mineralization at Al Hajrah (formerly Jabal As Silsilah) are associated with low-Ca granitic rocks; Bi'r At Tawilah is associated with high-Ca granites; and Bid Al Jamalah is associated with a pluton of peraluminous granite.

As discussed by Çerny and others (2005), greisens and mineralized tin, tungsten or molybdenum veins occur within the apical portions of high-level, highly fractionated granites. These granites are typically felsic, silica rich, peraluminous, metaluminous or less commonly alkaline, and are located dominantly in Phanerozoic orogenic belts within continental interiors or margins. The granites themselves typically represent recycled older crustal lithologies.

Greisen deposits consist of disseminated mineralization in the upper roof zones and cusps of hydrothermally altered granite. They can be associated with vein, pipe, lode, and breccia mineralization styles. Greisens represent hydrothermal quartz-muscovite replacement of primary granite. Other minerals include topaz, andalusite, tourmaline, beryl, and fluorite. The zone of greisen alteration may be underlain by zones of feldspathic alteration (K-feldspar and/or albite).

Vein deposits consist of single veins, lodes, or sheeted or stockwork vein systems that may be within the granite or extend into the wall-rock zones. Veins orientation varies depending on local internal or externally-imposed stresses. Veins range in thickness from the millimeter scale to tens of centimeters. The veins consist mainly of quartz and ore minerals, and have siliceous, feldspathic, or muscovite alteration envelopes. There may be vertical alteration and ore mineral zoning.

For granite-related veins and greisens, cassiterite, wolframite, and molybdenite are the main ore minerals, but other elements, such as copper, lead, zinc, silver, fluorine, boron, beryllium and lithium may be locally enriched. Significantly, from a geophysical viewpoint, granite-related Sn-W-Mo systems are poor in sulphur, compared to porphyry systems. Gold in Au-As-Sb vein and disseminated mineralization styles can be present in some tin-tungsten provinces; the Bi'r At Tawilah gold deposit (MODS 1925) near the Bi'r At Tawilah tungsten deposit may be an example of this, although in this instance the gold appears to be related to a different structural event (the Nabitah Fault Zone).

World-wide, examples of (tin - tungsten) mineralization include: the Cornwall district, UK; Panasqueira, Portugal, and the former producing East Kemptville tin mine in Nova Scotia, Canada. Dominantly tungsten-bearing deposits with subordinate tin and molybdenum are exemplified by the Xihuashan system in south-eastern China (China is the world's dominant tungsten producer), Sisson Brook in Canada, and the "tin belt" of Bolivia. Molybdenum (+tungsten-bismuth) deposits include Paleozoic greisen-hosted in eastern Australia; and the Mt. Pleasant deposit in New Brunswick, Canada.

A number of tungsten occurrences in the Jaal Zinan area in the Asir Terrane appear to be stratabound in amphibolitic metamorphic rocks. Worldwide, stratabound tungsten mineralization, often with no direct relation to granitic rocks, is not a major source of tungsten, but includes: laterally extensive, skarn-like horizons in Precambrian gneissic terrane in northeastern Brazil; and Austria's famous Mittersill deposit in metamorphosed volcanic rocks. This type of occurrence in the Kingdom, however, is of relatively low importance.

3.7.2 DISTRIBUTION OF OCCURRENCES

WGM's review of the Saudi Mineral Occurrence Database (MODS) identified 14 occurrences (including prospects and deposits) for which tin is the primary metal; 47 for tungsten; and 24 for molybdenum (85 in total). In addition, there are 67 occurrences in which tin, tungsten and/or molybdenum are listed as a minor constituent, or constituents; the primary metals for these latter occurrences cover a spectrum including gold, silver, copper, cerium and beryllium. These latter occurrences are discussed in this review only when they occur within or near an identified cluster of tin, tungsten and/or molybdenum.

Filtering of the MODS database reveals that only eight of the 85 sites for primary tin, tungsten or molybdenum have been drill-tested, and only three sites where tin, tungsten or molybdenum is a minor commodity have been drill-tested. Clearly, tin, tungsten and molybdenum targets have not attracted a lot of attention in the Kingdom. Most of the exploration work appears to have been completed in the 1970s and 1980s, and then decreased for many years through the 1990s to 2000s, possibly due a combination of low prices (especially for tungsten) and the small sizes of the occurrences in comparison with the Kingdom's other more valuable target types (gold, base metals). A search of the SGS report database by WGM revealed *(almost)* no significant exploration for tin, tungsten or molybdenum as primary commodities since the completion of the WGM review reports in 1992.

Many occurrences are isolated, while others are in clusters of two or three to as high as 11 occurrences. Even within the clusters, occurrences are often widely separated. WGM has identified 16 such groupings, encompassing 57 MODS occurrences, where the occurrences share similar geological controls. These are listed in Table 87. WGM has included in these clusters, where appropriate, possibly related MODS occurrences where tin, tungsten or molybdenum are minor constituents. Given that there are very few large prospects that are relevant to this study, the clusters are often based on relatively minor occurrences of low (or even undefined) importance which do not qualify as prospects, and which have never been drilled. In addition, a number of the clusters occur in regions of other types of mineralization, such as gold. In the following review, only clusters are discussed, except for one tin prospect (Jibal Akkash) which has no known neighbouring mineralization, as well as molybdenum mineralization in the Sidarah pluton which occurs over a broad area.

As shown on Figure 103, nine of the clusters discussed in this review, including the three tin and tungsten deposits with initial resource estimates, are located within the Afif Terrane; three within the Asir Terrane; two in the Hijaz Terrane; and one in each of the Ar Rayn and Ha'il Terranes.

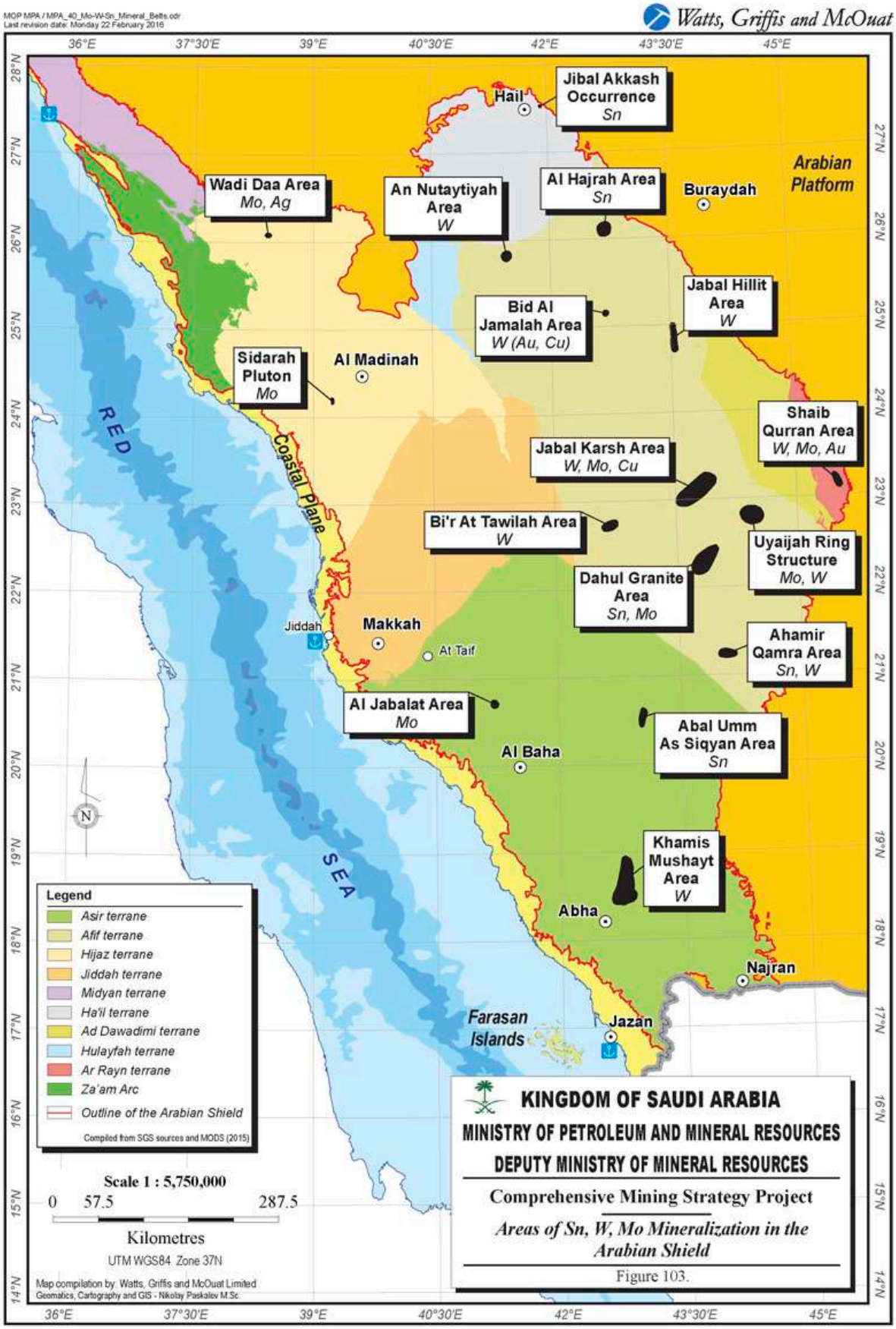
Table 87
Name and Location of Significant Clusters of Tin, Tungsten and Molybdenum Occurrences in the Arabian Shield

MODS	New Name	Old Name	Commodities	Location		Nearest Town	Potential Ranking	Geometry
				long	lat			
AFIF TERRANE								
Al Hajrah Tin, Tungsten								
3262	Al Hajrah	Silsilah	Sn	42.664111	26.094833	Emarah center	Medium	dd, v
4217	Al Hajrah-S	Silsilah-SE	W	42.677806	26.091806	Emarah center	Medium	dd, v
Bid Al Jamalah Area								
2661	Bid Al Jamalah	Bid Al Jamalah	W	42.681250	25.154528	Ar Rass	Medium	dd., stwk vt
2660	Abraq Shawfan-S	Abraq Shawfan-S	Au, W, Cu	42.572472	25.057694	Ar Rass	undefined	v
Bi'r At Tawilah Area								
2688	Bi'r At Tawilah-N	Bi'r At Tawilah-N	W	42.718611	22.775972	At Ta'if	Medium	v
2689	Bi'r At Tawilah-SE	Bi'r At Tawilah-SE	W	42.745278	22.750528	At Ta'if	Very Low	v
3276	Bi'r At Tawilah-SE1	Bi'r At Tawilah-SE1	W	42.730944	22.753861	At Ta'if	Medium	Stwk v
4004	Radamat Jaza	Shaib Lamisah	W	42.597889	22.703917	At Ta'if	Medium	uncertain
1923	Quhban Al Baqarah	Baqarah	Au, W	42.744944	22.952944	'Afif	Very Low	dd, v
Jibal Hillit Area								
3945	Jabal Minyah	Mibari	Sn	43.397611	24.991361	Ad Duwadimi	Very Low	v
4468	Jibal Hillit	Hillit-N	W	43.530889	24.815528	Ad Duwadimi	Very Low	dd, v
4469	Jibal Hillit	Hillit Central	W	43.532333	24.782333	Ad Duwadimi	Very Low	v, ff
4470	Jibal Hillit	Hillit-SE	W	43.523722	24.748056	Ad Duwadimi	Very Low	v, ff
2832	Shaib Umm Adhir-NW2	Umm Adhir mine	Au, As, W, Ag	43.470000	24.793028	Ad Duwadimi	Medium	dd, v
An Nutaytiyah Area								
0539	An Nutaytiyah	An Nutaytiyah	W	41.477778	25.836111	Al Ghazalah	undefined	v
0540	An Nutaytiyah-S	An Nutaytiyah-S	W	41.472222	25.829167	Al Ghazalah	undefined	v
Jabal Karsh Area								
0088	Jabal Karsh	Jabal Kirsh	Mo	43.734889	23.039556	Al Quway'iyah	Medium	uncertain
3622	Halat Khinzir-SE	Halat Khinzir	W	43.852917	23.141500	Al Quway'iyah	Very Low	structural
0090	Abar Ar Raddadi	Jabal Karsh-W	Cu, Zn, Mo	43.587750	23.058806	'Afif	Very Low	v
2287	Madharib Ad Dihasiyah	Jabal Zaydi	Au, Cu, Mo, Zn, Ag	43.965028	23.214556	Al Quway'iyah	Very Low	dd, v
Uyaijah Ring Structure								
0634	Jabal Umm Khurq	Jabal Umm Khurq	Mo	44.520083	22.762722	Al Quway'iyah	Medium	dd, v
0667	Hadabat Al Uwayja	Uyaijah-Thaaban Area	Mo	44.400139	22.799667	Al Quway'iyah	Medium	dd, v
2270	Buhayran	Buhayran	W	44.475830	22.736944	Al Quway'iyah	undefined	dd, len, v
2271	Buhayran-W	Buhayran-W	Mo	44.468972	22.737472	Al Quway'iyah	undefined	dd, len, v
Dahul Granite Area								
2264	Himam Ash Shahad	Jabal Hammat Ash Shah	Mo	43.959722	22.451389	Al Quway'iyah	undefined	dd, strat
2822	Hidab Al Umaylah	Dahul granite District	Sn	43.759139	22.232639	Al Quway'iyah	Low	dd
2823	Hidab Al Umaylah	Jabal Dahul Specialised Granite	Mo	43.759139	22.232639	Al Quway'iyah	undefined	dd
2824	Jabal Al Makhshush	Jabal Al Makhshush	Sn	43.836194	22.311028	Al Quway'iyah	Very Low	uncertain
2825	Jibal Ad Dukhul	Jabal As Suqm granite	Sn	43.814250	22.383167	Al Quway'iyah	undefined	dd
Ahamir Qamra Area								
1176	Ahamir Qamra	Jabal Tarban	W	44.014528	21.252333	Wadi Ad Dawasir	Very Low	uncertain
4036	Ahamir Qamra-SE	Jabal Tarban-SE	W	44.042333	21.218944	Wadi Ad Dawasir	Very Low	dd, v
4037	Jabal Dumar Al Ahmar	Damar Abiad	W	44.165111	21.229361	Wadi Ad Dawasir	undefined	dd
3019	Ahamir Qamra-N	Jabal Tarban-N	Be, Mo, Bi, Ag	44.014667	21.252028	Wadi Ad Dawasir	Very low	dd, v
HA'IL TERRANE								
3362	Jibal Akkash	Jabal Akkash	Sn	41.917444	27.528222	Ash Shinan	High	uncertain

Table 87
Name and Location of Significant Clusters of Tin, Tungsten and Molybdenum Occurrences in the Arabian Shield

MODS	New Name	Old Name	Commodities	Location		Nearest Town	Potential Ranking	Geometry
				long	lat			
ASIR TERRANE								
Khamis Mushayt Area								
0614	Wadi Al Hifah	Bani Thewr	W, Mo	42.668306	18.551611	Khamis Mushayt	Very Low	dd, len
1088	Wadi As Salam	Harfayn	W	42.780861	18.903694	Khamis Mushayt	Very Low	uncertain
1236	Rawdan	Rawdan	W	42.837806	18.580417	Khamis Mushayt	Very Low	len, v
3010	Jibal Iqnan Al Hamam	Jabal Az Zinan	W	42.834056	18.683611	Khamis Mushayt	Very Low	V, ff
3012	Jabal Abu Asidah	Wadi As Samarah	W	42.760944	18.615833	Khamis Mushayt	Very Low	bx
3013	Wadi Al Maytha	Wadi Wahaba	W	42.834806	18.462639	Khamis Mushayt	undefined	v, ff
3015	Wadi Al Faydah	Jibal Marya	W	42.853444	18.530278	Khamis Mushayt	Medium	dd., v, ff
3024	Wadi Al Maytha-N	Wadi Aqbah	W	42.840000	18.487778	Khamis Mushayt	Very Low	v, ff
3025	Wadi Arais	Jabal Al Homrah	W	42.625556	18.456944	Khamis Mushayt	Very Low	len, ff
3026	Jibal Khurus	Sha'lb Samhat Githeir	W	42.626389	18.468611	Khamis Mushayt	Very Low	len, v, ff
4457	Jibal Iqnan Al Hamam-N	Jabal Az Zinan	W	42.839806	18.699028	Khamis Mushayt	Very Low	dd, stwk vt, ff
Al Jabalat Area								
3017	Al Jabalat-S	Jibalat-SE	Mo	41.233056	20.700472	At Ta'if	undefined	dd, v
3018	Shaib Rik	Jibalat-N	Mo	41.190278	20.741667	At Ta'if	Medium	dd, v
Abal Umm As Siqyan Area								
3014	Abal Umm As Siqyan	Abal Umm Al Suqian	Sn	43.017361	20.592111	Tathlith	Medium	dd, v
4033	Abal Al Jharra	Abal Al Jharra	Sn	43.023528	20.486528	Tathlith	Medium	dd, v
AR RAYN TERRANE								
Shaib Qurran Area								
4476	Ashqar Al Wahwahi	Jabal Wahwahi Area	W	45.525278	23.112444	Al Quway'iyah	Low	v
4479	Shaib Qurran	Wadi Gharrah	Mo	45.480083	23.208111	Al Quway'iyah	Medium	v
HIJAZ TERRANE								
Wadi Daa Area								
3145	Wadi Daa-NW2	Jabal Thaa	Mo	38.423694	26.079333	Al 'Ula	Very Low	dd
3146	Wadi Daa-NW1	Jabal Thaa	Mo	38.428056	26.089306	Al 'Ula	Very Low	dd, v
3147	Wadi Daa-NW4	Jabal Thaa	Mo	38.402694	26.081667	Al 'Ula	Very Low	dd
4034	Wadi Daa-N	Jabal Thaa Anc. Work.	Mo	38.440444	26.082444	Al 'Ula	Medium	dd
3143	Wadi Daa-NW3	Jabal Thaa	Ag, Mo, Au	38.420222	26.084139	Al 'Ula	Very Low	dd, v
Sidarah Pluton								
2843	Wadi As Sidarah	Wadi Sidarah	Mo, Ag, Bi	39.200000	24.166667	Emarah center	Medium	dd, v

NOTES: dd= disseminated; v=veins; vt= veinlets; stwk=stockwork; ff=fracture fillings; bx= breccia elements; len=lenses; strat= stratiform


MOP MPA / MPA_40_Mo-W-Sn_Mineral_Belts.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
Jibal Akkash Occurrence Sn
Hail
Wadi Daa Area Mo, Ag
An Nutaytiyah Area W
Al Hajrah Area Sn
Buraydah
Arabian Platform
Jabal Hillit Area W
Bid Al Jamalah Area W (Au, Cu)
Sidarah Pluton Mo
Al Madinah
Shaib Qurran Area W, Mo, Au
RED
Coastal Plane
Jabal Karsh Area W, Mo, Cu
Bi'r At Tawilah Area W
Uyaijah Ring Structure Mo, W
Dahul Granite Area Sn, Mo
Jiddah
Makkah
At Taif
Ahamir Qamra Area Sn, W
Al Jabalat Area Mo
Abal Umm As Siqyan Area Sn
Al Baha
Khamis Mushayt Area W
SEA
Abha
Najran
Farasan Islands
Jazan
Legend
Asir terrane
Afif terrane
Hijaz terrane
Jiddah terrane
Midyan terrane
Ha'il terrane
Ad Dawadimi terrane
Hulayfah terrane
Ar Rayn terrane
Za'am Arc
Outline of the Arabian Shield
Compiled from SGS sources and MODS (2015)
Scale 1 : 5,750,000
0 57.5 287.5
Kilometres
UTM WGS84 Zone 37N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Areas of Sn, W, Mo Mineralization in the Arabian Shield
Figure 103.

3.7.3 TIN AND TUNGSTEN DEPOSITS AND NEIGHBOURING OCCURRENCES

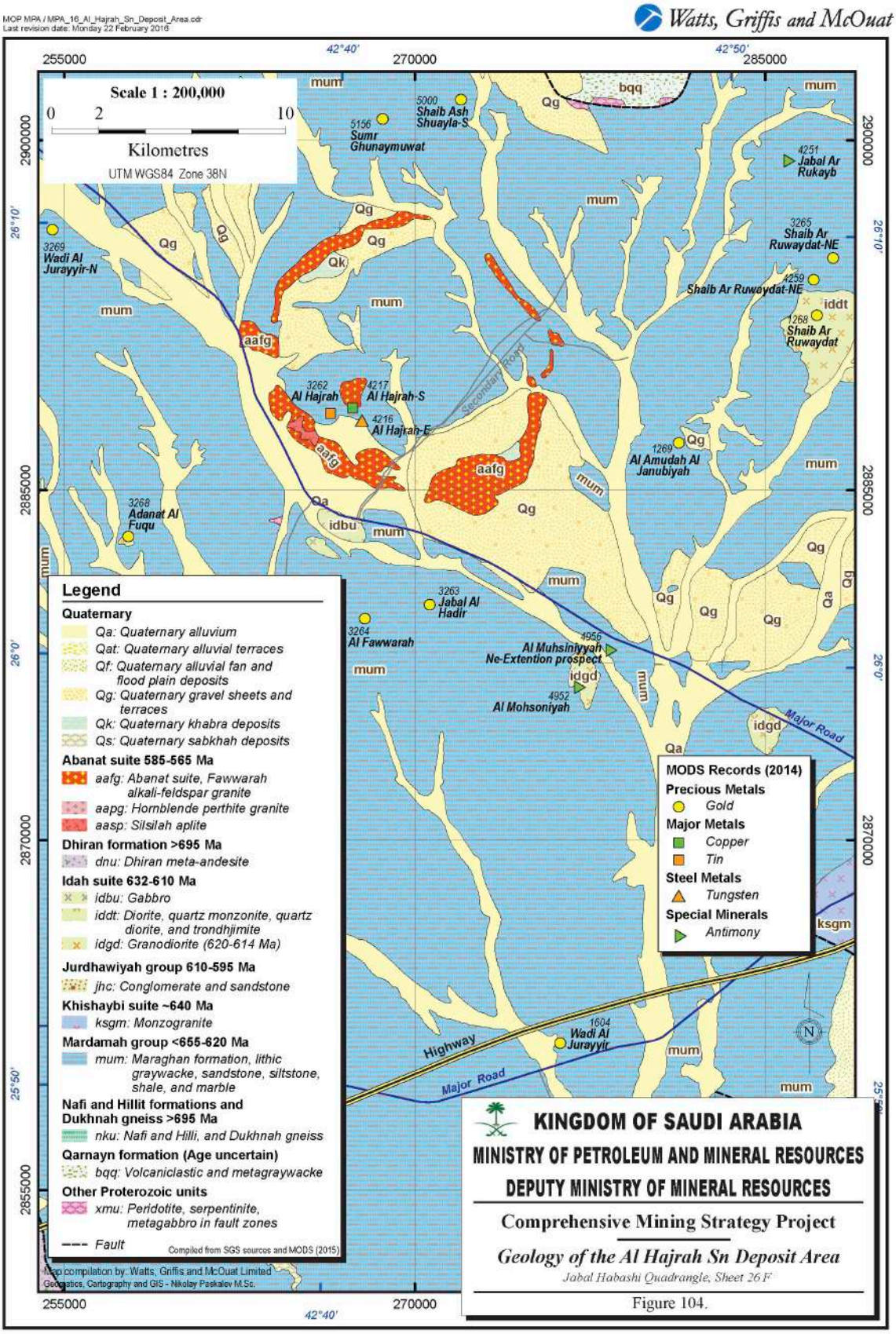
3.7.3.1 Al Hajrah Tin Deposit Area

The Al Hajrah tin deposit (MODS 3262), formerly known as Silsilah, the Al Hajrah S tungsten occurrence (4217) and the Al Hajrah E copper occurrence (4216) are associated with the Silsilah pluton, an "S-type" alkali feldspar granite emplaced into Maraghan sandstones of the Mardama Group (Afif Terrane). The granite forms a ring complex about 12 km in diameter, which was later cut by 587 ± 8 Ma bodies of the Fawwarah granite (Figure 104). Chilled phases of the Fawwarah granite, known as the Hadir aplite, are thought to have acted as barriers to migrating fluids which altered and mineralized the Fawwarah granite. At Al Hajrah, mineralized greisen underlies the Hadir aplite in the southwest part of the complex. Cassiterite (up to 10%) and minor wolframite, pyrite, galena, chalcopyrite, sphalerite and arsenopyrite are localized within greisen zones. Quartz veins cutting the Farawwah granite are enriched in silver, lead and molybdenum.

In the early 1980s, the deposit was drilled to a depth of 50 m with 39 percussion holes and six diamond drill holes. A resource, likely non-compliant to modern standards, was estimated at 1.2 Mt grading 0.187% Sn; this has been updated in the MODS to 1.5 Mt grading 0.2% Sn, but any work done for the modification is unclear to WGM. In 1992, WGM noted that the mean grade from diamond drill holes was about 42% higher than from percussion holes, suggesting the potential for significant increase in grade by re-drilling with cored holes. Figure 105 suggests limited depth potential in the area of the deposit. However, telluric-electric and audio-magnetotelluric surveys of the ring complex delineated an electrically conductive zone extending from 150-400 m below the Fawwarah granite in the western interior of the ring complex. This has been interpreted as strong argillization due to hydrothermal alteration, possibly containing metallic mineralization. It could be a target for additional tin or gold mineralization, or possibly even a kaolin deposit. In 1992, WGM recommended re-drilling of percussion holes with diamond drill core holes (3,900 m) as well as additional detailed drill testing, if warranted, of the two main greisen areas (8,900 m).

The Al Hajrah S tungsten occurrence has been trenched, and is considered medium importance in the MODS. The Al Hajrah E copper (-silver-lead-zinc) occurrence (MODS 4216) is in the same area as the tin and tungsten occurrences, and is associated with granitic rocks and quartz veining. The ancient workings are of very low importance.

For comparative purposes, it is noteworthy that the feasibility of re-opening the dormant East Kemptville tin mine, in Canada, is being contemplated, probably pending improved tin pricing; there is a recently-announced (2015) indicated resource of 18.47 Mt grading 0.176% Sn, and an inferred resource of 16.95 Mt grading 0.148% Sn (0.1% Sn cut-off; plus minor Zn and Cu). The grade is similar to Al Hajrah, but the deposit is more than 20X the size.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Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
Scale 1 : 200,000
0 2 10
Kilometres
UTM WGS84 Zone 38N
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qs: Quaternary sabkhah deposits
Abanat suite 585-565 Ma
aafg: Abanat suite, Fawwarah alkali-feldspar granite
aapg: Hornblende perthite granite
aasp: Silsilah aplite
Dhiran formation >695 Ma
dnu: Dhiran meta-andesite
Idah suite 632-610 Ma
idbu: Gabbro
iddt: Diorite, quartz monzonite, quartz diorite, and trondhjimite
idgd: Granodiorite (620-614 Ma)
Jurdhawiyah group 610-595 Ma
jhc: Conglomerate and sandstone
Khishaybi suite ~640 Ma
ksgm: Monzogranite
Mardamah group <655-620 Ma
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
Nafi and Hillit formations and Dukhnah gneiss >695 Ma
nku: Nafi and Hilli, and Dukhnah gneiss
Qarnayn formation (Age uncertain)
bqq: Volcaniclastic and metagraywacke
Other Proterozoic units
xmu: Peridotite, serpentinite, metagabbro in fault zones
Fault
Compiled from SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
MODS Records (2014)
Precious Metals
Gold
Major Metals
Copper
Tin
Steel Metals
Tungsten
Special Minerals
Antimony
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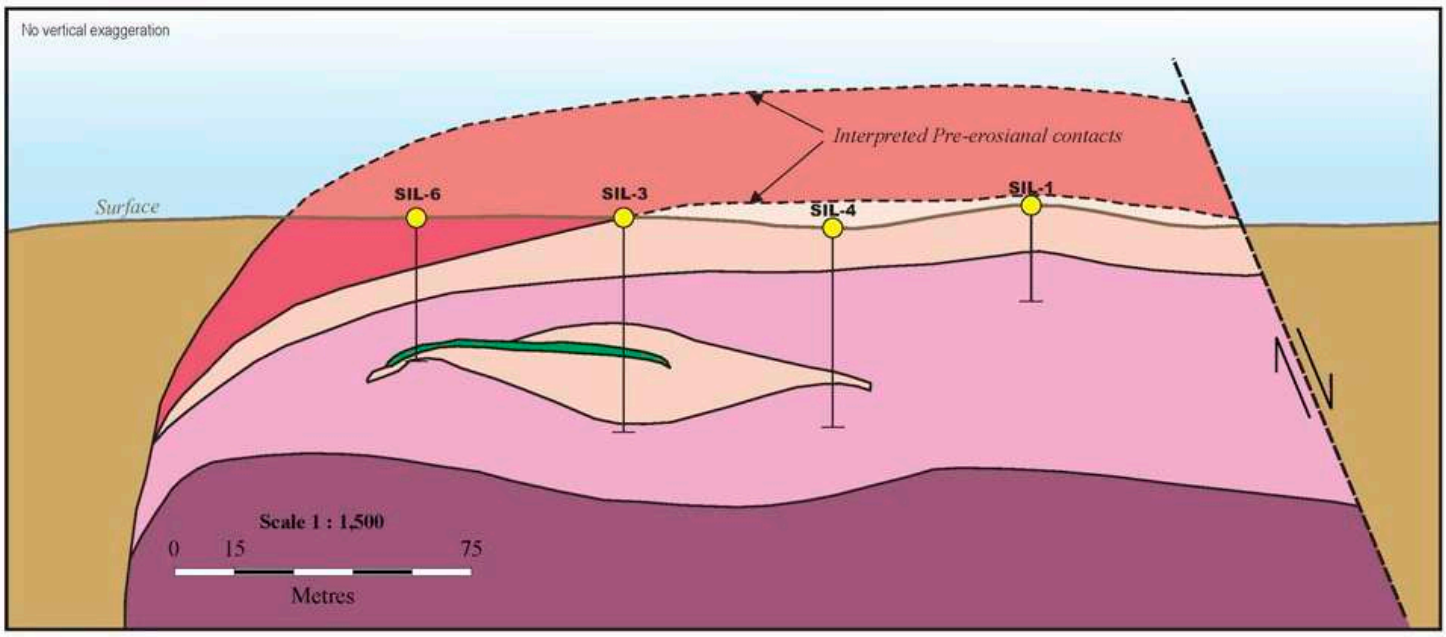
Comprehensive Mining Strategy Project
Geology of the Al Hajrah Sn Deposit Area
Jabal Habashi Quadrangle, Sheet 26 F
Figure 104.
Shaib Ash Shuayla-S
Sumr Ghunaymuwat
Jabal Ar Rukayb
Shaib Ar Ruwaydat-NE
Wadi Al Jurayyir-N
Shaib Ar Ruwaydat
Al Hajrah
Al Hajrah-S
Al Hajrah-E
Al Amudah Al Janubiyah
Adanat Al Fuqu
Jabal Al Hadir
Al Fawwarah
Al Muhsiniyyah Ne-Extention prospect
Al Mohsoniyah
Wadi Al Jurayyir
Secondary Road
Major Road
Highway
255000
270000
285000
2900000
2885000
2870000
2855000
42°40'
42°50'
26°10'
26°0'
25°50'



Legend

- *Hadhir aplite and pegmatite*
- *Pegmatite*
- *Greisenized Fawwarah granite*
- *Albitized Fawwarah granite*
- *Fresh Fawwarah granite*
- *Murdama sandstone*

SIL-1 — *Diamond drillhole, showing drillhole number*

Fault showing relative vertical movement

After Kamilli (1987)

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Comprehensive Mining Strategy Project

Interpretive Section Across Area of Al Hajrah Tin Mineralization

Figure 105.

lap compilation by: Watts, Griffis and McOuat Limited
eomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

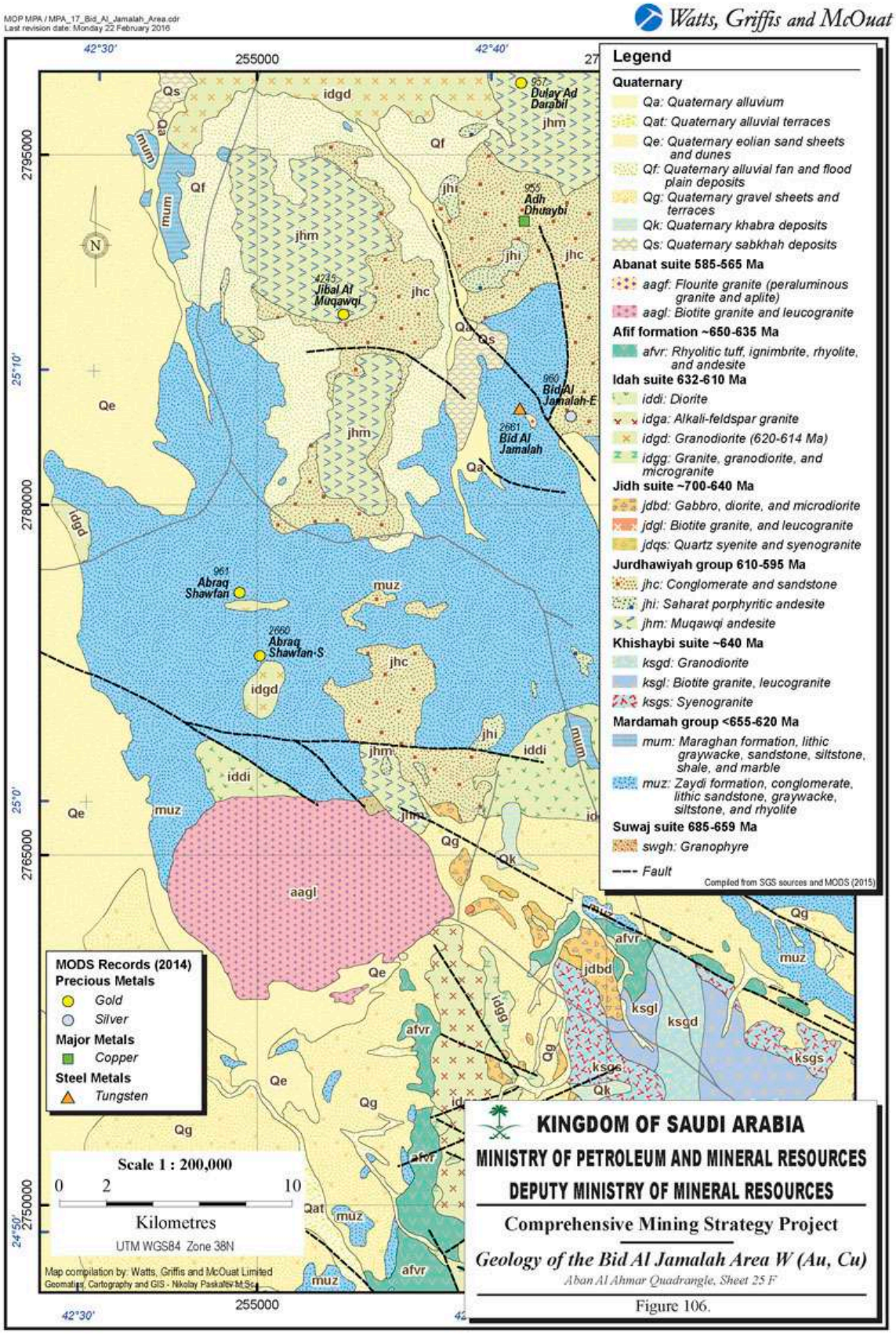
Because of its small size, economic potential for the Al Hajrah tin deposit is, at the present level of knowledge, limited. Nevertheless, of the three deposits of tin and tungsten in the Kingdom with some resources outlined, Al Hajrah is the most valuable in terms of contained metal. The exploration database for the deposit should be thoroughly reviewed and evaluated.

3.7.3.2 Bid Al Jamalah Area

At the Bid Al Jamalah tungsten deposit (MODS 2661), previously known as Baid al Jimalah, quartz vein-hosted tungsten mineralization is associated with a peraluminous biotite granite porphyry (569 ± 16 Ma). A regional northwest-trending Najd fault crosses the prospect area (Figure 106). The mineralization is exposed in a window where overlying clastic sedimentary rocks of the Zaydi Formation (Mardama Group, Afif Terrane) have been eroded. Four zones of east-southeast-trending quartz veins, with wolframite and rare cassiterite, are mostly located in the granite where it is greisenized and quartz-muscovite-altered. A resource estimate of 10 Mt grading 0.117% WO_3 and 0.012% Sn was based on the arithmetic average of mineralization in cored diamond drill holes (six totaling 1,113 m) and shallow percussion holes (17 holes totaling 482 m) to a total depth of only 25 m. This 1980s estimate is not up to modern standards, particularly in light of the reliance on percussion drill hole samples. In an earlier report, WGM stated that additional potential cannot be evaluated without understanding the sub-surface disposition of the granite; the small size of the pluton could, however, may limit the potential. Accessory sulphide minerals (pyrite, pyrrhotite and arsenopyrite) suggest that induced polarization could be a useful geophysical exploration tool.

The Bid Al Jamalah tungsten deposit has open-pit potential only if substantial additional resources could be outlined and the grade increased somewhat. Although historic (1983), it is noteworthy that the Mt. Carbine deposit in Australia, a significant past-producer, at one time had a resource of 8.2 million tonnes grading 0.12% WO_3, similar in size and grade to Bid Al Jamalah. Current Mt. Carbine mineral resources stand at 39 Mt at a grade of 0.14% WO_3 (more than 4X the WO_3 content of Bid Al Jamalah), and the deposit is not in production. Mt. Carbine is of further note because it pioneered the use of photometric sorting to upgrade ore prior to milling. According to Carbine Tungsten, more recent trials on stockpiled material using a transmission X-ray sorter resulted in a "conservative upgrade of more than 8X the bulk sample grade"; this avenue could be investigated for wolframite mineralization in the Kingdom.

In a previous report, WGM (1992) concluded that most of the veins at Bid Al Jamalah had been adequately tested by drilling, but that several significant geochemical anomalies, largely beyond the monzogranite, deserved diamond drill testing (1,310 m).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Last revision date: Monday 22 February 2016
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42°40'
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25°10'
25°0'
24°50'
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qs: Quaternary sabkhah deposits
Abanat suite 585-565 Ma
aagf: Flourite granite (peraluminous granite and aplite)
aagl: Biotite granite and leucogranite
Afif formation ~650-635 Ma
afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
Idah suite 632-610 Ma
iddi: Diorite
idga: Alkali-feldspar granite
idgd: Granodiorite (620-614 Ma)
idgg: Granite, granodiorite, and microgranite
Jidh suite ~700-640 Ma
jdbd: Gabbro, diorite, and microdiorite
jdgl: Biotite granite, and leucogranite
jdqs: Quartz syenite and syenogranite
Jurdhawiyah group 610-595 Ma
jhc: Conglomerate and sandstone
jhi: Saharat porphyritic andesite
jhm: Muqawqi andesite
Khishaybi suite ~640 Ma
ksgd: Granodiorite
ksgl: Biotite granite, leucogranite
ksgs: Syenogranite
Mardamah group <655-620 Ma
mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble
muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
Suwaj suite 685-659 Ma
swgh: Granophyre
Fault
Compiled from SGS sources and MODS (2015)
MODS Records (2014)
Precious Metals
Gold
Silver
Major Metals
Copper
Steel Metals
Tungsten
Scale 1 : 200,000
0 2 10
Kilometres
UTM WGS84 Zone 38N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
957 Dulay Ad Darabil
955 Adh Dhuaybi
4245 Jibal Al Muqawqi
960 Bid Al Jamalah-E
2661 Bid Al Jamalah
961 Abraq Shawfan
2660 Abraq Shawfan-S
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Geology of the Bid Al Jamalah Area W (Au, Cu)
Aban Al Ahmar Quadrangle, Sheet 25 F
Figure 106.

The Abraq Shawfan gold-tungsten-copper occurrence about 15 km to the SW of Bid Ad Jamalah, is hosted in hornfelsed Zaydi Formation strata, and is associated with granodiorite (and possibly leucogranite) of the Idah suite. There are no other similarly-age intrusions in the area, so the regional potential is somewhat limited. Nevertheless, additional work could be done at Bid Ad Jamalah.

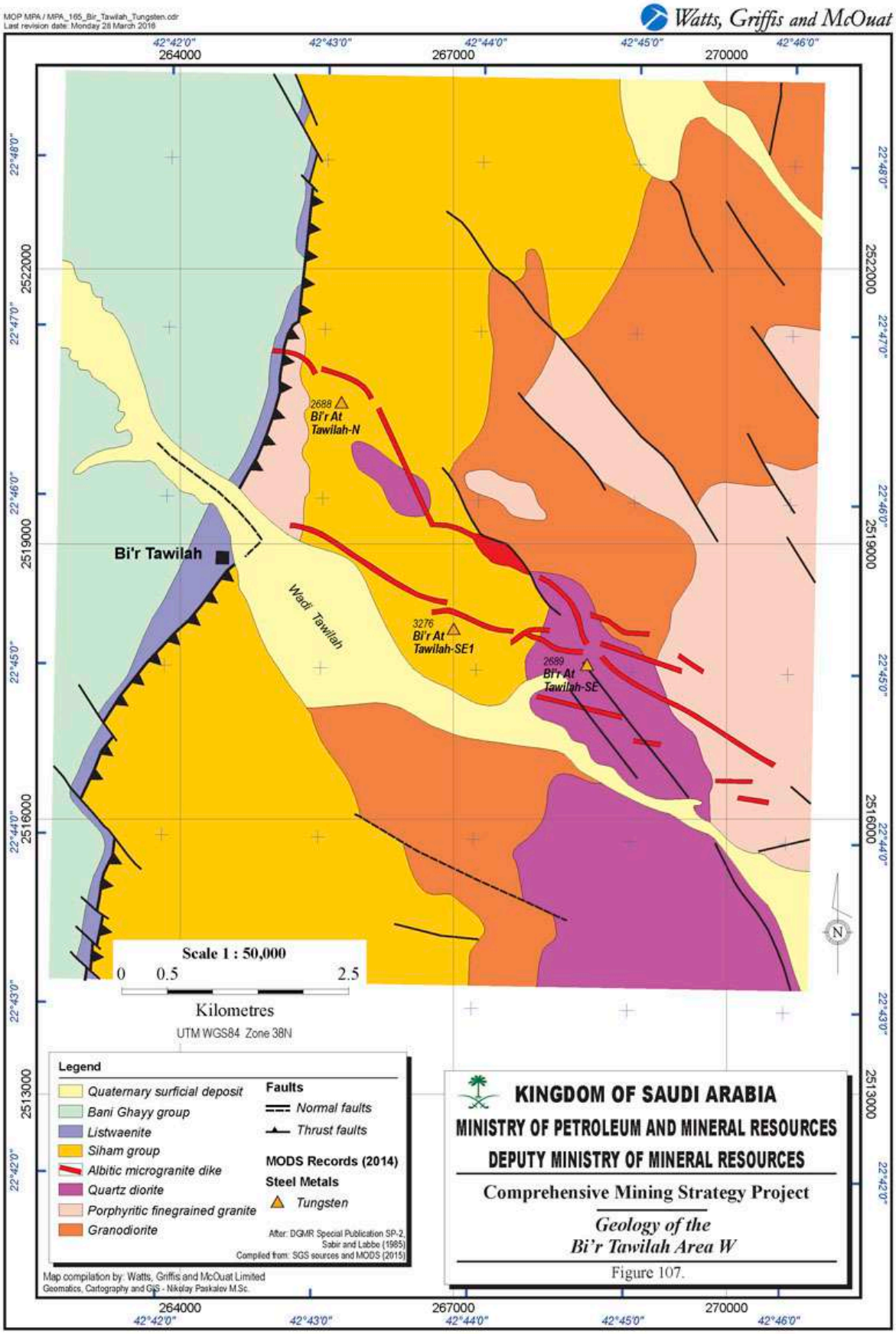
3.7.3.3 Bi'r At Tawilah Area

With respect to grade and contained metal, the Bi'r At Tawilah area hosts the most significant tungsten (-molybdenum-tin) mineralization in the Kingdom: at Bi'r At Tawilah N (MODS 2688), Bi'r At Tawilah-SE1 (3276) and Bi'r At Tawilah SE (2689) (Figure 107). Bi'r At Tawilah N has a quoted mineral resource of 265,000 t grading 0.69% WO_3, 0.13% Sn and 26 g/t Ag; outlined from seven percussion and six diamond drill holes in 1985. This estimate is not up to present regulatory standards, and is based on the arithmetic "average" grade of intercepts in drill holes without allowing for volumetric calculations based on the distance between holes. *(It should be noted that Bi'r At Tawilah-SE1 is listed in MODS as having a resource of 1.8 t contained gold, as well as a mineral resource of 265,000 t grading 1.2% WO_3; WGM believes that there is some confusion with Bi'r At Tawilah N and the Bi'r At Tawilah gold deposit, and that neither resource pertains to Bi'r At Tawilah-SE1; clarification is required.)*

Geochemical programs, and percussion and diamond drilling were done in the mid-1980s. The three occurrences have been geophysically examined on the ground with varying combinations of magnetics, induced polarization, TUREM-EM and gravity.

Of interest are several gold occurrences in the vicinity, including Bi'r At Tawilah (MODS 1925), Wadi As Sara (3279), Dil Al Manthurah (3278), and Dil Al Manthurah-S (4492). All of these are prospects which have been drilled with established Mineral Resources. Bi'r At Tawilah, held by Ma'aden, is a gold deposit on which a 2011 JORC-compliant mineral resource has been estimated, as discussed previously in this report. This and other gold occurrences are all located adjacent to the low-angle thrust fault, and are associated with the Nabitah Fault Zone.

The Bi'r At Tawilah tungsten occurrences are in a 1 km x 4 km, northwest-trending zone. All are structurally controlled, and consist of veins or stockwork veins, and are in proximity to or within a monzogranite of the Humaymah Suite. Host rocks include granite, and quartz-sericite schists. Bi'r At Tawilah-N lies in proximity to a thrust fault, west of which are sedimentary rocks of the Majayrib Fm. The occurrences are within the Afif Terrane. The resources outlined at Bi'r At Tawilah are of relatively good grade, but of insufficient tonnage to be considered potentially economic. Bi'r At Tawilah-N has been drilled to at most 100 m from surface; a single hole at Bi'r At Tawilah-SE1 showed that veins are present up to 250 m deep. Based on a Chinese model of vein and veinlet distribution, Sabir and Labbé (1986) proposed that Bi'r At Tawilah-SE1 presented the best potential for additional resources.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Last revision date: Monday 26 March 2018
Watts, Griffis and McOuat
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42°46'0"
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267000
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22°42'0"
2522000
2519000
2516000
2513000
2688
Bi'r At
Tawilah-N
Bi'r Tawilah
Wadi Tawilah
3276
Bi'r At
Tawilah-SE1
2689
Bi'r At
Tawilah-SE
N
Scale 1 : 50,000
0 0.5 2.5
Kilometres
UTM WGS84 Zone 38N
Legend
Quaternary surficial deposit
Bani Ghayy group
Listwaenite
Siham group
Albitic microgranite dike
Quartz diorite
Porphyritic finegrained granite
Granodiorite
Faults
Normal faults
Thrust faults
MODS Records (2014)
Steel Metals
Tungsten
After: DGMR Special Publication SP-2,
Sabir and Labbe (1985)
Compiled from: SGS sources and MODS (2015)
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
KINGDOM OF SAUDI ARABIA
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DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the
Bi'r Tawilah Area W
Figure 107.

WGM (1992) concluded that none of the tungsten mineralized zones at Bi'r At Tawilah had been completely delineated by drilling, and all prospects had untested geochemical or geophysical anomalies. Amongst other work, drilling (1,600 m) of an unexplained gravity anomaly was proposed. Although the mineral resources at present are subeconomic, it is recommended that a review of existing geophysical, drill hole and trenching data be undertaken to determine any potential for increasing the volume (tonnage) of the deposit. A minimum target threshold would be roughly 1 million metric ton units ("**mtu**") of contained WO_3.

Regional data, including wadi geochemistry, should be compiled to determine the possibility of an association of tungsten mineralization with other plutons of the Humaymah suite. With some exceptions – most notably the scheelite-chalcopyrite-pyrrhotite association of the Cordillera of northern Canada - tungsten mineralization is difficult to explore with geophysics; however, the local presence of sulphide minerals at B'ir At Tawilah is encouraging for the expanded use of IP. Drainage geochemistry and basic prospecting are fundamental.

Although probably genetically unrelated to the tungsten, the structurally-related gold occurrences add an extra incentive to further exploration in this region. At least some of this area is located on a Ma'aden lease.

The Radamat Jaza tungsten prospect (MODS 4004) is located about 17 km west-southwest of the Bi'r At Tawilah prospects. It has been examined with a variety of geophysical surveys (self potential, induced polarisation, mise a la masse), trenched and drilled. It is considered of medium importance in the MODS. Radamat Jaza occurs near the contact of basalt and andesite of the Tandab Formation and monzogranite of the Jidh Suite; however, a body of alkali-feldspar granite of the Humaymah Suite is located nearby. Although it has been reportedly drilled, the morphology of the mineralization is "unknown".

3.7.4 CLUSTERS OF OCCURRENCES AND PROSPECTS

3.7.4.1 Jibal Hillit Area

Three tungsten occurrences (MODS 4468-4470) lie near the contact between granitic rocks of the Najira granite and metasedimentary rocks of the Hillit Formation. All of the occurrences are structurally-related, have had no physical work, and are of very low importance in the MODS. A review of the details of past exploration could draw attention to the locally sheared (?) contact between the sedimentary and intrusive rocks around Jabal Hillit. There is a tungsten-bearing gold occurrence to the west known as Shaib umm Adhir (2832), but it is located within a cluster of gold occurrences within hornblendite and gabbro of the Suwaj suite and appears to be unrelated to tin and tungsten metallogenesis. At Jabal Minyah (3945), situated about 25 km north-northwest of the Jibal Hillit occurrences, a tin occurrence is associated with granitic rocks, greisen and hornfels of the Abanat suite.

3.7.4.2 An Nutaytiyah Area

Two vein-related tungsten occurrences of undefined importance occur within a subcircular body of granite of the Idah Suite and orthogneiss (MODS 0539-0540). Neither has been trenched or drilled. Several small gold occurrences are located just southeast of the granite. An area of 14 copper occurrences and two tungsten occurrences about 20-30 km to the south; they are structurally- or vein-related but occur mostly in volcanic and sedimentary rocks of the Isamah Formation. No economic potential is evident for the An Nutaytiyah occurrences, but the area of the granite should be re-assessed with systematic prospecting and geochemistry because there is no evidence of any sustained tin-tungsten exploration in this area.

3.7.4.3 Jabal Karsh Area

The Jabal Karsh (Kirsh) molybdenum prospect (MODS 0088) was discovered by prospecting and geochemical sampling; it is considered a medium-importance prospect. The surrounding area is underlain by sedimentary and volcanic rocks of the Zaydi Formation (Mardama Group), intruded by a series of felsic plutons of early (syntectonic) granodiorite, peralkaline granite, and leucogranite. Mineralization is hosted in a shear zone cutting a small exposure of leucogranite. The structure was traced for 160 m and found to be up to 30 m in width. Bedrock surface sampling yielded assays as high as 564 ppm Mo. Fine grained molybdenite-pyrite mineralization occurs within a “hyper-silicified” breccia with quartz veins ranging from a few millimetres to approximately 10 m in thickness. The zone was shallowly percussion- and diamond-drilled (5 holes for 494 m) with poor results although only two percussion holes were drilled on the main prospect (maximum 108 ppm Mo over 3 m, and 262 ppm Mo over 12 m).

All the prospects are low importance targets and, at present, this area has no evident economic potential. In 1992, WGM concluded that surface work was adequate at Jabal Karsh, but felt that the drilling program required additional diamond drill holes to more systematically explore the host structure. The geology is interesting and so-called “hyper-silicified” structures could have potential for precious metals mineralization. Two holes are insufficient to kill a good target, and the fact that the holes were very short percussion holes does not present sufficient evidence to dismiss this target with a high level of comfort. Additional diamond drilling is recommended with +/- 200 metre long holes on five sections along the exposed length of the breccia zone/structure. All samples should be analysed by ICP for a multi-element package and fire assayed for gold using a 50-gram charge.

The Halat Khinzir tungsten occurrence (15 km northeast of Jabal Karsh), as well as a molybdenum-bearing gold occurrence and several copper occurrences, are situated within or near the margins of bodies of granitic rocks of the Al Khushaymiyah Suite. These also should be explored to the extent that the geology and trace element and precious metal content can be known although drilling is not recommended at this time.

3.7.4.4 Uyaijah Ring Structure

Two molybdenum occurrences (MODS 0634 and 0667) and one tungsten-molybdenum occurrence (2270-71) are associated with the Uyaijah ring structure. The ring structure is part of the Kushaiymah intrusive complex which was emplaced into clastic sedimentary strata of the Zaydi Formation (Mardama Group). Older rocks of the complex include porphyritic granodiorite and quartz monzonite, the latter forming the core of the ring dyke. The ring dyke itself consists of an alkali granite suite including granite, pegmatite and rhyolite. Quartz veins, containing local scheelite and molybdenite, occur in swarms and stockworks over widths of up to 100 m. The occurrences are listed as undefined to medium importance in MODS. Although evident economic potential is low, the ring structure is large (at least 16 km across) and may warrant additional investigation. Detailed mapping and bedrock sampling is recommended to quantity the prospects beyond what is know at this time.

3.7.4.5 Dahul Granite Cluster

In this broad area, five tin and molybdenum occurrences (with minor tungsten, tantalum and niobium) are associated with several phases of the regional-scale Haml intrusive suite: tin in monzogranite-granodiorite showing evidence of large fracture/fault systems; tin and molybdenum in calk-alkaline and alkaline granite in the core of a ring complex; and molybdenum in metamorphic rocks of the Surayh Complex, but possibly in proximity to orthogneiss of the Haml Suite. All are listed in the MODS index (2264, 2822-2825), as being structurally-controlled. Those within intrusive rocks are hosted in “granite and pegmatite”. None has had any physical work, and all are categorized as undefined, very low or low importance. These are considered to be minor occurrences with no apparent economic potential under the present level of understanding. Detailed mapping and bedrock sampling is recommended to quantity the prospects beyond what is know at this time.

3.7.4.6 Ahamir Qamra Area

This cluster consists of three tungsten occurrences (1176, 4036-47) and one beryllium-molybdenum occurrence over a distance of about 16 km. The tungsten occurrences are related to monzogranite and syenogranite of the Haml Suite. The beryllium-molybdenum occurrence is associated with monzogranite, pegmatite and peralkaline granite within an older tonalite. All are of low to undefined importance and display little economic potential with the present state of exploration. Detailed mapping and bedrock sampling is recommended to quantity the prospects beyond what is know at this time.

3.7.4.7 Jibal Akkash

The Jibal Akkash tin-bearing greisen (MODS 3362) was discovered during regional geological mapping in 1983. Follow-up exploration consisted of 1:10,000 scale plane-table mapping of the greisen along the contact of the granite. Approximately one-half of the granite and its contact are exposed. The main greisen is about 400 m long, and up to 50 m wide, although there are several other mapped greisen zones to the north and south over a distance of about 3 km. The best tin content from the USGS sampling as of 1992 was 1,600 ppm; the average was 710 ppm based on 32 grab samples.

Although isolated, this occurrence has potentially significant mineralization, consisting of disseminated cassiterite and sphalerite in a greisen on the western margin of a small pluton of the Akkash granite in contact with older Ha'il granite. In the MODS, the occurrence is listed as high importance. The work to date has focused on lithogeochemical characterization of the granite rather than exploring the greisen. WGM (1992) recommended detailed geological, geochemical and ground magnetic surveys over the 3-km known zone of greisens bodies using a 100 x 50 m grid, followed by trenching and 2,000 m of drilling, if warranted, to a vertical depth of 200 m. IP surveying was also recommended in areas where tin and associated mineralization might provide targetable anomalies at depth. Systematic prospecting is warranted over the Akkash granite, particularly along the 20-km long contact to search for additional (similar) greisens.

3.7.4.8 Khamis Mushayt (Southern Asir) Tungsten Area

Eleven tungsten occurrences, including Wadi al Hifah (MODS 0614), Wadi as Salam (1088), Rawdan (1236), Jibal Iqnan al Hamam (3010, 4457), Jabal Abuasidah (3012) and Wadi al Maytha (3013, 3024), Wadi al Faydah (3015), Wadi Arais (3025) and Jibal Khurus (3026), are located over a broad area of approximately 20 km x 50 km in the north-central Abha Quadrangle, north of Khamis Mushayt. Only one of these occurrences, Wadi Al Faydah (previously known as Jabal Marya), has seen any drilling *(by Riofinex in 1983)*, and the rest are classified as low or undefined importance. The occurrences are located in amphibolite of the Talath Complex, volcanic rocks and amphibolite of the Khadra belt, and granodiorite/granite gneiss of the Nabitah gneiss suite. There is an overall spatial relationship with large to small bodies of biotite monzogranite of the Ibn Hashbal Suite. Regionally, there is a variety of modes of mineralization (see previous summary in Table 87), including disseminations, veinlets and fracture fillings in hornblendite, large quartz veins and shear zones and calc-silicate horizons within mafic amphibolitic sequences (Jackson, 1985). The best scheelite mineralization at Wadi Al Faydah is disseminated within a hornblendic phase of a gabbro outcropping over a 150 m x 60 m area. The best intersection in four diamond drill holes (350 m total) was 0.13% WO_3 across 4.20 m.

The amphibolite-grade host rock is reminiscent of the stratabound tungsten (scheelite) mineralization in the Serido tungsten province in the northeastern Brazilian shield, which has been a small but significant

producer of scheelite since the Second World War. In 1992, WGM noted an association of tungsten with sulphide minerals at Jibal Iqnan Al Hamam and Jibal Iqnan Al Hamam-N, and recommended ground geophysical surveys, to be followed by trenching or drilling if appropriate. In general, however, the Khamis Mushayt area occurrences are widely scattered and are thought to have little economic potential based on the present level of understanding. Wadi Al Faydah may be the exception. Although there is not enough information to recommend aggressive exploration, there is also a lack of information that would limit its potential. Additional systematic geological mapping and surface sampling is recommended to enhance the knowledge base of this tungsten occurrence. If continuity of the mineralization can be demonstrated, then additional exploration including geophysical surveying such as magnetometer and IP surveying may be justified to define targets for drilling.

3.7.4.9 Al Jabalat Area

The two molybdenum occurrences are about 6 km apart, Al Jalabat-S (MODS 3017) and Shaib Rik (3018), which were formerly known as Jibalat SE and North. Neither has seen physical work, although Al Jalabat-S is considered to be a “prospect” where mineralization consists of disseminations and veins in granite and pegmatite of the Qazayel monzogranite. The other occurrence is in older diorite, microgranite and greisen of Buwwah Suite intrusive rocks. Tin, bismuth, copper and silver are listed as minor constituents. Because of the lack of physical work done, there is no evidence of economic potential. Some additional mapping and systematic sampling is recommended to determine the size of the prospects in relation to strike length and width of mineralization, and the average molybdenum content.

3.7.4.10 Abal Umm As Siqyan Area

Two minor tin occurrences, Abal Umm As Siqyan (MODS 3014) which contains minor niobium with some tin (up to 244 ppm) and tantalum (up to 330 ppm), and Abal Al Jharra (4033) are associated with a variety of granitoid rocks (diorite, microgranite, calc-alkaline granodiorite and monzogranite) belonging to what appears to be the Kawr Suite. Mineralization is disseminated and vein-hosted. Although listed as medium importance, the occurrences have only been visited (prospected), and no economic potential is apparent based on the present degree of exploration. The Kawr Suite of intrusive rocks is very widespread in the region (i.e. Wadi Bishah Quadrangle) and the geochemical data should be reviewed. Some localized systematic geological mapping and systematic sampling is recommended to determine the size of the prospects in relation to strike length and width of mineralization, and the average tin content.

3.7.4.11 Shaib Qurran Area

Although the molybdenum and tungsten mineralization at Shaib Qurran Area (MODS 4479) and Ashqar Al Wahwahi (4476) most likely formed under different conditions, Doebrich and others (2005) considered them together because they were both clearly related to the latest and most highly evolved episode of magmatism, specifically syn- to post-Al 'Amar Group intrusive rocks including granite, alkali-feldspar granite and pegmatite. Mineralization is related to quartz veining and greisenization. In the MODS, these are considered low and medium importance occurrences, and have seen no work beyond sampling; no economic potential is evident on the basis of work done to date. Given that the size of the prospects is unknown in relation to strike length and width of mineralization, and the average molybdenum and tungsten contents are also unknown, some systematic mapping and sampling is justified to better define these prospects.

3.7.4.12 Wadi Daa Molybdenum Cluster

The four molybdenum occurrences and one silver-molybdenum occurrence in the small Wadi Daa cluster (MODS 3143, 3145-3147 and 4034) consist of disseminations and veins associated with a small body of undifferentiated (?) calc-alkaline granite, granodiorite and (quartz) syenite. This area was previously known as Jabal Thaa. The intrusion was emplaced into mafic volcanic rocks of the Matran Formation (Al Ays Group). Four of the occurrences are of very low importance; one is ranked as "Medium". Only one of the prospects had any physical work completed (trenching). Ancient workings have been recognized at Wadi Daa-N (4034) which has been given a medium ranking in the MODS. The specific technical reason for its ranking is unknown, and this needs to be explained. At present, there is no recognizable economic potential in the area based on the other three occurrences. WGM recommends systematic detailed mapping and sampling at Wadi Daa-N for two reasons:

- the grade and physical dimensions of the mineralization is uncertain; and,
- the ancient miners would not have been interested in molybdenum as they had no use for this mineral/metal, and so if some level of mining was sustained, it stands to reason that the ancient miners may have been exploiting something of greater value such as copper, gold or silver.

3.7.4.13 Sidarah Pluton

At Wadi as Sidarah (2843), formerly known as Wadi Sidarah, quartz and quartz-feldspar veins locally containing disseminated pyrite and molybdenite (with minor silver, bismuth and lead) are scattered throughout an area of 7 km x 2.5 km in the northern part of the Sidarah pluton, a monzogranite. This area of mineralization is treated as a single MODS having medium importance. Based on the available information, there has been no trenching or drilling of this prospect. It is worth noting that the MODS

database co-ordinates give a location that is outside of the area of mineralization shown in Jackson (1986). The veining is associated with extensive hydrothermal alteration. Although mineralization at a local scale may contain up to 0.6% Mo, it is sporadic. Most of the mineralized veins are oriented at 010°, and may be related to tension features associated with Najd faulting, and synchronous with emplacement of the Sidarah pluton. Although there is no apparent economic potential at the current level of work, the large size of the mineralized area suggests that systematic geological mapping and sampling is warranted to test for the potential of bulk mineralization.

3.7.5 GENERAL COMMENTS AND RECOMMENDATIONS

As currently defined, mineralization of tin, tungsten and molybdenum in the Kingdom has limited economic potential. As noted above, however, there is the possibility that resources at the three main deposits – Al Hajrah (Sn), Bid Al Jamalah (W) and Bi'r At Tawilah (Sn,W.Ag) - could be better defined and expanded with further exploration including core drilling and/or the drilling of untested anomalies. In addition, the number of occurrences associated with anorogenic granites suggests that additional occurrences may remain to be found. This is supported by extensive regional geochemical (including heavy mineral) surveys done by Riofinex in the 1970s and 1980s, which led to the discovery of a number of occurrences and outlined areas of Sn-W-Mo anomalies (as reviewed in WGM's 1992 reports). It would be prudent to review these geochemical data to outline any anomalies which remain unexplained, and to assess if sample density in all areas was adequate. For example, in mountainous terrane in western Canada, it has often been necessary to sample for heavy minerals at the junction of every minor tributary in drainages in order to detect and successfully trace anomalies.

WGM has also identified a number of prospects which have some level of mineralization that places them above their peer group, for example the Wadi Al Faydah tungsten prospect. These identified prospects require additional ground based exploration, especially detailed geological mapping and sampling to better define the mineralization because the work done to date does not sufficiently condemn exploration potential. In some of the better prospects in this group, additional diamond drilling is warranted at this time, such as along the hyper-silicified breccia at the Jabal Karsh (Kirsh) molybdenum prospect.

The methodologies of exploring for tungsten, tin and molybdenum have not appreciably changed in several decades. The approach is still a strongly field-based, including drainage geochemistry, prospecting and geological examination at both regional and prospect scales. Ground-based geophysics (magnetics, IP, resistivity) can be useful in outlining mineralized zones associated with silicification (quartz flooding or veins), clay alteration, or sulphide mineralization in minor to significant amounts, which are common to mineralization of tin, tungsten and molybdenum. Types and results of surveys conducted in better-mineralized areas should be reviewed to determine the best techniques and identify unexplained anomalies. Given the manner in which gold mineralization tends to hide, all samples should be fire assayed for gold.

Because extraction techniques for tin and tungsten are fairly simple, and usually involved only crushing and gravity separation, artisanal mining for these metals has been, and still is, used successfully in many parts of the world: tin in Nigeria and the Congo basin; tungsten in northeastern Brazil. Although the use of water would be required, higher-grade veins, such as those at Bi'r At Tawilah, could potentially be mined by small-scale mining efforts.

3.7.6 REFERENCES

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3.8 IRON ORE DEPOSITS

3.8.1 Metallogenic Model and Existing Deposits

In the KSA, there are 162 indices in the MODS database with iron designated as the principal commodity. These occurrences are all shown in Figure 108. Only a few of the MODS occurrences are sufficiently or properly classified with respect to deposit type or style as described by either by their "Type_label" or "Gitology" database fields to provide for efficient evaluation and assessment of potential. This lack of classification data is likely mostly due to the fact that many of these "occurrences" have very small physical extents as presently known or described in geoscience literature. Also for most of the MODS occurrences, the information available in other fields within the MODS database is also insufficient to properly classify the deposits with much certainty. Proper and complete information concerning deposit classification is only available for those deposits or occurrences or areas where detailed geological reports of work or maps have been completed. Undoubtedly, most of the 162 iron occurrences and deposits in the MODS can be classified according to the mineralization types or styles listed in Table 88 if more information of higher quality was available.

Table 88
Iron Deposit Models

EMINERS Model ID	EMINERS Model Name	Cox – Singer Model Number	Reference	Alternative Model Name
076	Volcanic-hosted magnetite	25i	Mosier(1986)	IOCG Kiruna type
072	Superior Fe and Algoma Fe deposits	34a	Mosier and Singer(1986)	Iron Formation
064	Skarn Fe	18d	Mosier and Menzie(1986)	IOCG and Fe-Skarn
029	Oolitic ironstones	34f	Orris(1992)	Ironstone
-	Bushveld Fe-Ti-V	3	Norman J. Page in Cox and Singer, editors (1986)	Layered Mafic-Anorthosite Intrusion

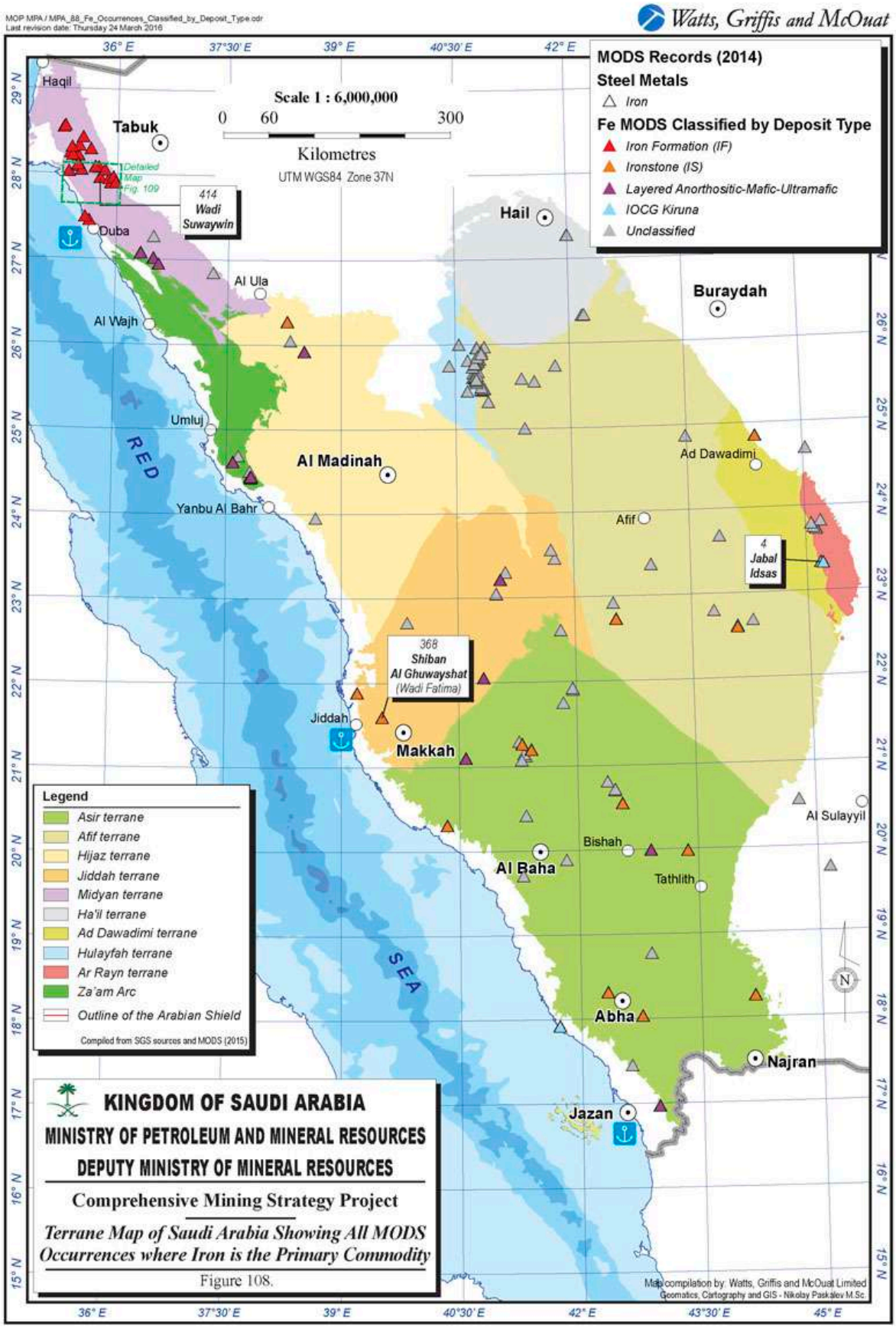
The foregoing classification does not encompass all of the 162 MODS records for iron. Some of the so-called iron occurrences are better classified as weathered sulphide occurrences or gossans rather than iron occurrences. Iron would never be commercially recovered from such sources on an industrial scale in modern times. These deposits may be more properly classified as the EMINERS' deposit-types listed in Table 89.

Table 89
Supplementary Iron Deposit Models

EMINERS Model ID	EMINERS Model Name	Cox-Singer Model Number	Reference
077	Volcanogenic massive sulfide Cyprus-type	24a	Norman J. Page in Cox and Singer, editors (1986)
078	Volcanogenic massive sulfide Kuroko-type	28a	
079	Volcanogenic massive sulfide Sierran-Kuroko-type	28a.1	
006	Besshi Massive Sulfide	24b	

Deposit type classification from a geological perspective is important for iron deposits. Although there are arguably some differences between different classification systems, most modeling schemes do share much in common. Iron deposit type or classification is important because while different types have different tonnage and iron grade potential, they contain characteristically different accessory and whole rock mineralogy, and because of these factors their response to mineral processing varies. Mineralogy, deposit morphology and response to mineral processing are especially important towards producing a marketable iron product. Hence, not only are geological factors such as tonnes and Fe-grade, Fe-mineralogy, Fe grain size and the grades for accessory minerals or metals and non-metals which are important for assessing the marketable potential of an iron deposit, but information from testwork is vital to assessing deposit metallurgy and response to mineral processing. Amenability to beneficiation is also essential because requirements to produce a saleable product are specific and stringent. The economic viability of any iron deposit is inescapable from one single underlying fact: iron is a low-value, bulk commodity compared to virtually any other mineral product.

In addition to the models listed in Table 89 there is another informal type or deposit style that is important, that being Direct Shipping Ore or “DSO” as it is commonly called. It is not actually a geoscientific deposit type, but in practice it is an important variant. DSO refers to iron ores that are of a quality that allow them to be marketed without any processing, or at least very little processing in contrast to most iron ores where some degree of beneficiation is required to make a saleable product. DSOs are mainly the product of natural iron concentration by supergene processes, however some iron mineralization also reaches DSO quality by hydrothermal-metamorphic or magmatic processes or superimposed supergene and hydrothermal-metamorphic processes in variable and multiple combinations. There does not appear to be any DSO resources in the Kingdom, but DSO represents an end member-type or situation that is important for understanding iron ore geology, and how supergene processes have affected some of the iron deposits in the Kingdom to some degree. Also the EMINERS’ database for Model #72, Superior Fe and Algoma Fe deposits, includes many DSO deposits.


MOP MPA / MPA_88_Fe_Occurrences_Classified_by_Deposit_Type.cdr
Last revision date: Thursday 24 March 2016
Watts, Griffis and McOuat
MODS Records (2014)
Steel Metals
Iron
Fe MODS Classified by Deposit Type
Iron Formation (IF)
Ironstone (IS)
Layered Anorthositic-Mafic-Ultramafic
IOCG Kiruna
Unclassified
Scale 1 : 6,000,000
0 60 300
Kilometres
UTM WGS84 Zone 37N
414 Wadi Suwaywin
4 Jabal Idsas
368 Shiban Al Ghuwayshat (Wadi Fatima)
Detailed Map Fig. 109
Haql
Tabuk
Duba
Al Ula
Al Wajh
Umluj
Yanbu Al Bahr
Hail
Buraydah
Al Madinah
Ad Dawadimi
Afif
Jiddah
Makkah
Al Sulayyil
Bishah
Al Baha
Tathlith
Abha
Najran
Jazan
RED SEA
Legend
Asir terrane
Afif terrane
Hijaz terrane
Jiddah terrane
Midyan terrane
Ha'il terrane
Ad Dawadimi terrane
Hulayfah terrane
Ar Rayn terrane
Za'am Arc
Outline of the Arabian Shield
Compiled from SGS sources and MODS (2015)
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Terrane Map of Saudi Arabia Showing All MODS Occurrences where Iron is the Primary Commodity
Figure 108.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
36° E
37°30' E
39° E
40°30' E
42° E
43°30' E
45° E
29° N
28° N
27° N
26° N
25° N
24° N
23° N
22° N
21° N
20° N
19° N
18° N
17° N
16° N
15° N

The most sought after source of iron on a world-wide basis is iron from Iron Formation. This is because Iron Formation provides large resources with low levels of impurities or deleterious elements. It is often amenable to low-cost processing to meet market specifications. Again, because iron is a low-value bulk commodity, its saleability is very cost-sensitive. Almost all of the iron from Australia, Brazil, the Ukraine, the United States and Canada is or historically was derived from Iron Formation, and/or from Iron Formation that has undergone supergene processes to produce DSO material. All iron formation deposits are however not necessarily satisfactory regardless of gross tonnage because they may not contain the iron mineralogy at a grain size amenable to inexpensive processing to produce a saleable product.

Less iron is won from IOCG-skarn and IOCG-volcanic-hosted magnetite deposits such as Kiruna in Sweden. Prevalence of deleterious elements in these types of deposits and their ores, particularly phosphorus, and copper or sulphur can make it unfeasible to produce a marketable product from these deposit types without expensive processing. Minor amounts of iron are won from mafic-ultramafic layered complexes particularly those dominantly anorthositic. Despite the very large size potential of these types of deposits that can be in the billions of tonnes range, it is often difficult/costly to separate the titanium from the iron for such mineralisation, thus making beneficiation of such ores cost prohibitive. In the recent past much iron in Central Europe and North America was mined from Ironstone deposits. These deposits can be very large tonnage and have similar iron grades as their sedimentary cousins, Iron Formation deposits, but characteristically ironstone deposits have higher, unwanted-deleterious phosphorus contents that are difficult to eliminate during processing, and consequently this type of deposit is no longer generally exploited as a source of iron in the western world.

The lack of classification in the MODS database for the iron occurrences hinders evaluation and assessment. The fact that the known Iron Formation in the Kingdom is not shown on the 1:250,000 or 1:500,000 scale geological maps is also strongly detrimental to a proper assessment. In other jurisdictions, such as Canada, Iron Formation is clearly identified on the government issued maps because its importance is well understood. According to SGS sources, 40 mineral occurrences in the Ar Rayn Terrane have been classified as Fe-oxide Cu-Au occurrences and prospects which have not been explored in the past as this type of model. As noted later in this section, Jabal Idsas, for example, was explored as a source of magnetite, not a potential gold occurrence. It is also very prospective for the discovery of porphyry copper in three locations. These types of deposits have the potential of being “company makers” when discovered, due to their potential enormous size, and a search for porphyry copper and Fe-oxide Cu-Au deposits is recommended as a new exploration frontier in the Ar Rayn Terrane.

Accepting the aforementioned caveats, and information limitations, the iron occurrences or deposits in the MODS that are of the highest significance, based on presence of defined mineral resources and drilling programs, are summarized in Table 90. Figure 108 shows all of the 162 iron occurrences where iron is the primary commodity in the MODS database. The figure also shows the occurrences that can be more

Table 90
Most Important Iron Deposits in the KSA From MODS Database

New Name	Longitude	Latitude	Deposit Type	Minor	Host Rocks	Gitology	Exploration	Mine
al Idsas	45.182278	23.313194	IOCG Kiruna		Metagabbro, tonalite, trondhjemite (leucotonalite)	Magnitite-rich Fe-oxide Cu-Au (Kiruna-type) (no comments)	Visited, trenching, drilling, feasibility study	(INF) 300 Mt at 2
ban Al wayshat	39.521581	21.575469	IS		Quartz diorite, sandstone	Sedimentary rocks (sedimentary chemical and biochemical deposits (Routhier 1963)	Visited, trenching, drilling	BRGM (est): 54 (to 150 m depth)
di Suwaywin	35.768722	27.942444	Iron Formation	S, phosphate	Jaspilite (chert), quartz, sandstone, tuffaceous sandstone	Sedimentary rocks (chemical and biochemical deposits, from VAX file)	Visited, trenching, drilling, feasibility study	245 Mt at 42% F mt, Dep. 3=Fe 4 3%), P (0, 31% OREBODY3)
r Al Andarah	37.655806	24.669139			Anorthosite, gabbroic plutonic rocks	Unclassified (no comments)	Visited, trenching	2 Mt at 46.9% Fe
di Wasat	44.167500	18.237278	Other Sedimentary	S	Andesitic tuff, black shale, diorite	Volcanic sedimentary (GIS Arabia tables), hydrothermal (hydrothermal foreign epigenetic (Routhier 1969) from VAX file)	Visited, drilling	
shm Sha	42.884778	18.754944		Ni	Gabbroic plutonic rocks	Unclassified (TI-Fe related) syngenetic (Routhier 1969)	Visited, drilling	
di Khumal-SW	37.818139	24.408197	Layered anorth-mafic-ultramafic intrusion	Ti, V, Cr, Ni	Anorthosite, dunite, gabbroic plutonic rocks, gabbronorite	Bushveld Fe-Ti-V (from VAX)	Visited, trenching	(Fe: 52%, Ti: 3.5
di Khumal-W	37.814306	24.409917	Layered anorth-mafic-ultramafic intrusion	Ti, V, Cr, Ni	Anorthosite, dunite, gabbronorite	Bushveld Fe-Ti-V (from VAX)	Visited, drilling	
ayniat-S	40.726389	25.715194		Cu	Diorite, rhyolite, rhyolitic tuff	Unclassified (no comments)	Visited, trenching, drilling	
l Musayniat-N1	40.789639	25.841111		Zn, Cu	Andesite, diorite, rhyolitic tuff	Unclassified (no comments)	Visited, trenching, drilling	
l Al Hamra	40.771444	25.567861		Ag, Cu	Microgranite, rhyolite	Unclassified (no comments)	Visited, trenching, drilling	
Huwaymidah-SE	40.771167	25.569361		Cu	Microgranite, rhyolite	Unclassified (no comments)	Visited, trenching, drilling	
di Al Kharis	35.469306	28.199806	Other Sedimentary		Granite, granodiorite (calc-alkaline plutonic), jaspilite (iron rock), microdiorite	Sedimentary rocks (sedimentary)	Visited	6 Mt at 48.4% Fe
al Saq-SE	41.299833	21.250750	Other Sedimentary	Au	Limestone, mudstone (rock), volcaniclastic rocks	Unclassified (Ancient workings are 900 m along series of parallel massive quartz veins cutting metasedimentary units and situated along NE-trending regional shear zone. Shearing is up to 20-30 m wide in the central part of the structure	Visited	BRGM: Reserve 7.7 g/t, 1,054.9 k

Table 90
Most Important Iron Deposits in the KSA From MODS Database

New Name	Longitude	Latitude	Deposit Type	Minor	Host Rocks	Gitology	Exploration	Mine
li Al Jufayr	41.29125	21.057194		Au, quartz	Amphibolite, greenschist, quartz, quartzo-feldspathic schist, rhyolite, rhyolitic lithic tuff	Unclassified (no comments)	Visited, trenching, drilling	
li Hayyan-NW	36.502500	27.003444	Layered anorth-mafic-ultramafic intrusion	Ti	Gabbroic plutonic rocks	Unclassified (TI-iron, magmatic segregation (Bateman, '64) from VAX file)	Visited	BRGM: (inf): 0.4
li Al Hamra	35.966667	27.900000	Iron Formation		Diabase, jaspilite (iron rock), quartz	Sedimentary rocks (sedimentary deposits (Bateman 1964), from VAX file)	Visited	6.5 Mt at 40% Fe 50%)
li Tirban	35.383333	28.300000			Jaspilite (iron rock), marble, sedimentary rock, volcaniclastic rocks	Unclassified (no comments)	Visited	30 Mt at 40% Fe 47%), 30 t
r Sumsaah 006)	41.816667	22.588889		Cu, Au	Gabbroic plutonic rocks, ultrabasic volcanic foidite	Hydrothermal (hydrothermal epigenetic, from the VAX file)	Visited, drilling	
hqal-E	39.845750	22.696028	Layered anorth-mafic-Ultramafic Intrusive	Ti	Granite, rhyodacite, skarn	Unclassified (no comments)	Visited	BRGM: (INF): 40 65% Fe,

reliably classified. Most of 162 deposits/occurrences can be easily assigned a low importance on the basis of deposit type, i.e. occurrences that are not iron formation. Any knowledge of large dimensions is important because iron deposits need to be of the order of several hundred million tonnes (minimum) to be of economic interest given the capital costs for development. Any lack of detailed knowledge concerning the occurrence's characteristics and/or lack of any or updated metallurgical testwork information is also grounds for down-grading importance.

Twenty of the iron occurrences and deposits listed in the MODS database report drilling programs and / or mineral resources. Of these only two contain resources of significance in that several hundreds of millions of tonnes of resources are generally required to provide a basis for an economically viable iron ore deposit.

Selected deposits/occurrences are described below and include some of the occurrences/deposits listed in Table 90 but also some others of interest. It also needs to be understood that the MODS is not all-inclusive. The manner in which deposits/occurrences are recognized as deposits or occurrences and then assigned a MODS identification is or has been somewhat subjective.

3.8.2 MAJOR IRON OCCURRENCES AND PROSPECTS

3.8.2.1 Wadi Suwaywin Area Al Wajh – Midyan Terrane - Silasia Formation of Late Proterozoic Age

Location, History and Current Status

The Wadi Suwaywin (or Wadi Sawawin) deposits (MODS #414) are located in the Midyan Terrane in the northeast corner of the Al Muwaylih quadrangle (27A) about 90 km southwest of Tabuk and 60 km inland from the Red Sea port of Duba. They are clearly and by far the most important iron deposits in the Kingdom. The readers should note that WGM has for this review had access to some of the older documents concerning the Wadi Suwayin deposits generated by British Steel Corporation Overseas Services Limited ("**BSCOS**") through the 1970s and 1980s but has seen very little of the documentation prepared by London Mining plc for its work program and Feasibility Study completed in 2010.

Formal discovery of the deposits was in 1953. Between 1953 and 1975 various surveys were completed and mineral dressing testwork was carried out on behalf of the DMMR. During the period 1976 to 1986 BSCOS conducted detailed exploration including mapping, drilling and testwork. These investigations culminated in a feasibility study that was completed in 1987. In January 2008, London Mining PLC formed a 50/50 joint venture company, Saudi London Iron Ltd., with the Saudi-based National Mining Company to develop the deposit and a new program of drilling and testwork was initiated. In January 2009 Ausenco Limited completed a pre-feasibility study on behalf of Saudi London Iron that showed that the project with a production of 5 Mt per annum ("**Mtpa**") direct reduction ("DR") pellets was feasible. A "Bankable

Feasibility" Study was then undertaken by Worley Parsons and completed in 2010. The Resources quoted in the BFS are summarized herein, in Table 91.

Table 91
Mineral Resources Wadi Suwaywin 2010 Feasibility Study for London Mining

Category	Tonnes (Mt)	Fe (%)	SiO2 (%)	CaO (%)	Al2O3 (%)	P (%)	S (%)
Indicated	247.67	39.78	31.00	3.81	2.48	0.31	0.13
Inferred	134.30	39.15	31.90	3.85	2.43	0.30	0.11

The proposed project is an open pit operation with the processing/beneficiation and pelletizing plant located on the Red Sea coast. The study assumes an 11 Mtpa mining operation to produce 5 Mtpa of pellets over a mine life of 20 years. Ore processing requires selective flocculation and flotation. More recently variations to the project have been studied. In April 2015, Papuan Precious Metals Corp. Entered into a letter agreement to form a joint venture with Juniper Capital Partners Ltd. to acquire London Mining PLC's rights to the carried interest in the National Mining Company which owns the project.

Geology

The iron formation is of Algoma type and occurs in the Silasia and Hegaf Formations of Late Proterozoic age; a time period known as Neoproterozoic, approximately 700 - 750 Ma (Stern et al., 2005) and formed during a "Snowball Earth" event. It is complexly folded and remnants form isolated segments (Figure 109). The discontinuous and intermittently distributed occurrences are known over a NW-SE distance of over 150 km and an area about 90 km wide. The most prominent deposits are situated in the Silasia Formation, Zaam Group of the Wadi Suwaywin district, and occur in an area of about 40 km long and 10 km wide. Historical airborne magnetic surveys cover most of the area, but these have insufficient resolution to delineate the iron formation. Adequate geological descriptions for the iron formation deposits other than the Wadi Suwaywin are not available.

The iron formation at Wadi Suwaywin consists mainly of hematite with minor magnetite. Magnetite content apparently decreases with depth, from surface, and likely this is the result of near-surface oxidation and resultant martinization of magnetite. The iron formation is exposed on surface is often 30 m to 60 m true width and dips gently but because of the folding thickness and dips vary considerably.

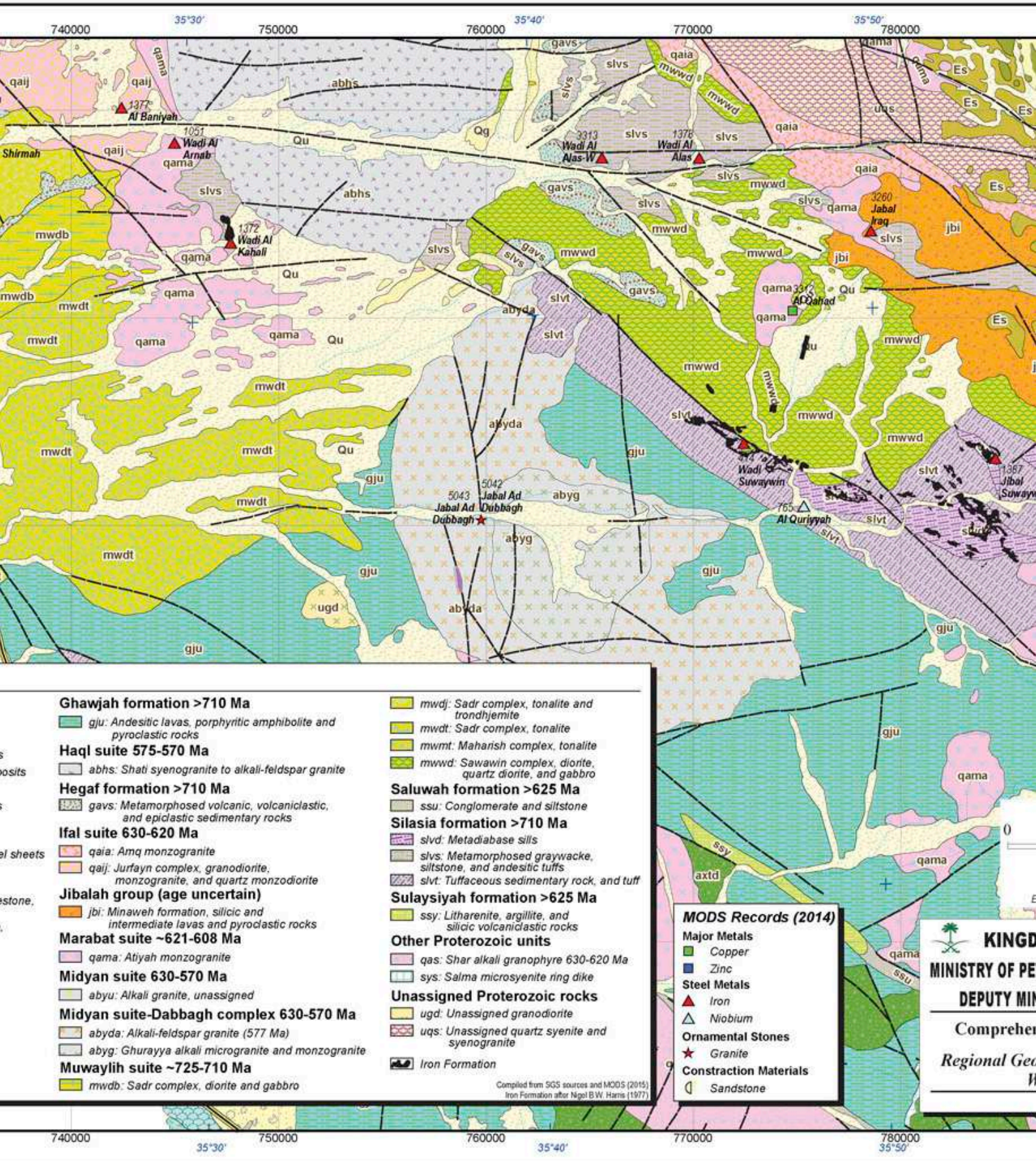

740000
750000
760000
770000
780000
35°30'
35°40'
35°50'
Wadi Al Arnab
Wadi Al Kahali
Al Baniyah
Wadi Al Alas-W
Wadi Al Alas
Jabal Iraq
Al Qahad
Wadi Suwaywin
Jabal Ad Dubbagh
Al Quriyyah
Ghawjah formation >710 Ma
gju: Andesitic lavas, porphyritic amphibolite and pyroclastic rocks
Haql suite 575-570 Ma
abhs: Shati syenogranite to alkali-feldspar granite
Hegaf formation >710 Ma
gavs: Metamorphosed volcanic, volcaniclastic, and epiclastic sedimentary rocks
Ifal suite 630-620 Ma
qaia: Amq monzogranite
qaij: Jurfayn complex, granodiorite, monzogranite, and quartz monzodiorite
Jibalah group (age uncertain)
jbi: Minaweh formation, silicic and intermediate lavas and pyroclastic rocks
Marabat suite ~621-608 Ma
qama: Atiyah monzogranite
Midyan suite 630-570 Ma
abyu: Alkali granite, unassigned
Midyan suite-Dabbagh complex 630-570 Ma
abyda: Alkali-feldspar granite (577 Ma)
abyg: Ghurayya alkali microgranite and monzogranite
Muwaylih suite ~725-710 Ma
mwdb: Sadr complex, diorite and gabbro
mwdj: Sadr complex, tonalite and trondhjemite
mwdt: Sadr complex, tonalite
mwmt: Maharish complex, tonalite
mwwd: Sawawin complex, diorite, quartz diorite, and gabbro
Saluwah formation >625 Ma
ssu: Conglomerate and siltstone
Silasia formation >710 Ma
slvd: Metadiabase sills
slvs: Metamorphosed graywacke, siltstone, and andesitic tuffs
slvt: Tuffaceous sedimentary rock, and tuff
Sulaysiyah formation >625 Ma
ssy: Litharenite, argillite, and silicic volcaniclastic rocks
Other Proterozoic units
qas: Shar alkali granophyre 630-620 Ma
sys: Salma microsyenite ring dike
Unassigned Proterozoic rocks
ugd: Unassigned granodiorite
uqs: Unassigned quartz syenite and syenogranite
Iron Formation
Compiled from SGS sources and MODS (2015)
Iron Formation after Nigel B.W. Harris (1977)
MODS Records (2014)
Major Metals
Copper
Zinc
Steel Metals
Iron
Niobium
Ornamental Stones
Granite
Constraction Materials
Sandstone
KINGD
MINISTRY OF PE
DEPUTY MIN
Comprehen
Regional Geo

Table 92
Iron Formation Deposit Records from the MODS for the Greater Wadi Suwaywin Area

New Name	Longitude	Latitude	Minor	Host Rocks	Gitology	Type_L
Wadi Suwaywin	35.768722	27.942444	Sulfur, phosphate	Jaspilite (chert), quartz, sandstone, tuffaceous sandstone	Sedimentary rocks (chemical and biochemical deposits, from VAX file)	Sedimenta
Wadi Al Arnab	35.492917	28.078056		Andesite, jaspilite (iron rock), metagreywacke, siltstone, tuffite	Sedimentary rocks (sedimentary)	Sedimenta
Wadi Al Kahali	35.519472	28.034194		Granite, jaspilite (iron rock), metagreywacke, siltstone, tuff, tuffite	Sedimentary rocks (sedimentary)	Sedimenta
Jabal Ar Rawa	35.483333	28.316667		Granite, jaspilite (iron rock), marble, metavolcanic rock, metavolcaniclastic rock, sedimentary rock	Sedimentary rocks (sedimentary, sedimentary deposits (Bateman 1964))	Sedimenta
Sirw Al Buhayr	35.366667	28.233333		Granite, jaspilite (iron rock), marble, metavolcanic rock, metavolcaniclastic rock, red mudstone, sedimentary rock	Sedimentary rocks (sedimentary)	Sedimenta
Wadi Ratiyah	35.349222	28.016972		Diabase, jaspilite (iron rock), marble, metavolcanic rock, metavolcaniclastic rock, red mudstone, sedimentary rock, shale	Sedimentary rocks (sedimentary)	Sedimenta
Wadi Al Kharis-W	35.397472	28.209917		Granite, jaspilite (iron rock), marble, metavolcanic rock, metavolcaniclastic rock, sedimentary rock	Sedimentary rocks (sedimentary)	Sedimenta
Al Baniyah	35.467333	28.093833		Granite, granodiorite (calc-alkaline plutonic), jaspilite (iron rock), metavolcanic rock, monzogranite, quartz, quartz monzodiorite, sandstone	Sedimentary rocks (sedimentary)	Sedimenta
Wadi Al Alas	35.750000	28.066667		Diabase, granite, jaspilite (chert), jaspilite (iron rock), metavolcanic rock, sandstone	Sedimentary rocks (sedimentary)	Sedimenta
Wadi Al Hamra	35.966667	27.900000		Diabase, jaspilite (iron rock), quartz	Sedimentary rocks (sedimentary deposits (Bateman 1964), from VAX file)	Sedimenta
Wadi Sadr	35.916667	27.883333		Diabase, jaspilite (iron rock), quartz	Sedimentary rocks (no comments)	Sedimenta
Jabal Suwaywin	35.891667	27.933333		Jaspilite (iron rock), sandstone	Sedimentary rocks (no comments)	Sedimenta
Wadi Al Hamra-NW	35.950000	27.950000		Diabase, jaspilite (iron rock), sandstone	Sedimentary rocks (no comments)	Sedimenta
Wadi Al Hamra-NE	35.983333	27.883333		Jaspilite (iron rock), sandstone, slate	Sedimentary rocks (no comments)	Sedimentar

The Wadi Suwaywin occurrence is the most prominent of the iron formation occurrences in the broader area and the name refers to several zones of mineralization that comprise the most important zones defined from a mining prospective in the 1970s by BSCOS. Other zones or segments of iron formation occurring both to the northwest and southeast of the Wadi Suwaywin occurrence also have MODS designation including: Jibal Suwaywin (1387), Wadi Sadr (1386), Wadi Al Hamra-NE (1389), Wadi Al Hamra (1385), Wadi Al Kahall (1372), Wadi Ratiyah (1375), Wadi Al Arnab (1051) and Al Baniyah (1377) as shown in Figure 109. In the MODs database these occurrences are described as sedimentary in the "Gitology" column, and "jaspilite" (a synonym for taconite) in the "MODs Host Rx" column, however they are more reliably classified as iron formation based on their spatial correlation with segments of iron formation shown on Figure 1.1 Regional Geology Map, BSCOC (1981) or / and map of Ashworth et al., 1975 reproduced as Figure 31 in WGM (1992). Figure 109 shows the outline of iron formation from the BSCOC map. The iron formation occurrences from the MODS database are listed in Table 92.

Recommendations

The Wadi Suwaywin iron formation outcrops on surface and dips gently making it suitable for mining by open pit. The Mineral Resource tonnage is relatively small. Its iron grade is relatively high for taconite which the Project literature refers to as jaspilite. Its sulphur and phosphorus levels are also a little higher than most taconite deposits. The mineralization requires very fine grinding for liberation. The fact that it mostly consists of hematite and needs fine grinding necessitates more costly methods to produce a suitable concentrate. WGM's knowledge concerning the current status of the geotechnical information for the belt as a whole is very incomplete.

In the absence of data describing the distribution of drill holes, WGM believes that the drilling completed to date is confined to the specific deposit area and no drilling or very little drilling has been done to evaluate the iron formation in terms of volume or grade elsewhere in the belt. To advance assessment of the area all drilling and mapping information needs to be compiled. An updated high resolution airborne magnetic survey will also be helpful to help map the iron formation.

WGM believes there is likely potential to increase the Mineral Resources in this area as those resources currently delineated are for the immediate Wadi Suwaywin deposit area rather than the greater Wadi Suwaywin area which should include extensions of the known iron horizons.

3.8.2.2 Other Iron Occurrences and/or Belts

General

The Wadi Suwaywin iron formation is by far the most significant iron deposit known in the Kingdom. Two other iron occurrences of less importance are described below. The Jabal Idsas occurrence, described as an IOCG-Kiruna type prospect, and the Shiban Al Ghuwayshat (Wadi Fatima) ironstone-type occurrences are of minimal interest for iron. Minimal interest in terms of providing potential sources if iron ore is also given to the various occurrences of titaniferous magnetite forming parts of layered anorthositic-mafic intrusives. Brief descriptions of these types of occurrences in the Hijaz Terrane (Wadi Kamal Complex (MODS 725-743) and in the Al Wajh-Midyan Terranes such as Wadi Hayyan (1328) and Wadi Qabqab (1326), can be found in WGM-CR-11-9 (1992).

As a footnote top the foregoing paragraph, IOCG deposits are of interest generally because of their potential to host large, sometimes gigantic, polymetallic deposits that are important sources of copper and gold but are not commercially interesting for iron. The SGS has informed WGM that there are 40 mineral occurrences in the Ar Rayn Terrane that are classified as IOCG-type. It is worth remembering also that Jabal Idsas was explored as a source of iron, but was never explored from the perspective of having interest for gold. IOCG deposits can literally make a company, however, these deposits can be very difficult to recognize. A technical paper on the discovery of the enormous Olympic Dam deposit describes how the geologists were astonished at first sight of the assay results because nobody recognized the mineralization in the discovery drill hole (Haynes, 2006).

Jabal Idsas MODS #4 – Ar Rayn Terrane

Location, History and Status

The Jabal Idsas magnetite deposits (MODS 0004, 1489, 0314 and 0315) are located in the central part of the Kingdom, 201 km southwest of Riyadh and 220 km from the Red Sea at Jeddah. They are found on 1:250,000 scale map sheet 23H. The nearest town is Ar Rayn, 40 km to the northeast. K.L Ashworth (1994) provides a good overview of this deposit in Mineral Resources of Saudi Arabia 1994 and much of the summary below is taken from Ashworth's account.

The deposits were discovered in 1956 and exploration conducted from discovery through to 1986. Magnetite mineralization occurs in a belt of andesites and gabbros that is approximately 7 km in length and up to 1 km wide. Seven separate magnetite lenses have been identified and each was surveyed by magnetometer following which 35 holes were drilled. These programs delineated a main body of disseminated magnetite and numerous small magnetite-rich lenses. Ashworth's description also includes:

> *"Some joint faces show malachite staining and rarely, small amounts of chalcopyrite and pyrrhotite are present within the magnetite or on the joint faces"*

The foregoing comment indicates some copper mineralization is associated with mineralization which is permissible for either deposit type, i.e. Bushveld or IOCG. This model was favoured by Doebrich of the USGS. His observations and those of others at the SGS lead some to conclude that the mineral associations indicate that the Jabal Idsas mineralization is IOCG-type. If Jabal Idsas was of IOCG type then the chalcopyrite might contain or be associated with gold and other metals. As they are very large deposits, the IOCG model is amenable to geophysical surveying through the combined use of magnetometer, gravity and IP.

Beneficiation testwork was carried out on the disseminated magnetite from drill core by the Royal School of Mines, London in 1978. Further testwork was completed by Granges International Mining in 1982. Inferred mineral resources and concentrate chemistry for Jabal Idsas from Ashworth is summary.

Geology

This occurrence and the adjacent Jabal IDSAS-SE (MODS 1489) are in the Sidriyah Formation of the Late Proterozoic Al Amar Group. The Sidriyah Formation consists of andesitic tuff and agglomerate and amphibole gneiss approximately 1 km east of the Al Amar – Idsas fault. The MODs database describes these deposits as Kiruna-type which would correspond to EMINERS model #76 (see Table 89) which also includes such deposits as the Gol-e-Gohar magnetite deposits of Iran. Ashworth describes how the origin of the Jabal Idsas deposits magnetite is uncertain and describes the mineralization as follows:

> *"Iron titanium minerals occur is small amounts either as discrete ilmenite-leucoxene grains or as a fine exsolution networks and layers within the magnetite crystals."*

This description suggests to WGM that these deposits are possibly more akin to Cox and Singer model 3 – i.e. iron in a Bushveld type layered mafic–ultramafic intrusive.

Beneficiation testwork was carried out on the disseminated magnetite from drill core by the Royal School of Mines, London in 1978. Further testwork was completed by Granges International Mining in 1982. Inferred mineral resources and concentrate chemistry for Jabal Idsas from Ashworth is summarized in Table 93.

Table 93
Mineral Resources for the Jabal Idsas Iron Occurrences

Material	Mt	Fe(%)	SiO2(%)	Al2O3(%)	CaO(%)	MgO(%)	TiO2(%)	MnO(%)	S(%)	P(%)	Cu(%)

Lens	1.3	66.9	2.4	n.d.	n.d.	n.d.	0.2	0.2	0.08	0.09	0.01
Disseminated Magnetite	300.0	21.8	40.6	10.6	6.1	6.4	0.6	0.2	n.d.	0.17	n.d.
Concentrate	n.a.	67.1	3.3	1.1	0.5	0.8	0.2	0.09	0.006	0.007	0.007

In 1985 a preliminary study of the economics of mining the Jabal Idsas deposit was carried out (Ashworth, Edwards & Attar 1985). It showed that mining, beneficiation and transportation costs for delivery of pellets to the steelworks at Al Jubail would be more than double the cost of purchasing and importing pellets from outside the country.

Recommendations

As far as WGM is aware no further work has since been done on the Jabal Idsas deposit. Similar deposits or occurrences might be found with further exploration of the Sidriyah Formation along the Al Amar - Idsas fault but no mineralized belt or permissive tract is presently defined. The present situation is of two relatively isolated iron occurrences with a relatively small resource tonnage base. The MODS database codes a number of occurrences as Bushveld type however none of these occur are in the immediate area of Jabal Idsas.

The historic drill hole and mapping information was not available to WGM during this study. If it were located it could be compiled and reviewed towards locating additional tonnage potential. One important detail concerning the grade of the mineralization is missing from Table 93. No value for the magnetite content of the mineralization is listed and this leaves the resource statement incomplete. Determination of the magnetite concentration of the mineralization by either Satmagan or Davis Tube methods should have been completed for the resource to more completely document the “grade” of the mineralization. For illustration – the Fe grade of the disseminated mineralization is listed in the foregoing table as 21.8%. If the remainder or the material other than the magnetite is mafic volcanic then about half of this reported iron grade, which is essentially non-recoverable, would come from iron in silicates from the mafic volcanic suggesting the iron from the magnetite is only about 10% to 11%. Bushveld type deposits have potential for nickel, copper, PGMs and vanadium. IOCG type deposits have potential for copper and gold plus an array of more exotic metals. The copper content of the Jabal Idsas mineralization appears to be quite low. The testwork results that are unavailable for review might provide some indication of the copper grade of the mineralization. Assay records for the drill hole and metallurgical samples might also provide information concerning the copper grade of the mineralization and whether any of the sulphide concentrates were ever assayed for gold. Copper in iron concentrates is detrimental and likely would require reduction to make a saleable iron concentrate. A copper concentrate might be achievable but an increased abundance of copper would likely be required to make such a copper concentrate a significant positive economic component for the project. Renewed exploration on the Jabla Idsas deposits should include

more comprehensive assessment towards identifying the deposit type more clearly and potential for metals other than magnetite including copper, gold, chromium, PGE and vanadium. A full lithogeochemical characterization of all rock types and mineralization is required.

WGM's review suggests the deposit has minimal potential because of its distance from infrastructure and the Al Jubail steelworks, its low magnetite grade, the ores requirement for fine grinding to achieve liberation and its titanium content.

Shiban Al Ghuwayshat (MODS 0368) – Formerly known as Wadi Fatima

Location, History and Status

The oolitic ironstones of Shiban Al Ghuwayshat, previously recorded in the MODS and existing literature as Wadi Fatima, is well described by Peter Collenette and David Grainger, editors in The Mineral Resources of Saudi Arabia from which the following descriptions are largely sourced (Table 94). The occurrence is located approximately 45 km east of Jiddah and is found on the 1:250,000-scale geological map of the Makkah Quadrangle (sheet 21D, GM-107).

Table 94
Examples of Ironstone Prospects in the Arabian Shield

MODS	New Name	Longitude	Latitude	Host Rocks	Gitology	Type_Label
0368	Shiban Al Ghuwayshat	39.521581	21.575469	Quartz diorite, sandstone	Sedimentary rocks (sedimentary chemical and biochemical deposits (Routhier 1963))	Sedimentary
2228	Jabal Umm Himar	41.416556	21.184361	Limestone, mudstone (rock), oolitic iron rock	Sedimentary rocks (from VAX file)	Sedimentary
3468	Shaib Musayfih	46.000000	22.500000	Ferruginous sandstone, oolitic iron rock, oolitic sand	Unclassified (sedimentary, from the VAX file)	Unclassified
4416	Shaib Uimir-NE	39.200000	21.866667	Chert, ironstone	Sedimentary rocks (volcanic (Ex, from VAX file)	Sedimentary

Geology

The ironstone is part of the Shumaysi Formation which is Paleogene in age, cropping out intermittently for 40 km north and south of Wadi Fatima. The formation is 74 to 183 m thick and consists of sandstone and siltstone, and subordinate beds of tuff, chert and laminated shale and dips 15º to 30º to the ENE. The oolitic ironstone beds occur in the lower and middle parts of the formation.

Five areas were drilled from 1962 through 1969 named Areas 1, 2a, 2B, 3 and 4. Area 1 is the most significant. The Shumaysi Formation dips shallowly eastwards and crops out intermittently over a distance of 4.75 km. It contains upper and lower beds of ironstone separated by a sequence of sandstone and shale

7.5 m thick. The upper ironstone bed ranges in thickness from 1.82 m to 5.18 m and the lower from 1.60 m to 2.25 m.

Recommendations

Beneficiation testwork was carried out in the 1960s and would need to be up-dated to today's standards however the deposit is clearly much too small to be of interest even if testwork was positive. WGM understands that the deposit is currently being mined by the cement industry for limestone.

Umm Jafr - Wadi Al Furu Area (MODS 0170-0172)

Location, History and Status

The Umm Jafr prospects (MODS 0170 and 0172) were formerly known as Umm Dzaffar-N and SE. The Wadi Al Furu prospect (MODS 0171) was previously known as Umm esh Shash. They are located in the Wadi ar Rufia area close to Al Quway'iyah. Dmm Esh Shash Cu-Ag occurrences are hosted within a belt of andesitic volcanic and volcanosedimentary rocks approximately 15 km south of Al Amar. In 1968, an INPUT survey was carried out over the area but no significant anomalies were recorded coincident with the Wadi ar Rufia occurrences. A regional reconnaissance wadi-sediment survey in 1979-1980 resulted in the discovery of several anomalies with their source attributed to the Wadi ar Rufia mineralization. Site-specific exploration consisted of detailed geological mapping and grab sampling as well as channel sampling across selected zones of mineralization. Grab samples carried as much as 1.7% Cu and 150 g Ag/t (Shanti, 1972). The SGS did some follow-up exploration in 2010 focusing on the Umm Jafr prospects in which copper and gold mineralization is associated with a hydrothermally altered shear zone within a 650 metre by 1.5 km area. Doebrich of the USGS had previously classified the mineralization in the area as being of IOCG-type. Geological sketch maps were produced at 1:1,000 scale and 20 surface samples were collected giving values as high as 4.5% Cu, 0.4 g Au/t and 64.36% Fe. The prospect has been selected for a more comprehensive exploration program in the future. WGM understands also that in 2012 the SGS has completed a small program of trenching and lithogeochemistry (415 samples) to again investigate the potential for near-surface Cu and Au mineralization and to evaluate the grade and tonnage of the copper and gold in the hydrothermally sheared zone. Eight drill holes (1,229.05 m) were completed in the area from which 1,243 drill core samples were taken for analysis, however this data was not available for review.

Geology

The country rocks are composed of a sequence of Al Amar Group mafic to felsic tuffs, carbonate, conglomerate breccias, chert and felsic porphyry. This north-trending lithologic sequence dips steeply to the east and is over-turned. The prospect area is identified as being part of the Umm ash Shash trough,

and located in the same volcanosedimentary formations as the troughs at Al Amar and Umm ash Shalahib. Phyllic and propylitic alteration is noted in the mineralized rocks, together with silicification and carbonatization accompanies by the presence of pyrite. Three separate areas of mineralization at the Wadi Al Furu site have been identified as the A, B and C prospects. Prospect A comprises malachite, azurite and hematite in a cherty tuffite unit that has been partially exposed in an ancient mine working. An alteration zone of uncertain affinity is mentioned as being present in the footwall rocks immediately northwest of the ancient workings. Maximum grades from grab samples taken in the ancient workings were 19,470 ppm Cu, 133 ppm Zn, 21 ppm Pb and 37.4 ppm Ag. Prospect B consists of fine-grained, disseminated pyrite and sphalerite in a carbonate unit with zinc mineralization in a calcite vein. The best grab sample of the disseminated mineralization returned values of 2,800 ppm Zn, 1,470 ppm Pb, 153 ppm Ag and 99 ppm Cu. One sample (grab) from the calcite vein gave a value of 20,120 ppm Zn but this is probably not representative of a mineralized zone. The C Prospect consists of disseminated pyrite in a chert unit. The metal contents in rock and chip samples were generally low, however values of up to 7,700 ppm Zn, 1,754 ppm Pb and 303 ppm Ag were obtained in selected samples with conspicuous mineralization. The prospect area is thought to be one of only a few examples of stratiform base-metal mineralization in the Al Amar belt. A thin reducing layer of black pelite several centimeters thick and oriented north/south contains much of the galena and chalcopyrite over a horizontal extension of about 50 m. Eijkelboom (1966c) reported that a fourth occurrence, BH 27, consisted of a zone 250 m long within which malachite coated fracture joints.

Recommendations

The exploration to date in the area has succeeded in outlining three mineralized occurrences containing variable amounts of base and precious metals. Occurrence A in particular maybe significant in view of the extensive footwall alteration noted during the mapping. Additional work is required to evaluate this occurrence and the associated alteration for subsurface mineralization. It is unfortunate that the original rock/channel samples were not analyzed for gold even though a number of gold occurrences are known in the general area. The occurrences warrant systematic exploration to determine the areal extent of the stratiform mineralization. Geophysical surveying in the form of magnetometer, gravity and IP could be useful tools in defining centres of mineralization. All future samples much be analysed for gold by the fire assay method.

3.8.3 PERMISSIVE TRACTS AND ECONOMIC VIABILITY OF IRON DEPOSITS

Iron on a world-wide basis is recovered from several different deposit types. These deposit types or styles include the following models (types) incorporated into the EMINERS software platform: iron formation (#72), IOCG ("**Iron Ore-Copper-Gold**") deposit - iron skarns (#64), IOCG-volcanic hosted magnetite deposits (#76), and layered – type mafic-ultramafic intrusives Cox & Singer (#3). These were summarized

in Table 89. Historically iron has also been won from ironstone deposits (#29) or even massive sulphide deposits, however these two types are now of much less or of no current importance in the Western World. The aforementioned Cox and Singer models (1986) prepared for the USGS and used by EMINERS are reasonably appropriate for classifying iron deposits as well as representing the deposits and occurrences known to exist in the Kingdom.

A permissive tract for iron as a commodity can be defined by the occurrences of Iron Formation-type deposits in the Silasia Formation. This formation hosts all known deposits of this type including the Wadi Suwaywin deposit. The Silasia Formation has a known extent of approximately 280 km^2. A more extensive permissive tract for iron formation type deposits can be defined by also including the areas underlain by the Hegaf and Amlas Formations, however insufficient information has been made available to WGM to enable this review to determine any probability of the existence of resources for these areas, i.e. the iron formation present in areas underlain by the Hegaf and Amlas Formations may exist as only narrow bands with true widths in the order of metres rather than 10s of metres or 100s of metres. Additionally a number of these other occurrences described as iron formation appear to be associated with intrusive rocks or tectonic elements (faults).

Iron Formation has been mapped intermittently throughout the Silasia Formation. WGM has no access to the actual map data and this map and data is critical in evaluating the amount of iron formation that might be present. For example: without review of the actual data it is impossible to know if areas where no iron formation is mapped are devoid of near-surface iron formation or that colluvium is simply hiding it. WGM assumes that information would be available if significant iron deposits existed in these areas. WGM also has very little information concerning any mapping conducted, or not conducted or any geophysical surveys carried out as part of London Mining PLC's programs or any details concerning most of the drilling that was done either by BSCOS or London Mining. BSOCS delineated five main deposits being part of the Jabal as Sinfa-Sahaloolah group of iron formation occurrences and these BSOCS considered constituting a mining entity containing a substantial part of the total resources of the district. Since WGM has no primary, up-to-date information it is impossible to evaluate whether this is still accurate or considered accurate or the status of the quality or reliability of the data base.

WGM considers that the best way of deriving a mineral potential estimate for the iron formation is achieved through reviewing the details of the data for the district, interpreting the information, assessing the potential for unknown iron formation, and attempting to derive 3D volumes for the deposits which can be added to indicate the potential volumes of iron formation (iron ore). The EMINERS' model - #072, for Superior Fe and Algoma Fe deposits is not very appropriate to complete this assessment because most of the deposits forming the model are DSO variants, or for the historic DSO portions of now exhausted Iron Formation deposits with Fe-grades greater than 50%. The model is not populated by a representative number of low-grade taconite/jaspilite deposits. Another complicating factor is that the EMINERS models may not be applicable as the Iron Formation occurrences in the Kingdom are the Rapitan subtype, i.e. Neoproterozoic associated with glacial sediments.

Considering the above factors, WGM believes it is possible that there could potentially be two or three more "deposits" akin to Wadi Suwaywin, on-surface or close to surface, existing within the Silasia Formation. Considering that the Wadi Suwaywin mineral resources currently aggregates approximately 400 million tonnes, the total potential of the district could be in the order of 1.0 to 1.5 billion tonnes. Again, considering the information available there is no reason to believe that the iron grade and mineralogy of this undesignated potential would be significantly different from that for the Wadi Suwaywin deposits. Most of this potential ore would be fine grained hematite with a lesser amount (possibly up to 20% of the total) of magnetite.

If a larger resource can be defined, it may provide economies of scale in respect to the economic viability of the deposit, but the "ore" is still inherently expensive to process. Mineralization similar to Wadi Sawawin is not mined in the Western World. Neoproterozoic Iron Formation sequences are known in British Columbia, Canada, but are not mined. Brazil contains similar Neoproterozoic Iron Formation and it is mined or has been mined in the Urucum District of Mato Grosso do Sol for decades by companies such as Rio Tinto and Vale, however this mineralization underwent supergene enrichment and it has much higher Fe grades. Taconites in the Labrador Trough of Canada are somewhat similar to Wadi Sawawin mineralization, however they are not mined. During the recent iron rush during the period 2004-2012, companies such as Adriana/New Millennium considered mining taconites in the Labrador Trough , but even for these cases the hematite mineralization is waste – production models only considered processing the magnetite mineralization. In Minnesota, USA, only magnetite taconites have ever been mined – hematitic taconite was never economic. Hematite-rich ore has been mined in Michigan at Tilden, but this material is meta-taconite not greenschist grade Iron Formation like Wadi Sawawin's fine grained hematite ore. Metamorphism increases grain size thus making the hematite easier (less expensive) to process.

The larger question concerns whether Wadi Sawawin Iron Formation will ever be economically viable. Historically, this question has always balanced on a very fine line. In respect to domestic Saudi iron production, it is certain that any mined Wadi Sawawin Iron Formation will be in a competitive disadvantage compared to imported ore, both now and in the future. Some of the additional costs attributed to Wadi Sawawin concerns how accurately transportation costs are known can be estimated for any ore transported from Sawawin to the steel plants in comparison to the increased processing costs inherent for this type/style of mineralization. Saudi strategic interests can trump fundamental economics as long as everyone is aware of the costs, both direct and indirect, economic, environmental and social.

3.8.4 REFERENCES

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3.9 PB-ZN DEPOSITS IN SEDIMENTARY ROCKS

3.9.1 METALLOGENIC MODEL AND EXISTING MINES

The known lead-zinc deposits in sedimentary rocks in Saudi Arabia are found solely along the Red Sea coast in a sequence comprising Lower and Middle Miocene Maqna Group, comprising shallow-water carbonate, anhydrite, claystone, marine sand and siltstone, and non-marine carbonate-cemented conglomerate (Figure 110). These unconformably overlie Lower Miocene non-marine arkose and claystone in the Al Wajh Formation which rests directly on granitic rocks of the Arabian Shield. The mineralization subscribes to the model for Mississippi Valley-Type ("**MVT**") deposits, also referred to as stratabound, carbonate-replacement deposits ("**CRD**"). Lead-zinc deposits are typically found along the margins of sedimentary basins as a result of the expulsion of metal-bearing pore fluids from deeper parts of the basin. These typically acidic and saline fluids are channeled upwards by permeable conduits found along formation contacts and faults until they reach a permeable and chemically reactive host rock. Buffering of the acidic solutions results in the precipitation of zinc and lead sulphides, together with small amounts of silver, in limestones and similar lithologies. Local structural factors that are important controls on mineralization include dilational jogs on major faults, fault intersections and breccia zones.

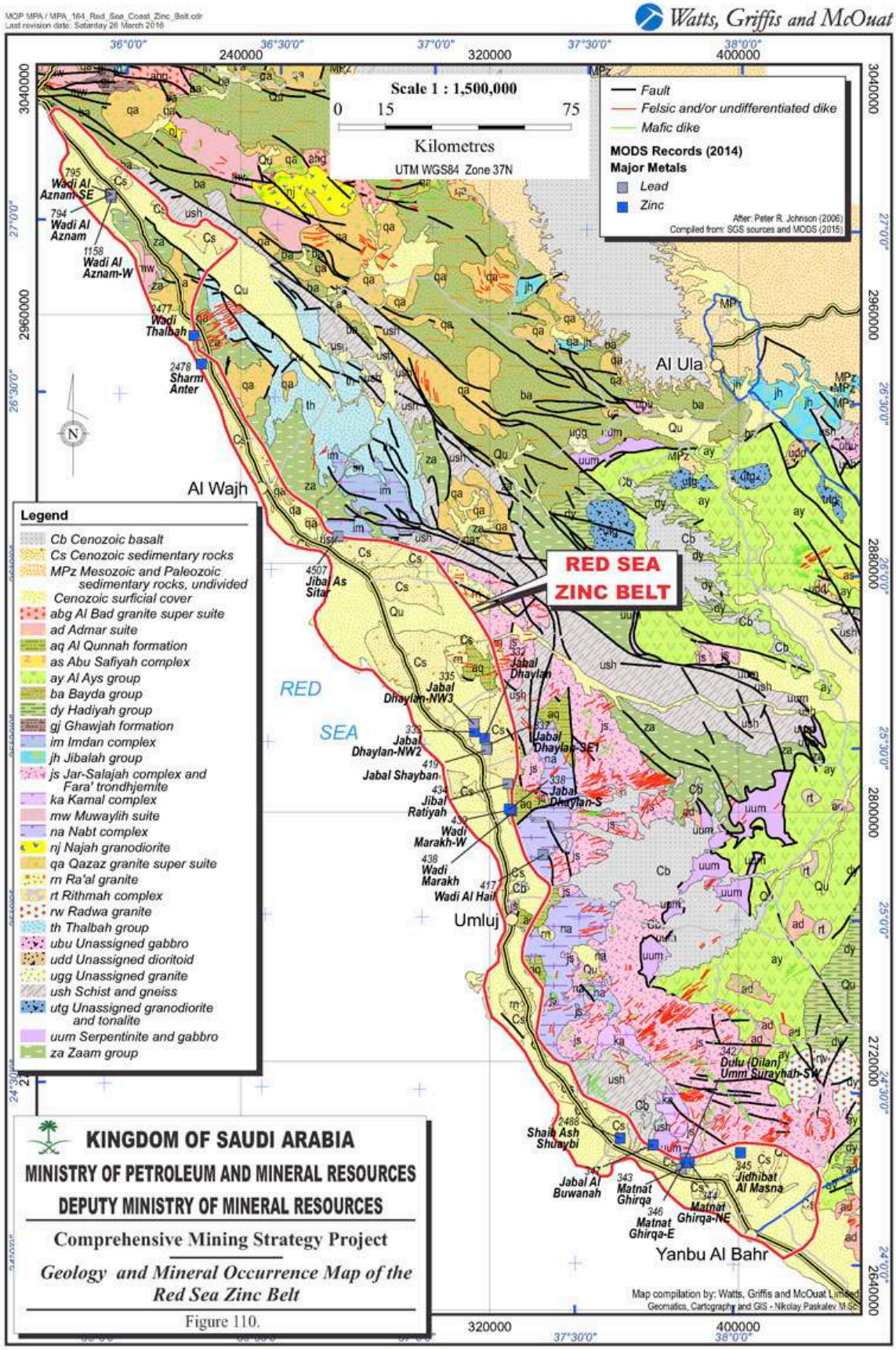
MVT deposits are found globally, and economically important examples are found throughout North, Central and South America, Europe, Asia, Africa and Australia. In the important 50 km long Viburnum Trend in SE Missouri, USA, eight separate mines operated. The average depth to ore was approximately 360 m. Most were discovered through the successful application of the geological model. Deposits averaged 10 to 25 m thick and were 60 to 600 m wide. Total ore production from individual mines ranged from approximately 20 M tonnes to more than 45 M tonnes at grades in sulphide ore as high as 8% Pb and 3% Zn. While this is an extreme example of what is possible in one of the world's great MVT belts, it also demonstrates the importance of exploring with a well-tested geological model.

At the latitude of Saudi Arabia, many of the world's near-surface deposits are highly oxidized such that little of the original sulphide mineralization remains. This is especially so for sphalerite which is commonly replaced by smithsonite and hydrozincite with lesser amounts of hemimorphite and other Zn-carbonate and -silicate minerals. Galena is far more resistive to oxidation, but is typically replaced by cerussite and other Pb-carbonate, -phosphate, -vanadate and other secondary minerals. The deposits found in the Red Sea area are oxidized and are classed as a sub-group named 'Non-Sulphide Zinc' deposits. Not all non-sulphide zinc deposits originate as MVT deposits, however most of the more economically important ones do.

On a regional scale, examples of these deposits are found in Turkey, Iran, Yemen, Sudan and Egypt. These deposits tend to be small, typically less than 10 Mt of mineralization with a combined lead-zinc grade of approximately 10%. This benchmark has been used by many as a means of determining the economic viability of a deposit, however this hurdle is highly influenced by commodity prices, mineralogy and the geometry of the deposit. There is a tendency for such deposits to cluster, and so many successful mining

operations have exploited the mineralization found in an open group of deposits to build a resource base sufficient to justify an investment decision.

In the Kayseri area of Turkey, a junior Canadian company named Pasinex operates a small-scale mine which was re-opened on a former producer. The ore is a mixture of oxide-type and sulphide mineralization. The oxide ore, comprised mostly of smithsonite, is treated in a Waelz kiln to recover zinc-oxide dust, and the sulphide is sold as a concentrate. Several other historical mines have operated in this area and it is WGM's understand that Pasinex will explore the area with the goal of reopening these mines. Closer to Saudi Arabia, the Jabali deposit in Yemen was a source of metals for the Queen of Sheba and now has been shown to contain a resource of approximately 10 Mt averaging 10% Zn+Pb.


Watts, Griffis and McOuat
Scale 1 : 1,500,000
0 15 75
Kilometres
UTM WGS84 Zone 37N
Fault
Felsic and/or undifferentiated dike
Mafic dike
MODS Records (2014)
Major Metals
Lead
Zinc
After: Peter R. Johnson (2006)
Compiled from: SGS sources and MODS (2015)
RED SEA ZINC BELT
Al Wajh
Al Ula
Umluj
Yanbu Al Bahr
RED SEA
Legend
Cb Cenozoic basalt
Cs Cenozoic sedimentary rocks
MPz Mesozoic and Paleozoic sedimentary rocks, undivided
Cenozoic surficial cover
abg Al Bad granite super suite
ad Admar suite
aq Al Qunnah formation
as Abu Safiyah complex
ay Al Ays group
ba Bayda group
dy Hadiyah group
gj Ghawjah formation
im Imdan complex
jh Jibalah group
js Jar-Salajah complex and Fara' trondhjemite
ka Kamal complex
mw Muwaylih suite
na Nabt complex
nj Najah granodiorite
qa Qazaz granite super suite
rn Ra'al granite
rt Rithmah complex
rw Radwa granite
th Thalbah group
ubu Unassigned gabbro
udd Unassigned dioritoid
ugg Unassigned granite
ush Schist and gneiss
utg Unassigned granodiorite and tonalite
uum Serpentinite and gabbro
za Zaam group
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Geology and Mineral Occurrence Map of the Red Sea Zinc Belt
Figure 110.
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.

3.9.2 DISTRIBUTION OF MINERAL OCCURRENCES

Saudi Arabia is host to only a single recognized MVT-type zinc deposit at Jabal Dhaylan. The current mineral resources are approximately 4.1 Mt with an average grade of 5.3% Zn and 1.1% Pb. This deposit has a long history of exploration beginning in 1968 when the BRGM discovered copper mineralization in the area. Soon after that, the potential for economically interesting zinc mineralization was recognized and the copper mineralization became less important. The deposit is associated with a cluster of additional lead and zinc occurrences within a radius of several kilometres. However, the Jabal Dhaylan area is central to a NNW-trending belt of similar zinc and lead prospects that extends northerly to the Red Sea coastline near Duba and southerly to an area within 30 km of Yanbu. From north to south, this prospective belt measures approximately 350 km. The known prospects are listed in Table 95.

Other directly comparable deposits in the region include the Um Gheig Deposit in Egypt which is also composed of non-sulphide ore with estimated reserves of about two million tonnes having an average grade of 10% Zn and 2% Pb (Farag et al, 2010). Other carbonate-hosted zinc and lead prospects in the area include Zug el Bohar, Essel, Wadi Ithil, Wizr, Abu Anz, Gebel el Rusas, Ranga and Abu Ghorban. The middle Miocene host rocks are considered to be facies equivalents of the host rocks in Saudi Arabia. The two mineral belts are parallel and situated directly opposite each other across the Red Sea. In Egypt, the main ore minerals are smithsonite (51%), hydrozincite (19%) and hemimorphite (15%). These deposits have periodically been important sources of zinc for Egypt. They define a relatively unexplored prospective belt that is at least 80 km in length.

3.9.3 PROSPECTIVE MINERAL BELTS AND ZINC OCCURRENCES

3.9.3.1 The Red Sea Miocene Zinc Belt

Location, History and Distribution of Prospects

The prospective belt of carbonate-hosted zinc and lead occurrences, herein referred to as the Jabal Dhaylan Belt, trends NNW parallel to the Red Sea between Yanbu in the south and Al Wajh in the north, a distance of some 350 km. The Jabal Dhaylan Belt is parallel to a second belt in Egypt which adds importance to the prospective character of the area because the mineralization in these sedimentary strata was formed during very early extension along the Red Sea rift.

Table 95
Name and Location of Carbonate-Hosted Zn-Pb Mineral Occurrences in the Red Sea Geological Province

MODS	New Name	Old Name	Main Commodity	Location		Nearest Town	Ranking *	Geometry
				Longitude	Latitude			
0345	Jidhibat Al Masna	Yanbu Al Bahr	Zinc	38.02083300	24.32425000	Yanbu'	VL	v
0795	Wadi Al Aznam-SE	Wadi Azlam	Lead	35.95355600	27.07897200	Duba	Med	strat
1158	Wadi Al Aznam-W	Wadi Azlam	Lead	35.95566700	27.07722200	Duba	Med	uncertain
0794	Wadi Al Aznam	Wadi Azlam	Lead	35.95736100	27.06866700	Duba	Med	strat
2477	Wadi Thalbah	Al Wajh-N	Zinc	36.23552800	26.67400000	Al Wajh	VL	dd
2478	Sharm Anter	Al Wajh-N	Zinc	36.26147200	26.59188900	Al Wajh	VL	dd
4507	Jibal As Sitar	Wadi Abu Maru	Lead	36.71250000	26.10019400	Al Wajh	VL	v
0335	Jabal Dhaylan-NW3	Jabal Dhaylan	Lead	37.15758300	25.56105600	Umluj	Med	dd, strat
0333	Jabal Dhaylan-NW2	Jabal Dhaylan	Zinc	37.15933300	25.53855600	Umluj	Med	dd, strat
0332	Jabal Dhaylan	Jabal Dhaylan	Zinc	37.19227800	25.51897200	Umluj	Med	dd, strat
0419	Jabal Shayban	Jabal Shayban	Lead	37.19911100	25.48727800	Umluj	VL	stwk v
0337	Jabal Dhaylan-SE1	Jabal Dhaylan	Lead	37.20038900	25.49405600	Umluj	VL	dd, strat
0434	Jibal Ratiyah	Umm Lajj	Lead	37.26891700	25.38836100	Umluj	VL	v
0439	Wadi Marakh-W	Umm Lajj	Zinc	37.27277800	25.31500000	Umluj	VL	v
0338	Jabal Dhaylan-S	Jabal Dhaylan-S	Lead	37.27963900	25.30902800	Umluj	VL	dd, strat
0438	Wadi Marakh	Umm Lajj	Zinc	37.28125000	25.31138900	Umluj	VL	v
0417	Wadi Al Hail	Umm Lajj	Lead	37.38388900	25.18416700	Umluj	Med	dd, v
2488	Shaib Ash Shuaybi	Wadi Shahib	Zinc	37.63861100	24.36361100	Yanbu'	Low	dd
0347	Jabal Al Buwanah	Wadi Al Hinu	Zinc	37.74416700	24.34500000	Yanbu'	Low	strat
0343	Matnat Ghirqa	Gherga	Lead	37.83333300	24.27500000	Yanbu'	Low	v
0342	Dulu Umm Surayhah-SW	Meretaba	Lead	37.84500000	24.30500000	Yanbu'	Low	dd
0344	Matnat Ghirqa-NE	Gherga	Zinc	37.85000000	24.29361100	Yanbu'	Low	strat
0346	Matnat Ghirqa-E	Gherga	Zinc	37.85833300	24.29361100	Yanbu'	Low	strat

NOTES: * Ranking is according to the importance designated in the MODS.
v = veins; dd = disseminated; stwk = stockwork; strat = stratiform

Prospects and Exploration Status

In 1968, Zn-Pb-Cu-Ag-barite mineralization was discovered by the BRGM in arkose and limestone at Jabal Dhaylan. In the main prospect area known as Calamine Hill, 21 diamond drill holes were completed to shallowly test the zinc mineralization in the weathered zone. During this period of time, the BRGM carried out an extended program of geophysical surveying including magnetometer, electrical sounding, Turam (EM), self-potential (SP) and IP surveying. Work by the USGS during the late 1990s included selective geological mapping, additional outcrop sampling, extensive ground geophysical surveys and the completion of another 13 diamond drill holes (2,252 m).

In 1996, the BRGM completed 21 diamond drill holes which were used as the basis for the first resource estimate for the deposit: 1.18 Mt averaging 5.6% Zn and 1.4% Pb. During the early 2000s, the area was taken under exploration licence by the Petro Hunt Middle East ("PHME")-Mawarid joint venture. Subsequent exploration by PHME included prospecting, geological mapping, rock chip sampling, trenching

and the collection of 1,359 rock chip samples for the assembly of a representative sample for metallurgical testing. Follow-up drilling totalled 14,675 m and encompassed 90 reverse circulation drill holes, 135 diamond drill holes and 160 rotary air blast ("**RAB**") post holes.

In late 2004, the New Gossan prospect was identified on the western side of Jabal Dhaylan, and south of the known mineralisation at Calamine Hill. This mineralization was black, porous 'gossanous' material that was relatively Mn-rich. A W-dipping mineralised horizon approximately 100 m wide was identified with assay values up to 16% Zn. Follow-up exploration carried out over several years consisted of trenching, RC drilling and some diamond drilling. The exploration of this West Zone, as it was named, led to the recognition of a third mineralized area, the East Zone, which occurs nearby within the same rock units. The West and East Zones are located above up-thrown blocks of granitic basement, suggesting that the bounding faults were conduits for mineralizing fluids. A core zone contains oxide mineralization up to 25 m thick. Continuing work by PHME has identified additional mineralization in the Red Road Cut prospect.

The Jabal Dhaylan mineral resources were digitally estimated by MineMap in 2010 using weighted inverse distance kriging for grade interpolation based on 5 m x 5 m x 4 m blocks and approximately a 1% Zn cut-off to constrain the mineralisation. Four separate mineralized bodies were modelled, comprising Calamine Hill area (JJM3m), New Gossan East, New Gossan West and JJM4m, located 4,600 m SSW of Calamine Hill. The Mineral Resources were classified as "Indicated" as shown in Table 96.

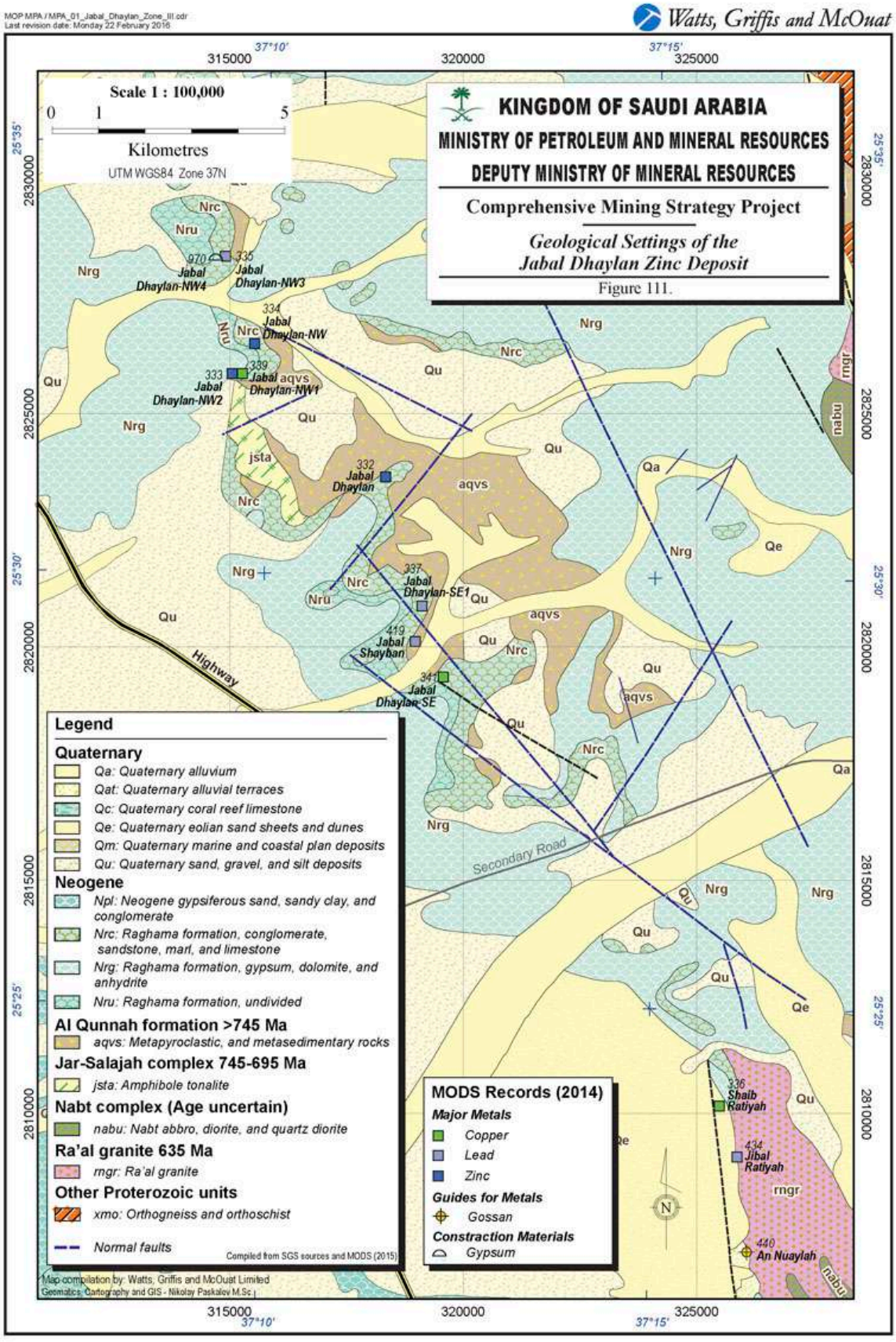
Table 96
Mineral Resource Estimate for Jabal Dhaylan Deposit

Zone	Tons	Grade / Contained Metal			
		% Zn	Zn (tons)	% Pb	Pb (tons)
New Gossan East	1,085,583	5.43	58,947	0.90	9,770
New Gossan West	460,791	5.73	26,403	0.76	3,502
JJM3m	2,382,373	5.10	121,501	1.26	30,017
JJM4m	146,982	6.09	8,951	0.29	426
Total	**4,075,729**	**5.29**	**215,802**	**1.07**	**43,715**

Geology

The Jabal Dhaylan deposit is hosted in early Miocene limestones of the Maqna Group (Figure 111). An simplified, regional-scale section through the deposit is illustrated in Figure 112. Several peneconformable beds are mineralized in a reef facies characterized by abundant coral-bearing biostromes. As stated, a similar belt of rocks are zinc-bearing in eastern Egypt, and it is likely that during the early Miocene, the two belts were continuous or only a few kilometres apart. The widespread zinc-lead mineralization is typical of MVT districts which may contain dozens of deposits. In keeping with the importance of secondary structure as a control on mineralization, it is worth noting that many of the occurrences in the Jabal Dhaylan Belt are located on or near NE-trending transfer faults that released stress during Red Sea rifting. This feature is also noted in many of the world's great MVT districts, such as along the Viburnum Trend in Missouri. This kind of faulting if in strong evidence at both Jabal Dhaylan and in the Umm Gheig zinc-lead belt in Egypt.

The controls on mineralization at Jabal Dhaylan have not been completely defined, however it is clear that permeable horizons within the marine sequence were the focus of high-grade sulphide mineralisation, which was followed by oxidation and supergene enrichment in the near-surface zone as the area was up-lifted during Red Sea spreading. WGM visited the site and noted the absence of mineralization in claystone (argillic) horizons even where adjacent overlying and underlying limestone and reef limestone beds were well mineralized. Permeability was clearly a major control on mineralization as was also the case for the Jabali Deposit in Yemen for which WGM managed definition drilling programs as well as a feasibility study in the early 1990s.


MOP:MPA / MPA_01_Jabal_Dhaylan_Zone_III.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
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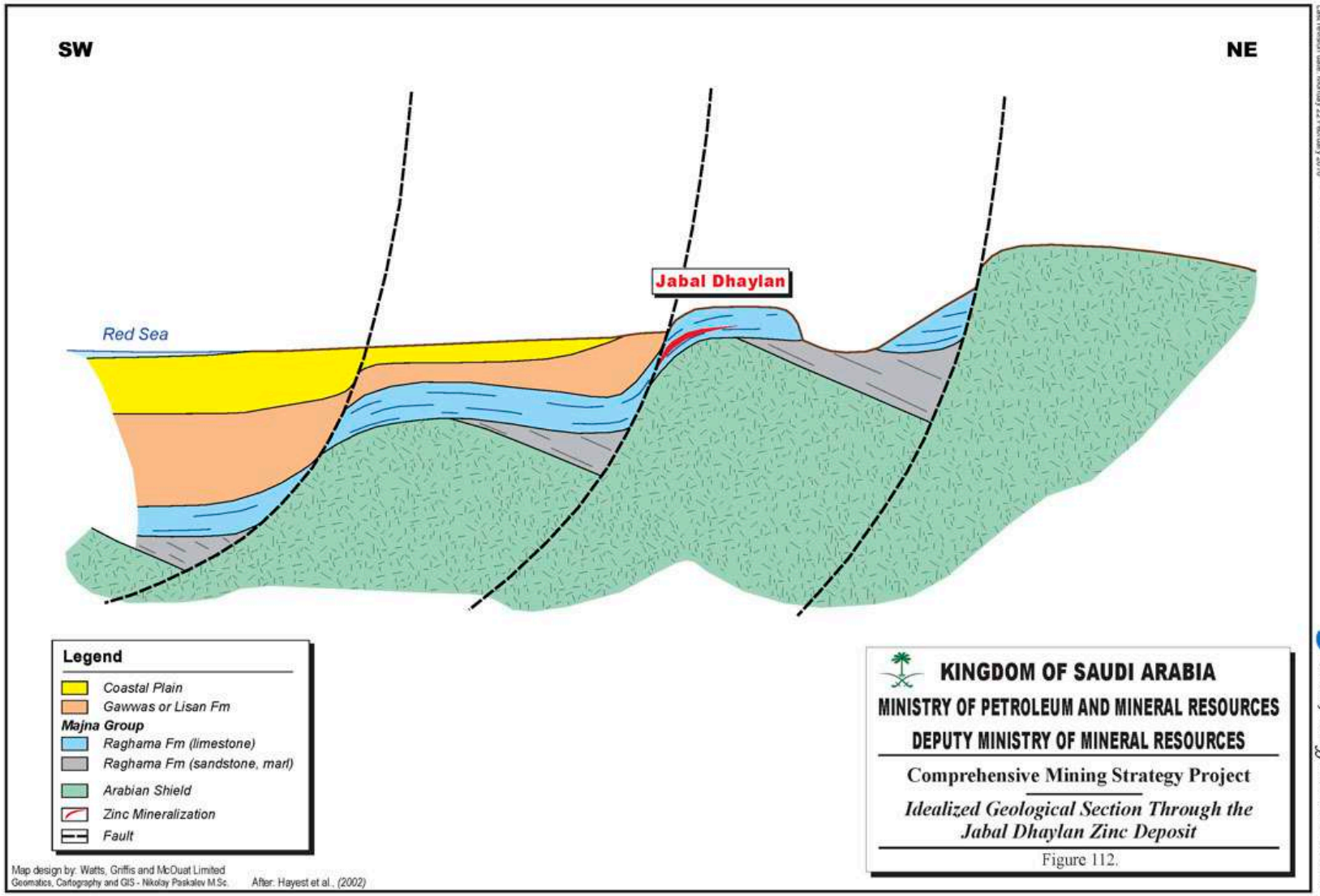
Geological Settings of the Jabal Dhaylan Zinc Deposit
Figure 111.
Scale 1 : 100,000
0 1 5
Kilometres
UTM WGS84 Zone 37N
37°10'
37°15'
315000
320000
325000
2830000
2825000
2820000
2815000
2810000
25°35'
25°30'
25°25'
970 Jabal Dhaylan-NW4
335 Jabal Dhaylan-NW3
334 Jabal Dhaylan-NW
333 Jabal Dhaylan-NW2
339 Jabal aqvs Dhaylan-NW1
332 Jabal Dhaylan
337 Jabal Dhaylan-SE1
419 Jabal Shayban
341 Jabal Dhaylan-SE
336 Shaib Ratiyah
434 Jibal Ratiyah
440 An Nuaylah
Highway
Secondary Road
Legend
Quaternary
Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qc: Quaternary coral reef limestone
Qe: Quaternary eolian sand sheets and dunes
Qm: Quaternary marine and coastal plan deposits
Qu: Quaternary sand, gravel, and silt deposits
Neogene
Npl: Neogene gypsiferous sand, sandy clay, and conglomerate
Nrc: Raghama formation, conglomerate, sandstone, marl, and limestone
Nrg: Raghama formation, gypsum, dolomite, and anhydrite
Nru: Raghama formation, undivided
Al Qunnah formation >745 Ma
aqvs: Metapyroclastic, and metasedimentary rocks
Jar-Salajah complex 745-695 Ma
jsta: Amphibole tonalite
Nabt complex (Age uncertain)
nabu: Nabt abbro, diorite, and quartz diorite
Ra'al granite 635 Ma
rngr: Ra'al granite
Other Proterozoic units
xmo: Orthogneiss and orthoschist
Normal faults
Compiled from SGS sources and MODS (2015)
MODS Records (2014)
Major Metals
Copper
Lead
Zinc
Guides for Metals
Gossan
Constraction Materials
Gypsum
N
Map compilation by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.


SW
NE
Jabal Dhaylan
Red Sea
Legend
Coastal Plain
Gawwas or Lisan Fm
Majna Group
Raghama Fm (limestone)
Raghama Fm (sandstone, marl)
Arabian Shield
Zinc Mineralization
Fault
Map design by: Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Paskalev M.Sc.
After: Hayest et al., (2002)
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MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Idealized Geological Section Through the Jabal Dhaylan Zinc Deposit
Figure 112.
MOP MPA / MPA_DTs_Jabal_Dhaylan_Structural_Relations.cdr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat

Recommendations

Exploration in the Jabal Dhaylan area, and in a wider sense the entire belt, is compromised by relatively low relief and eolian sand cover. There is little doubt of the lateral continuity of the host Miocene carbonate formation, however irregularities in the basement and block faulting result in structural discontinuities that affect the location and distribution of the favourable host rocks.

None of the geophysical surveys completed to date has been effective in directly detecting mineralization because the primary sulphide minerals sphalerite and galena are nonmagnetic and relatively unresponsive to electrical surveys. The oxidized mineralization consisting of variable amounts of smithsonite, hydrozincite, hemimorphite, cerrusite and other minerals are even less responsive. Geophysical surveying has been effective at delineating major contrasts in lithologies, such as the boundaries between horsts of up-lifted basement and the sedimentary cover, and this can be useful information in modelling potential structural traps for mineralization. Geochemical surveying can be very effective where wadis have cut down through alluvial and aeolian cover, but such instances are relatively uncommon along the trend of the favourable zone. Geological mapping is similarly hampered by wind-blown sand and low relief.

It is clear from experience elsewhere that understanding the geology is of paramount importance in defining targets for drilling. Any future exploration must be focused on this goal. It is also clear that structural features, primarily faults parallel and normal to the margins of the basin, have played important roles in channeling metal-bearing fluids upwards into permeable and chemically reactive host rocks. Because the faults are post-Miocene and therefore relatively young, they are visible where they cut areas of the Arabian Shield proximal top the basin margins. These structures tend to be NE- to E-striking, and they are visible on Google Earth images. These may be used as guides to prospective areas. For example, there are a large number of such lineaments in an area populated by several zinc prospects (MODS 0417, 0438, 0434) located 15 to 40 km north to northeast of the coastal town of Umluj (Umm Laij). From a regional and local perspective, the evaluation of higher resolution and relatively low cost Aster and Landsat satellite imagery should be a basic first step in any new exploration plan as a means of identifying important lineaments than may control basement topography below the Miocene cover rocks. After being identified, such areas should be geologically mapped and prospected to identify:

1) dislocations in the geology (potential conduits);
2) areas of dolomitization (evidence of fluid through-put); and,
3) rocks anomalous by zinc (using Zinc-Zap – wait for delayed reactions indicating low-level mineralization).

At the same time, these areas can be geochemically sampled at a sample density of 5 sample sites per square kilometre to identify areas into which zinc or lead mineralization has been shed. As most secondary zinc and lead minerals are heavy minerals (e.g. smithsonite, cerrusite, hemimorphite, hydrozincite, etc.), sampling should be carried out from locations in the wadis where heavy minerals are likely to concentrate (i.e. in topographic/channel traps). All samples should screened to reduce the effects of windblown sand and some orientation surveying might be required to determine the best fraction for analysis. The hardness

of the secondary minerals is generally moderate to soft, and they will reduce rapidly away from source. The samples should initially be analysed using a multi-element technique such as ICP with a solvent (aqua regia or 3-acid) that provides good digestion without volatilizing important indicator elements. All samples that exceed the upper detection limit must be reanalyzed using a more quantitative method for ore-grade analyses. QA/QC protocols must follow industry standards. A small (50-100 gram) archive sample of reject material should be retained from each sample.

Any occurrences detected by the foregoing should be surveyed using IP equipment to provide data to a minimum 150 m. This could mean, for example, using a dipole–dipole array with a 25-metre 'a' spacing and taking readings for n=1 through n=8 which would provide for good resolution. Deeper penetration would be possible with a wider 'a' spacing (e.g. 50 m) and fewer reading points (n=1 to n=6), however the data resolution would be reduced. The initial targets for drilling should be relatively close to surface. The greatest challenge will be getting current into bedrock and reducing noise in the survey data.

Finally, all targets should be drill-tested using diamond drilling equipment. As the targets are likely to be large relative to (say) a gold zone, a budget of 1,500 m to 2,000 m should be assigned each target. Normal practices and protocols for core logging, sampling and QA/QC should be followed.

3.9.3.2 The Arabian Platform

Location, History and Distribution of Prospects

In addition to the known deposits and occurrences along the Red Sea coastal plain, there is anecdotal evidence from various sources (former employees of Ma'aden and ARAMCO) of significant zinc and lead intersections in oil and gas exploration wells in Phanerozoic strata along the eastern margin of the Arabian Shield. The presence of stratabound, replacement-type (carbonate-hosted or MVT) deposits is permissible given our general geological knowledge of the sedimentary basins that formed on the Arabian Platform to the east of the Arabian Shield. These basins host the great oil and gas deposits of the Arabian Gulf region, and there is significant evidence from other parts of the world that basins such as these can host economically significant zinc deposits as well as other minerals such as halite and sylvite. The Ramlat as Sabatayn Graben in Yemen is an extension of the basins that underlie the Ar Rub al Khali, and this graben contains not only oil and gas deposits but also the Jabali lead-zinc deposit hosted in a Jurassic carbonate reef. Similar potential exists within the Arabian Platform in the KSA. The anecdotal evidence concerning such mineralization along the margin of the Shield places the mineralization at a depth of several thousand metres, clearly too deep to have any economic viability, however the mere presence of such mineralization, if it truly exists, confirms the viability of the metallogenic model in this setting. WGM has not been provided with any locations or other data concerning the occurrences and so at this time we are unable to do more than speculate as to what might be possible, however, it is clear that potential exists for mineralization closer to surface and probably within a few kilometres of the exposed margin of the unconformity between the Shield and cover rocks.

Recommendations

The presence of mineralization at extreme depth in Phanerozoic strata along the eastern margin of the Arabian Shield should be investigated. If the location of the drill hole intersections can be disclosed by ARAMCO, an assessment should be made of any structures that might control the localization of mineralization, especially structures that extend from the Shield into the younger cover rocks. Little is known by metals geologists about the margin of the Shield and the gradient (slope) of the unconformity on which the cover rocks were deposited. The unconformity surface is an excellent exploration target for carbonate-hosted (MVT-type) lead-zinc mineralization. The SGS should dedicate a program to investigating this geological setting in the hope of identifying prospective areas. These areas would contain favourable carbonate host rocks at a shallow depth and would be cut by faults at angles normal to the edge of the basin, possibly defining horsts and graben structures along the basin margin. Zinc mineralization at surface would likely manifest itself as mineral species such as smithsonite, hydrozincite, hemimorphite or willemite due to long-term weathering effects on sphalerite. Lead minerals might be present as galena and other mineral species including cerrusite and mimetite. The deposits are generally unresponsive to geophysical surveying, however if significant mineralization is exposed on surface, geochemical anomalies should be present in wadi sediment samples. Regional geochemical surveying is therefore a useful tool in locating in-situ mineralization. Ancient mine sites may also be present where artisanal miners extracted galena which was used for various purposes, including as a source for silver.

3.9.4 MINERAL POTENTIAL ASSESSMENT

The assessment of the potential of the Tertiary Red Sea Zinc Belt may be possible using the EMINERS software developed by the US Geological Survey. The geological and metallogenic model is clearly Mississippi Valley-Type mineralization. The challenge is in adapting the USGS model for local circumstances which include:

- a general lack of feasibility study level (advanced) projects or mines in the local area on which to develop baseline data for anticipated resources in respect to grades and tonnages;
- an abundance of small under-explored deposits which, if included, would skew outcomes towards the lower quartile of deposits on a global basis; and,
- determining how many large deposits from the global populations should be included and which deposits to include.

Given the status of the single zinc deposit in the KSA, WGM decided to use a weight of evidence approach because whether EMINERS is used or not, the outcome hinges solely on an estimate as to the likelihood of Jabal Dhaylan achieving sufficient size to be economically exploitable and an estimate of the number of similar deposits that might be found.

As a general rule of thumb, carbonate-replacement deposits such as Jabal Dhaylan should have a Mineral Resource of approximately 10 Mt averaging approximately 10% combined Zn+Pb to qualify as economically viable. An excellent analogue for this benchmark is the Jabali deposit in Yemen. This ancient mining site, rediscovered by the BRGM and subsequently delineated through diamond drilling by WGM during 1991-92, has undergone several feasibility reports including studies by WGM and by its various owners. At the time the exploration drilling was completed, WGM estimated that Jabali precisely matched this benchmark, however at that time the price of zinc declined to less than $1,000 per tonne and the project was clearly uneconomic. As the price has risen over the years, currently standing at approximately $1,500 per tonne, deposits such as Jabali have been brought into production. At recent highs of more than $2,200 per tonne the economics of these projects can favour smaller deposits, depending on overcoming metallurgical and infrastructure challenges.

WGM believes that the Red Sea Zinc Belt has the potential for four (4) Jabali-sized deposits totalling some 40 Mt of mineralization grading approximately 9% zinc and 1% lead. The Jabal Dhaylan deposit would be one of these. Silver contents in the range of 10-20 g/t can be anticipated. Without convincing evidence of deposits clustering, there is no basis for estimating a top-cap on the maximum number of deposits, however it would be unlikely that the belt would contain significantly more than 7 deposits. Much is uncertain regarding the fundamental geology due to alluvial and eolian deposits and younger cover rocks.

A potential for deposits similar to Jabal Dhaylan exists in the Arabian Platform adjacent to the Arabian Shield. At this time, WGM has no useful knowledge of any such mineralization, however anecdotal information from various sources at Ma'aden and ARAMCO indicates that replacement type zinc mineralization has been encountered at great depth in one (or many?) oil/gas wells in the basin directly east of the shield. With the knowledge that such mineralization is present, there is excellent potential for deposits to be found along the eastern margin of the shield, however any estimation of economic viability would be pre-mature in the extreme until such time as more specific information is shared between ARAMCO and the SGS.

3.9.5 TECHNICAL AND ECONOMIC VIABILITY OF PREDICTED UNDISCOVERED ZN-PB DEPOSITS

Introduction

The WGM consensus view is that the Red Sea Zinc Belt has the potential to host 4 10 Mt deposits grading 9% Zn and 1% Pb with an average silver content of 15 g/t. This view would correspond to the 50% confidence level generated by EMINERS software. As this is a weight of evidence opinion, there are no issues relating to under-reporting. WGM's high-level or "blue-sky" outcome corresponding to a 10% confidence level estimate, places the potential for as many as seven such deposits.

For the purpose of viability modeling, the undiscovered carbonate-hosted Zn-Pb-Ag resources were allocated equally amongst all deposits although in reality some variations will occur. On the basis of the existing geological evidence, WGM believes that all of these deposits would be open pit operations as permitted by a near-surface setting and relatively flat-lying to shallowly dipping carbonate stratigraphy.

The undiscovered zinc-lead-silver resources in the Red Sea Zinc Belt are summarized in Table 97. This information was provided to WGM's engineering group for further assessment such that a provisional mining schedule could be developed as a basis for determining what mining method might be appropriate given the "average" geometric configuration of such deposits. This was used as a basis for selecting and sizing equipment as well as estimating capital, operating and other cost factors. It must be cautioned at Jabal Dhaylan currently has a JORC-compliant mineral resource of approximately half that used for modeling purposes, and additional exploration is needed to enlarge this resource base. WGM is optimistic that further drilling will add to the resources. The other three locations shown in the table are established zinc prospects that are essentially unexplored and therefore lack mineral resources. These names reflect three of the better prospect areas in the coastal belt, however their names are used here for illustrative purposes only in the viability modeling process. There is no assurance that these specific prospects can be developed into deposits.

Table 97
Summary of WGM's Allocation of Zn-Pb-Ag Resources to Undiscovered Mines for Viability Modeling

Name of Potential Mine	EMINERS Output at 50% Confidence Level				
	Number of Mines	Tonnes per Undiscovered Mine (millions)	Average Grade of Each Undiscovered Mine		
			Zn (%)	Pb (%)	Ag (g/t)
Jabal Dhaylan	1	10	9.0%	1.0%	15.0
Wadi al Aznam	1	10	9.0%	1.0%	15.0
Matnat Ghirqa	1	10	9.0%	1.0%	15.0
Wadi Marakh	1	10	9.0%	1.0%	15.0

Mining and Processing

In order to evaluate undiscovered mines, cost estimates were prepared for a range of typical mines in the Kingdom. These are order-of-magnitude cost estimates, designed to get an initial reading on potential viability. WGM initially prepared personnel lists for typical small, medium, and large mines, both open pit

million tonnes was selected. This results in a mine life of 10 years. Mining of waste rock was modelled at a constant annual tonnage.

Mining and maintenance personnel quantities were estimated based on a mining fleet analysis. For each mine, a few positions were assigned international salaries; for all other jobs filled by Saudi nationals, wages and benefit estimates were based on the 2014 SGS report "Directory of Mining Services Cost in Saudi Arabia". Quantities of consumables were then prepared for each of the six models. Costs were prepared using information from WGM data.

Personnel costs and consumables costs were combined to provide an estimate of operating cost per tonne for all mine site costs for Mining. Equipment lists and personnel lists for typical medium-sized open pit mines are shown in Section 3.1.6 in Table 32 and 33. Capital cost estimates for Mining were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM sourced data.

The Jabal Dhaylan deposit is a member of the non-sulphide carbonate replacement deposits, or CRDs as they are commonly referred. These deposits are typically the oxidized remnants of what had been a sulphide deposit, typically a Mississippi Valley-Type deposit or Irish-type CRD. In some cases, the original deposit is thought to be a SEDEX-type deposit. Typically, the zinc mineralization is predominantly composed of secondary smithsonite, with variable amounts of hydrozincite and hemimorphite. Lead mineralization is typically cerrusite but may include such minerals as mimetite or anglesite. These ores tend to be very acid-consuming and various hydrometallurgical processes, including both acid-leach and alkaline-leach, can be used to treat the ore for the recovery of zinc metal.

Limited metallurgical testwork completed in 2005-2007 period concluded that it was not possible to concentrate the zinc oxide mineralization (Mintec, 2007). Hydrometallurgical testing concluded that the high acid consumption necessary to digest the high carbonate host rock and complex solutions that resulted would be prohibitively expensive as a processing option. However process testing of whole ore calcination followed by electric arc furnace ("**EAF**") treatment and recovery of zinc and lead in condensers in the off gases could become an economic treatment process for this style of mineralization. High grade zinc metal would be produced at the mine site as well as lead and silver metal. Although commercial applications of the technology are not available, studies completed by Mintec were referenced in considering application of this technology in the economics of the carbonate hosted Zn-Pb-Ag deposits in the Red Sea Belt.

Capital and operating costs for the scale of projects considered were factored from the Mintec estimates that were reported to be + or - 50%

To reduce capital costs, WGM has assumed that a hydrometallurgical plant to produce zinc metal will not be constructed, and that the mines will produce a high-purity electric arc zinc-oxide dust.

General and Administration

Each mine was considered as a typical remote location and self-contained with an accommodation village for personnel and diesel power generation along with the facilities necessary to mine and process the deposit and carry out the associated maintenance.

General and administrative ("**G&A**") costs were estimated to reflect all the operating costs inside the mine gate including security, insurance, and environmental costs. Personnel costs and consumables costs were combined to provide an estimate of the operating cost per tonne for G&A. G&A capital cost estimates were prepared for each cost model. Estimates were based on the SGS cost directory along with WGM sourced data.

Economic Analysis

The economic analysis of the undiscovered carbonate-hosted, zinc-lead-silver mines within the Red Sea Zinc Belt yields the results summarized in the following for the four identical deposits (Table 98).

Table 98
Summary of Economic Modeling of the Undiscovered Carbonate-Hosted Zn-Pb-Ag Deposits

Mineral Belt	Project	Total IRR (%)	Net Cash Flow	
			($ / t ore)	($M)
Red Sea Miocene Zinc Belt	Jabal Dhaylan	15%	$65.91	$659
Red Sea Miocene Zinc Belt	Wadi Al Aznam	15%	$65.91	$659
Red Sea Miocene Zinc Belt	Mat Ghirqa	15%	$65.91	$659
Red Sea Miocene Zinc Belt	Wadi Marakh	15%	$65.91	$659
Averages and Total		15%	$65.91	**$2,636**

In estimating the economic viability of the zinc oxide deposits, WGM used the following parameters:

- Zinc metal price - $2,161/tonne
- Lead metal price - $1,550/tonne
- Silver price – US$20.20/oz.
- Recovery of the zinc to metal – 90%
- Recovery of the lead to metal – 90%
- Recovery of the silver – 90%.

The forecast metal prices were long-term estimates provided by McKinsey. The results for Jabal Dhaylan show that the projects are likely to be cash-flow positive, and there is reasonable potential in the non-sulphide (oxide-type) Red Sea zinc deposits. **Individually, these mines show an IRR of 15% with a net cash flow of $65.91 per tonne of ore. On mine closure, the net cash flow ("NCF") to the mine would be $659 million. The group of four mines would generate approximately $2.64 billion in NCF. If the mines clustered in such a manner that the number of production facilities could be reduced through sharing, then the overall economics of the clustered mines would improve dramatically.**

Notwithstanding the predicted positive results, much work needs to be done to build an information base suitable for exploring the Red Sea Zinc Belt, and metallurgical testing data is needed at Jabal Dhaylan to allow a proper evaluation of processing options for this mineralization. The Jabal Dhaylan remains an exploration project at this time, arguably one of the better base metal projects in the Kingdom. Increasing zinc prices could lower the hurdle required for this deposit to be minable.

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3.11 THORIUM DEPOSITS

3.11.1 METALLOGENIC MODEL AND EXISTING MINES

As a result of the same airborne radiometric surveying by Minatone (1984) and ARGAS (1982) and subsequent surveys that resulted in the identification of thorium anomalies, combined with the unique spectral characteristics of thorium given its higher energy decay particle, the identification of thorium anomalies was possible. A list of thorium occurrences for the KSA, as sourced from the MODS is provided in Table 101. According to the available information in the database, there are 23 thorium prospects in the Kingdom, however these reflect mineralization in only six areas of which the Jibal Tuwalah area is prevalent with 18 of the occurrences. There are no known thorium occurrences in the Phanerozoic cover rocks of the Arabian Platform or in the Phanerozoic rocks along the Red Sea Coastal plain.

These anomalies are associated with very late Proterozoic granites, generally of an alkaline to peralkaline composition. Most are associated with late-stage pegmatite phases of the host granites and some are associated with yttrium, niobium, tantalum and the rare earth metals. These metals are naturally enriched in granites of all types.

Thorium is not mined as an ore but is captured as a by-product. The world's primary source of thorium is from rare-earth mining and it is sourced from monazite, a thorium phosphate mineral. Monazite has also been produced historically as a by-product of processing heavy-mineral sand deposits for titanium and zirconium minerals although no such activity is occurring at this time. Globally, there is only a very small market for thorium. Globally, less than ten companies processed or fabricated various forms of thorium for uses such as catalysts, high-temperature ceramics and welding electrodes. Thorium's use has been in decline due to concerns over its radioactivity. The market is quite variable and, for example, the value of imports into the United States during 2014 is estimated at only $302,000 at a value of approximately $450-500 per kilogram.

Without demand for the rare earths, monazite would probably not be recovered for its thorium content. In 2014, in descending order, India, Malaysia, Vietnam, and Brazil led global production of monazite and have the required refinery infrastructure for producing thorium. Other ore minerals with higher thorium contents, such as thorite, would be available if demand significantly increased.

Despite waning industrial interest, thorium has received attention as a potential energy source. The CANDU reactor, developed by Atomic Energy of Canada Limited, uses heavy water as a moderator and has the capability of using various concentrations of thorium as a nuclear fuel. Light-water reactors, developed and in use by many other countries, do not have this capability.

Table 99
Summary Of Thorium Occurrences

MODS	New Name	Old Name	Location		Nearest Town	Ranking *	Geometry
			Latitude	Longitude			
3360	Badayi Naqbayn	Naqbein	27.6306940	41.6699720	Hail	Undefined	Granite - Undetermined
0184	Jabal Sumayra Al Afnah	Jabal Ebed	25.9444440	40.8416670	Al Hulayfah	Medium	Pegmatite Veins
4215	Jibal Ad Diyahin	Hadb Addiaheen-E	23.5333330	41.2500000	Mahd adh Dhahab	Undefined	Granite - Undetermined
0200	Jibal At Tuwal	Jabal At Tuwalah	25.5555560	40.9708330	Al Hulayfah	Low	Pegmatite Lenses
0204	Jibal At Tuwal-E	Jabal At Tuwalah	25.5541670	40.9888890	Al Hulayfah	Low	Pegmatite Veins
0203	Jibal At Tuwal-NE	Jabal At Tuwalah	25.5583330	40.9750000	Al Hulayfah	Low	Pegmatite Veins
0201	Jibal At Tuwal-NW	Jabal At Tuwalah	25.5541670	40.9652780	Al Hulayfah	Low	Pegmatite Veins
0202	Jibal At Tuwal-S	Jabal At Tuwalah	25.5500000	40.9680560	Al Hulayfah	Low	Pegmatite Veins
0205	Jibal At Tuwal-SE	Jabal At Tuwalah	25.5472220	40.9888890	Al Hulayfah	Low	Pegmatite Veins
2312	Jibal Nitaq	Jabal Hentag	23.8583330	44.1625000	Ad Dawadimi	Undefined	Granite - Undetermined
0198	Jibal Tuwalah	Jibal Tuwalah	25.5416670	40.9722220	Al Hulayfah	Low	Pegmatite Veins
0213	Jibal Tuwalah	Jibal Tuwalah	25.5416670	40.9722220	Al Hulayfah	Low	Pegmatite Veins
0214	Jibal Tuwalah	Jibal Tuwalah	25.5416670	40.9722220	Al Hulayfah	Low	Pegmatite Veins
0215	Jibal Tuwalah	Jibal Tuwalah	25.5416670	40.9722220	Al Hulayfah	Low	Pegmatite Veins
0216	Jibal Tuwalah	Jibal Tuwalah	25.5416670	40.9722220	Al Hulayfah	Low	Pegmatite Veins
0211	Jibal Tuwalah-SW	Jibal Tuwalah-SW	25.5222220	40.9430560	Al Hulayfah	Low	Pegmatite Veins
0212	Jibal Tuwalah-SW1	Jibal Tuwalah-SW1	25.5236110	40.9375000	Al Hulayfah	Low	Pegmatite Veins
0208	Jibal Tuwalah-SW2	Jibal Tuwalah-SW2	25.5277780	40.9638890	Al Hulayfah	Low	Pegmatite Veins
0210	Jibal Tuwalah-SW3	Jibal Tuwalah-SW3	25.5305560	40.9500000	Al Hulayfah	Low	Pegmatite Lenses
0209	Jibal Tuwalah-SW4	Jibal Tuwalah-SW4	25.5302780	40.9605560	Al Hulayfah	Low	Pegmatite Veins
0206	Jibal Tuwalah-W	Jabal At Tuwalah	25.5388890	40.9625000	Al Hulayfah	Low	Pegmatite Veins
0207	Jibali Tuwalah-S	Jibali Tuwalah-S	25.5194440	40.9680560	Al Hulayfah	Low	Pegmatite Veins
3361	Qufar	Qufar	27.4576110	41.6041390	Hail	Low	Granite - Undetermined

3.11.2 DISTRIBUTION OF DEPOSITS

Most of the known thorium occurrences are associated with RE-enriched peralkaline granites and the distribution of such occurrences is related to mineralogically unique phases within these bodies generally reflecting late stage melts (typically pegmatites) into which the heavy metals were partitioned. As such, these occurrences are intimately associated with specific, irregularly distributed intrusions rather than in mineral belts in the conventional sense. Like the granite-hosted thorium prospects, the thorium

occurrences are sporadic in their distribution. In some cases, these occurrences can be volumetrically significant, however challenges relating to potential refractory mineralogy and poor markets combine with all the usual factors affecting mining and processing to make these deposits uneconomic as sources for thorium.

Reconnaissance work by the USGS and Riofinex during the 1980s indicated that alkalic granite intrusions at Qufar and Naqbein in the Hail area contained anomalous concentrations of REE. Follow-up programs focused on tin and tungsten and did not assess the REE potential of these intrusions. Additional work was required to adequately investigate the REE content of the anomalous intrusions, however there was no work recommended specifically for thorium exploration.

3.11.3 PROSPECTIVE MINERAL BELTS AND THORIUM OCCURRENCES

3.11.3.1 Jibal Tuwalah Prospect

As noted there are no thorium belts in the sense that geologists refer to mineral belts. The major thorium occurrences are somewhat isolated and the only occurrence of note is the Jibal Tuwalah prospect. This is the best example of a thorium prospect in the KSA, at least in the sense that it has been extensively sampled by the SGS. The SGS collected 426 bedrock samples that comprised 126 samples of the host Jibal Tuwalah granite/pegmatite, 55 samples of sheared granite and 244 samples of granite and pegmatite from the surrounding area. With the single exception of a mineralized quartz vein, all of the samples with more than 0.1% thorium were of pegmatite. Only two samples with between 500 and 1,000 ppm thorium were not of pegmatite, one a quartz vein and the other a sample of alkali granite. All of these samples were very elevated in zirconium, ranging from 11,429 ppm to 305,004 ppm (30.5%). The samples containing more than 500 ppm thorium were also elevated in REEs (2,564 ppm – 58,003 ppm), niobium (51 ppm – 2,506 ppm) and tantalum (0.5 ppm – 229 ppm). The Th-Zr -REE correlation was very good in the most strongly mineralized samples which were characteristically sheared pegmatites which suggests the possibility of some degree of hydrothermal enrichment and/or alterations in these rocks.

3.11.3.2 Other Prospects

There are a number of what might be considered miscellaneous notes on thorium such as geochemical enrichments in the Abt Schist, however these are thought of as nothing more than low level geochemical anomalies, generally less than 100 ppm, and are of no economic interest. In retrospect, it is difficult to find fault with the approach given the vast difference in commercial value between these metals and thorium. Some of the aforementioned thorium prospects, such as Qufar, were recommended for follow-up on the basis of REE content.

3.11.4 RECOMMENDATIONS

Any scenario that would precipitate a revolution in thorium markets would be predicated on the successful development and widespread deployment of a thorium nuclear energy reactor design. This appears to be unlikely, certainly in the foreseeable future. Given that the thorium in any of the alkaline granites and associated intrusive phases has little or no commercial value, WGM cannot recommend any type of exploration what would target thorium. As a component of any REE mineralization, thorium contents need to be determined as baseline information governing the implementation of spectrometer and scintillometer surveys and the use of radiometric data generated. As any development of a REE deposit would need to deal with thorium as a potential waste product, analytical data on thorium is also required.

3.11.5 ECONOMIC VIABILITY ASSESSMENT

For reasons mentioned above, it is difficult to envision any scenario in the near to medium term that would create an economic incentive to justify exploring for and developing a thorium mine. The world has sufficient resources for hundreds of years at current rates of consumption. According to the USGS 2015 commodity review of thorium, India's Department of Atomic Energy the country's heavy-mineral sands were estimated to have a resource base of 12 M short tons of monazite with an average thorium oxide content of 9–10% (7.0-7.8 Mt of Th metal). The United States is estimated to have resources of approximately 200,000 tonnes of ThO_2 (156,000 tonnes of thorium metal). Alternative sources such as the World Nuclear Association put global resources at 6.36 M tonnes of thorium. The current global market for thorium is estimated to be approximately equal to the amount produced in SE Asia each year, or approximately 10,000 tonnes per year. Current thorium resources are probably sufficient for the next 600 years and beyond at current rates of consumption. It is extremely difficult to imagine a series of developments that could justify investment in the exploration and development of thorium resources in Saudi Arabia.

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3.12 MISCELLANEOUS DEPOSITS

3.12.1 EPITHERMAL GOLD AND SILVER DEPOSITS

The deposits described in this chapter are important in the Kingdom in terms of economic impact, or potential impact, as well as representing viable exploration targets. As models, however, these deposits are localized and not widely represented in respect to known prospects. The fact that they are not widely known is probably due to a combination of geological factors that may make these deposits somewhat unique. However, the fact that they are not known outside the areas in which they occur may also be due to a lack of exploration dedicated to these specific deposit types. The exploration carried out to date in the Kingdom has focussed on ancient mine sites and known prospects as these represent higher-probability targets than testing unique metallogenic models that may not be well understood. Consequently, these models have not been widely tested even in the areas in which they occur. The reader may be surprised to find the Mahd adh Dhahab deposit on this list, however as a polymetallic high-sulphidation, epithermal deposit, the Mahd adh Dhahab Mine is unique even though it is arguably one of the world's oldest mines. Similarly, the Lahaf, Samrah and Hajlan prospects represent under-appreciated prospects that are compliant with the general aspects of the high-sulphidation epithermal deposit model.

The examples contained in this section are selected as the most prominent examples of their kind. They represent the more promising end-members of a potentially large population of occurrences that has not been well studied in the KSA. There are 258 silver prospects in the MODS, many of which are polymetallic and may fit the aforementioned model. Most of these are hosted in granite or other plutonic rocks, and are clearly related to their host rocks and may not be epithermal. However, the presence of high silver values in the presence of base metal and gold values can also be an indicator for VMS-type mineralization, especially in calc-alkaline volcanic belts. It is interesting that 47 of the 258 silver prospects (27%) are hosted in felsic to intermediate volcanic rocks or in rocks that could be metavolcanic rocks. Clearly, this group of occurrences deserves greater attention than has been given to them to date.

3.12.2 EPITHERMAL HIGH-SULPHIDATION GOLD DEPOSITS

3.12.2.1 Mahd adh Dhahab Mine

Location, History and Status

There is no doubt that the Mahd adh Dhahab mine (MODS 0003) located at 23°10'N and 40°52'E, is the most significant gold mine in the Kingdom. Mines originally for gold, it is not a polymetallic operations producing significant amounts of silver and base metals as well as gold. Studies of the ancient mine located at Mahd adh Dhahab ("Cradle of Gold") in Saudi Arabia indicate that gold, silver and copper were produced from this site during the reign of King Solomon (961-922 B.C.). The U.S.-Saudi team that rediscovered the

location of the ancient mine estimated from the size of the ancient workings, the largest in Saudi Arabia, and the volume of waste rock, that Mahd adh Dhahab produced over 31 metric tons of gold in ancient times, or approximately one million ounces. In addition, there are gold mines in the area which have been worked intermittently since ancient times. Some near Taif are of pre-Islamic date, although how early they are is not yet determined. It is generally accepted that gold mining probably began about 2100 BC in the Arabian Peninsula, although copper mining is known to have begun much earlier in Mesopotamia and undoubtedly also in Arabia. The post-glacial period had much higher levels of rainfall that the area experiences today, and so the availability of water supported a significant mining industry estimated to have comprised as many as 1,000 mines at its peak. All of the mines were developed using hammer and chisel techniques, combined with firing the rock and quenching to produce thermal shattering. The mines rarely extended below the water table due to the inability of miners to expel water from the workings. Mining in the Arabian Peninsula gradually declined during the Ottoman Empire, possibly as a result of exhaustion of easily won gold resources, and possibly due to sources of gold outside of the region.

Gold production in the region fell into a long period of decline until the modern era. Production resumed in Saudi Arabia in 1983 with the re-opening of the Mahd adh Dhahab Mine by Petromin, representing the interests of the King and the Saudi people. The mine was subsequently operated by the Saudi State mining company, then known as Petromin.

Geology

The Mahd adh Dhahab deposit is a high sulphidation, epithermal deposit located near a felsic volcanic centre. The host rocks are mafic to felsic volcanic and volcano-sedimentary rocks predominantly represented by andesite, agglomerate and tuff which are intruded by a rhyolite porphyry stock. The primary stratigraphic trend is east-west striking and moderately north-dipping. Gold mineralization is controlled by N to NW-trending faults and shears in which quartz veins and stockworks have developed. The host rocks are silicified, moderately to intensely sericitized and chloritized. Pervasive carbonate alteration surrounds the mineralized zones which contain pyrite, chalcopyrite, sphalerite, galena and silver. The average gold grade is 16.1 g/t and approximately 1 Mt of resources and reserves remain in the mine. However, the deposit has not been drill-tested to great depth which allows substantial potential for future drilling to result in the discovery of additional ore bodies.

Recommendations

The Mahd Group is associated with a series of gold-rich, base metals deposits in a belt extending to the west into the Samran-Shayban area. This area has been explored periodically for stratabound VMS-type mineralization, however it is uncertain whether the exploration programs have considered the potential for epithermal precious and base metals mineralization which would be discordant with stratigraphy. The prospects hosted in the Mahd Group that are associated with a volcanic centre should be assessed for the

potential for discordant stockworks and vein systems controlled by cross-cutting shears that interest caldera-type volcanic sequences.

Deposits such as Mahd adh Dhahab are detectable at surface by strong geochemical anomalies and the use of soil, steam sediment and potentially selective or partial extraction leach geochemical technology such as MMI offer the best methods for exploration. However, where these deposits do not come to surface, only the partial leach geochemistry offers any chance for detection, although the results may be ambiguous. Geophysical means, such as that recommended for the Al-Amar deposit may be useful. Complex veins systems typically generate IP responses that are complex and difficult to model due to the effects of current paths crossing many mineralized shoots that have potentially different orientations and mineralogy. However, the mineralized zones usually generate an anomaly that is in sharp contrast to the surrounding rocks, and this alone will demand follow-up exploration (drilling).

3.12.2.2 Jabal Lahaf Prospect

The Jabal Lahaf sites, formerly known as Al Lahuf or simply “Lahuf”, comprise a copper prospect (MODS 0515) and a gold prospect (4821) located in the At Taif-Jeddah Terrane. The copper prospect is located about 9 km west of the famous Mahd adh Dhahab Mine which is owned by Ma’aden. The gold prospect is situated 950 m to the southeast as shown in the accompanying satellite image (Figure 113).

Figure 113: Distribution of Copper and Gold Prospects in the Mahd adh Dhahab area. The Al Lahuf copper and gold prospects are shown at lower right in respect to the location of Ma’aden’s flagship Mahd adh Dhahab Mine licence (green shaded area). The distance from the mine complex (yellow dot) to Lahuf is approximately 9.8 km, a very short distance in geological terms.

Given its location with respect to Ma’aden flagship mine, the Lahaf prospect is highly significant. It is hosted in the same group of rocks, the Mahd Group, 10 km west and on strike with the mine sequence. The

prospect is underlain by andesite and various felsic to intermediate pyroclastic rocks with plug-like domes of rhyolite and rhyodacite. It is generally described as a pyroclastic-hosted, quartz vein-type prospect with quartz vein stockworks. The pyroclastic rocks are foliated, intensely fractured and silicified in strongly veined areas, and the bordering rocks contain quartz-sericite-pyrite alteration haloes within an outer zone of propylitic alteration. The mineralization comprises pyrite, chalcopyrite, sphalerite, rare galena and gold. On surface, malachite and chrysocolla mineralization is associated with gold. The mineralized zone is up to 100 m wide and 750 m long.

During the early 1960s, the Mahd adh Dhahab area was studied by the Saudi Arabian Mining Syndicate (SAMS) which focused its work on the ancient mine and little work was done at Lahaf. In the mid-1960s, some work was carried out to investigate the potential for alluvial gold in the area but this found minimal potential due to the incised drainage systems in the area. A 91 m diamond drill hole was completed in 1965 in the southern ancient copper mine area at Lahaf intersecting fracture-controlled sulphide-bearing veins grading 1.6% Zn and 1.2% Cu with 13.7 g Ag/t and traces of gold over a true thickness of 5.2 m. This was one of 6 holes drilled in the prospect area. Geological mapping at 1:1,000 scale and systematic geochemical sampling and chip sampling followed in a 21 hectare area measuring roughly 100 m by 200 m. Maximum grades of 5.8% Cu, 6 g Au/t and 45 g Ag/t were discovered.

During 1973, a USGS geochemical survey indicated some potential for alluvial gold and estimated that a resource of 263,455 m^3 grading 0.262 g Au/m^3 might be present near Mahd adh Dhahab for a total gold resource of approximately 69,000 ounces or 2.15 tonnes (a rather small resource). Continuing work by the USGS revealed that slag from the ancient mine at Mahd adh Dhahab possibly totaled as much as 725,750 tonnes averaging 1.89% Zn, 0.51% Cu and 0.60% Pb with 2.4 g Au/t and 8.9 g Ag/t. At the same time, a very modest resource estimate for Mahd adh Dhahab indicated the presence of only 56,708 tonnes of "ore" remained in the mined orebody – this is a good indicator of how a very modest resource can develop into a major gold deposit.

In 1987, the DMMR carried out 1:10,000 scale geological mapping and bedrock sampling in a 16 km^2 area centred on Lahaf. The slag at Lahaf was tested and found to average 1.6% Cu, 0.4% Zn, 0.4% Pb, 0.7% Te, 2.93 g Au/t and 19.8 g Ag/t – similar values to those found at Mahd adh Dhahab. Through 1988 and 1989, geophysical surveying (ground magnetometer, VLF-EM, Genie EM, IP and gravity) was completed. The EM anomalies were selected as prime targets for drilling, and eight shallow percussion drill holes totaling 867.7 m were completed by the Ministry. The best intersection was 10 m averaging 2.10% Zn, 0.72% Pb, 0.25% Cu, 80.46 g Ag/t and 15.64 g Au/t. The results were variable in the holes, but only one hole on the extreme eastern end of the zone failed to intersect interesting values. The other holes discovered economically interesting polymetallic mineralization over a distance of approximately 700 m. The composition of the mineralization was very similar to that at Mahd adh Dhahab pointing to a similar metallogenic model.

During 1991-93, Petromin carried out 2,715 m of trenching and three phases of drilling at Lahaf resulting in more than 20 cored drill holes totalling 3,741 m to a maximum depth of 200 m. The main target was the

700 m long "Central Breccia" zone of quartz vein stockworking. This drilling led to a resource estimate divided into oxide and sulphide mineralization and into measured and indicated resources totalling 1.24 Mt averaging 2.83 g Au/t or 113,000 ounces of gold. In 1999, Ma'aden (the successor to Petromin) completed an additional shallow drilling programme to a maximum depth of 116 m which totalled 17 holes (1,060 m) within the Central and Eastern Breccia zones in order to close off the deposit along strike and to increase the confidence level of the mineral resources. The average hole length was 62 m to an average vertical depth of 44 m. The estimated resources in the Central, Eastern and Western Breccia zones totaled 1.7 Mt averaging 2.6 g Au/t or 142,000 ounces of contained gold. It is clear that Ma'aden's exploration only scratched the surface. Ma'aden is thought to have terminated the licence to save on costs in 2005-2006.

Vertex is thought to have applied for a 96 km^2 exploration licence over the Lahaf deposit during 2006-2007 and proposed an exploration program budgeted at $1.25 million over a 2-year period. It is unlikely that this program was completed because Citadel Resources acquired the Lahaf rights (Option Agreement?) and carried out an initial percussion/core drilling program of 17 holes in the first half of 2009. The best intersections were a 1-metre section averaging 3.18% Cu, 1.04% Zn and 1.64 g Au/t in hole LH003RC, and 0.64% Cu, 1.61% Zn and 3.50 g Au/t in hole LH014RC. Most of the intersections were only one metre in length. The longest intersection was 6 m averaging 0.22% Cu, 1.29% Zn and 6.90 g Au/t in hole LH017RC. Citadel's follow-up surface work showed extensions of the mineralized system to the north or north-northwest and to the southeast of the previous drilling. Similarities in the vein orientations between Lahaf and Mahd adh Dhahab are recognized. Citadel's interests at Lahaf were subsequently acquired through the take-over by Equinox Resources and then were acquired by Barrick. It is uncertain what if any plans Barrick has for Lahaf as its current focus is the ramp-up of activity at the Jabal Sayid Mine. The Lahaf area remains desirable despite the work done. Although the exploration to date has been comprehensive at times, it has only shallowly tested the zone. During the last 20 years or more, nearly all of the drilling is within 150 m of surface and the focus has been on gold, and most recently on developing a resource that is minable by open pit. WGM believes that the focus should be on base metals and gold, and that geophysics can be used as an effective tool for delineating targets at depth for drilling.

3.12.3 EPITHERMAL VEIN-TYPE SILVER DEPOSITS

3.12.3.1 Samrah Prospect

Location, History and Status

The Samrah (Smayrah) sites (MODS 0145 to 0149, 0745, 0756, 0803, 0805, 0808, 0810, 0847, 0848, 0854) are a widely scattered group of silver prospects and ancient mines in the Ad Dawadimi Terrane of the Eastern Arabian Shield. The central (main) prospect, MODS 0145, is located at 44° 23' 00" E and 24° 20' 00" N. Additional sites are mostly found within a 2.5 km to 5 km radius of this location. According to the MODS, 45 silver prospects are known within an approximate 10 km radius of Samrah, many of which bear the word "Samrah" in some part of the site's place name. Of this group, the farthest such record from Samrah (11 km) is the site formerly known as Samrah SE (MODS 0847) now known as Shaib Raqan SW1. The main sites in the more immediate area, within 5 km of Sanrah, are summarized in Table 102 and illustrated in Figure 114.

Table 100
Prospects in the MODS for the Samrah Silver Area in Saudi Arabia

MODS	Name (new)	Name (old)	Main Commodity	Longitude	Latitude	Nearest Town	Potential Ranking	Geometry
0145	Samrah	Samrah District	Ag	44.3331940	24.3575560	Dawadimi	Medium	dd, v
3647	Hadabat Umm Ruqaybah-W	Jabal Umm Ar Ragabah	Ag	44.3320830	24.3520280	Dawadimi	Very low	uncertain
0797	Hadabat Umm Ruqaybah-E	Umm Ergabah	Ag	44.3395000	24.3524440	Dawadimi	Medium	dd
0747	Samrah-NW	Jabal Abiad	Ag	44.3371110	24.3655000	Dawadimi	Very low	dd, v
0746	Samrah-SW	Samrah	Ag	44.3436940	24.3632220	Dawadimi	Very low	dd
4148	Abal Abu Hufur-SE	Siliceous Zone-NW,	Ag	44.3194440	24.3638890	Dawadimi	Low	v
0745	Hadabat Umm Ruqaybah-NE1	Samrah	Ag	44.3488610	24.3653060	Dawadimi	High	v
0748	Abal Abu Hufur	Samrah	Ag	44.3173330	24.3656110	Dawadimi	Very low	dd, v
0756	Samrah-E	Samrah	Ag	44.3508060	24.3651940	Dawadimi	Medium	v
4482	Hudaybat Ar Rajajil-W	Sahrah District	Ag	44.3511110	24.3458330	Dawadimi	Very low	v
0851	Hadabat Al Uwayja-SE	Jabal Al Aouejah	Ag	44.3350000	24.3361110	Dawadimi	Very low	dd, v
0744	Hadabat Umm Ruqaybah-SE	Samrah	Ag	44.3553610	24.3510000	Dawadimi	Medium	dd, v
0750	Hadabat Al Uwayja	Jabal Al Aouejah	Ag	44.3211670	24.3370560	Dawadimi	Medium	dd
0850	Hadabat Al Uwayja	Jabal Al Aouejah	Ag	44.3360280	24.3328610	Dawadimi	Very low	dd
0144	Hidab Rudayhat	Jabal Ar Radahat	Ag	44.3183060	24.3777220	Dawadimi	Medium	dd, v
0810	Samrah-NE2	Samrah-E	Ag	44.3616110	24.3618890	Dawadimi	Medium	dd
0808	Samrah-SW	Samrah-SE-E	Ag	44.3628060	24.3616110	Dawadimi	Medium	dd, v
0849	Samrah-NE3	Samrah	Ag	44.3605560	24.3711110	Dawadimi	Very low	dd, v
0803	Samrah-NE6	Samierah	Ag	44.3637780	24.3738330	Dawadimi	Medium	dd
0805	Samrah-NE1	Samrah-E	Ag	44.3667500	24.3692500	Dawadimi	Medium	dd
0804	Samrah-NE4	Samrah	Ag	44.3660280	24.3738610	Dawadimi	Undefined	dd
0139	Al Gilani	Sidriyah	Ag	44.3175000	24.3944440	Dawadimi	Medium	dd, v
0802	Samrah-NE7	Samrah	Ag	44.3681390	24.3772500	Dawadimi	Medium	dd, v
0852	Hadabat Al Maslukhah-NE	Jabal Ar Radahat	Ag	44.2972220	24.3833330	Dawadimi	Very low	dd, v
0148	Samrah-NE4	Samrah	Ag	44.3779720	24.3699440	Dawadimi	Medium	dd, v

Notes: The potential ranking is sourced from the MODS and does not necessarily reflect WGM's views.
dd = disseminated, v = veins

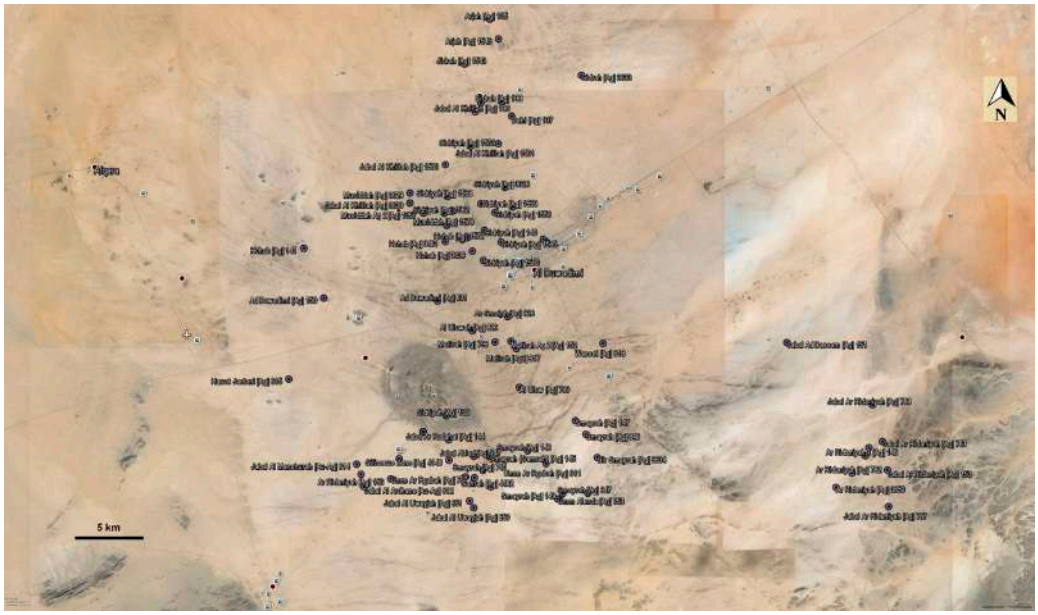


Figure 114: Satellite view of the Samrah ancient silver mining area. Figure shows the large cluster of MODS records present in this cluster of ancient silver mines and prospects. The town of Ad Dawadimi is located at mid-level on the eastern side of the cluster (red dot). The Samrah silver area is centred on the Dawadimi-Najirah Batholitic Complex (dark area south of Ad Dawadimi). Silver prospects (grey dots) occur along numerous dark coloured fracture zones striking NE. Many were ancient mines.

The Samrah area was initially mapped by the USGS during the 1950s, and in during the 1960s, plane table mapping at 1:2500 scale was completed. Thirty-two dump samples averaged 229 g Ag/t. During 1965, the prospect was geologically mapped and then the zone was tested with 18 cored holes totaling 3,226 m over a strike of 400 m. The average hole length was 179 m. Resource figures based largely on this drilling range from 230,000 to 301,000 tonnes with grades of 5.0% to 5.3% Zn, 0.9% to 1.64% Pb and 411 to 750 g Ag/t (Kiilsgaard, 1968). Follow-up work in the 1970s included detailed prospect targeted geological mapping, and geophysical surveying by Argas (magnetometer, IP-resistivity and gravity) of individual prospects. IP and SP were carried out using a line spacing of 50 m and an electrode spacing of 20 m. It is doubtful that any data was collected more than 80-90 m below surface. The USGS work terminated in 1972.

During 1976, the BRGM re-estimated the resources at 278,000 tonnes averaging 5.12% Zn, 1.64% Pb and 651 g Ag/t. During 1976 the DMMR remapped the prospect. A regional structural study in the 1980s was completed by the BRGM, but no work specifically targeted the Samrah prospects. Riofinex included Samrah in its 1984 study of the mineral deposits of the Kingdom (published in 1986).

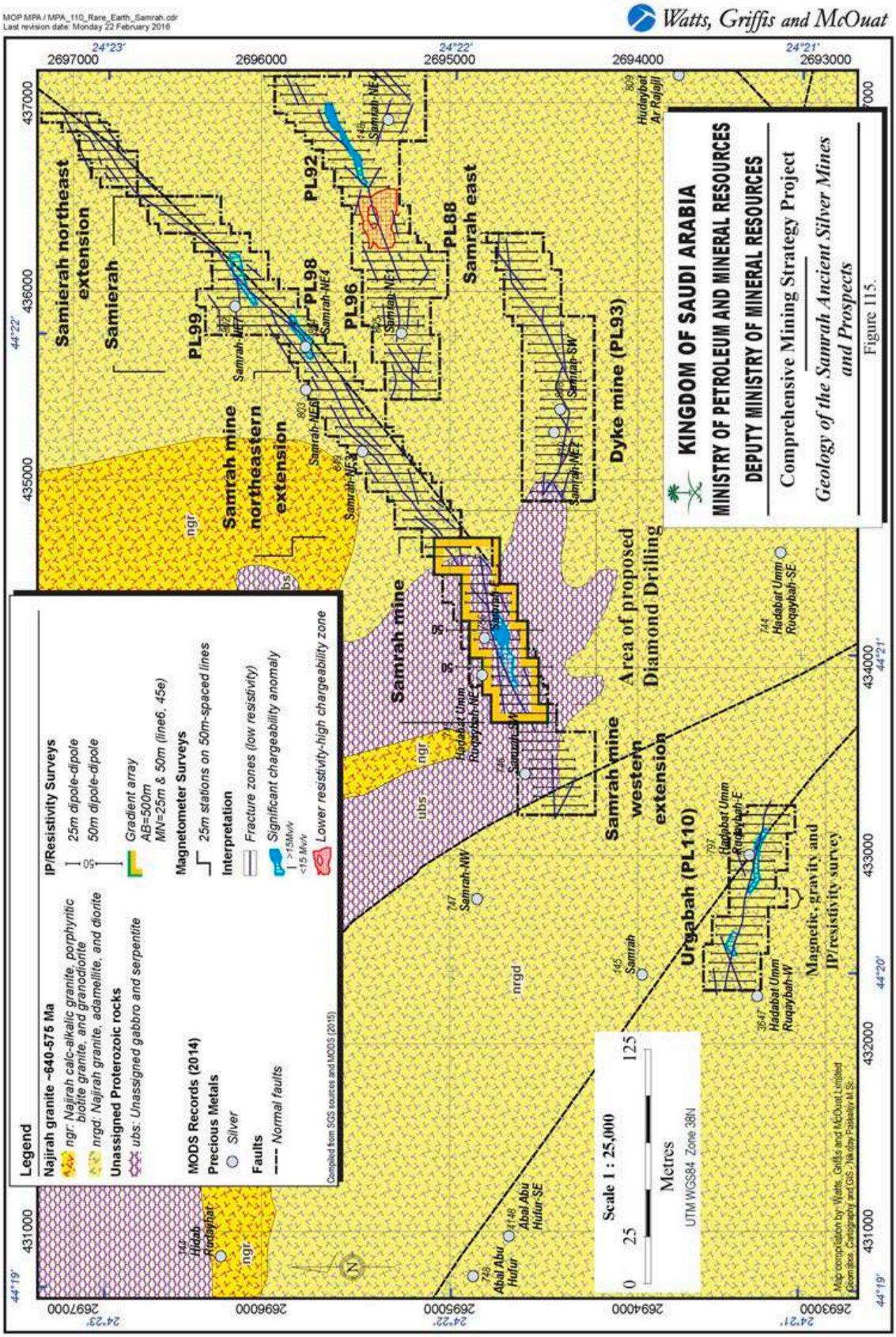
Geology

Most of the Samrah area is underlain by the Dawadimi-Najirah Batholitic Complex and layered volcano-sedimentary sequences are not well represented. The layered sequence is represented by albite-sericite-chlorite schist, phyllite, slate, arenite and conglomerate. Mineralization occurs within granite and is structurally controlled by NE shearing and E-W tensile fractures – the main mineralized structure has been traced for 1.4 km on surface (Figure 115). Four generations of pyrite, sphalerite, galena and chalcopyrite veining are present in silicified breccia zones. Galena tends to occupy the centre of the veins whereas sphalerite is more common near vein margins. Minor minerals include magnetite, hematite, arsenopyrite and silver minerals such as polybasite, pyrargyrite, freibergite, acanthite and stromeyerite. Although the deposits are known for their high silver content for which they were mined in ancient times, they also carry substantial base metal values. The deposits are thought to be in the class of epithermal polymetallic veins.

Recommendations

WGM questions the use of magnetometer and gravity surveying for mineralization that is non-magnetic and represents too small a target to create a gravity anomaly. Perhaps it was to assess the subsurface extent of the intrusive complex. Many IP anomalies (PL-92 and PL-110) remained untested as of 1992 when WGM reviewed the area. These correspond to MODS 0148 and 0797, respectively. Selected in 1999 for promotion at the Minetime 99 Minerals Conference in Dusseldorf, Germany, and presented as one of two silver targets in the shield rated as “promising” by the DMMR – the other was the Sidriyah ancient silver mine, located approximately 20 km to the north and partially under the town of Dawadimi. The selection criteria is unknown but the zinc and lead grades were mentioned (but not copper) (ref. DMMR conference document).

Deeper geophysics is needed to extend and enlarge the anomalies downwards and along strike. The drilling to date has yielded mixed results, however closely spaced drilling is needed to trace and extend economically interesting zones, beginning with the most strongly mineralized target. The attempts in the past seem to have been to try to outline a mine with a single hole or pair of holes. It is simply not that easy. The area of interest takes in the Al Ulow (MODS 0825), Hehab (1572) and Sidriyah (0005) prospects that are located between 5.5 and 6.5 km to the northwest where minimal drilling has been done on similar prospects having NE-trending vein systems. As of a 2014, the DMMR database indicated that no exploration licenses have been issued in this area which is surprising given the excellent exploration potential in this area.


MOP MPA / MPA_110_Rare_Earth_Samrah.odr
Last revision date: Monday 22 February 2016
Watts, Griffis and McOuat
KINGDOM OF SAUDI ARABIA
MINISTRY OF PETROLEUM AND MINERAL RESOURCES
DEPUTY MINISTRY OF MINERAL RESOURCES
Comprehensive Mining Strategy Project
Geology of the Samrah Ancient Silver Mines and Prospects
Figure 115.
Legend
Najirah granite ~640-575 Ma
ngr: Najirah calc-alkalic granite, porphyritic biotite granite, and granodiorite
nrgd: Najirah granite, adamellite, and dionite
Unassigned Proterozoic rocks
ubs: Unassigned gabbro and serpentite
MODS Records (2014)
Precious Metals
Silver
Faults
Normal faults
IP/Resistivity Surveys
25m dipole-dipole
50m dipole-dipole
Gradient array
AB=500m
MN=25m & 50m (line6, 45e)
Magnetometer Surveys
25m stations on 50m-spaced lines
Interpretation
Fracture zones (low resistivity)
Significant chargeability anomaly
>15MHz
<15 MHz
Lower resistivity-high chargeability zone
Compiled from SGS sources and MODS (2015)
Samierah northeast extension
Samierah
Samrah mine northeastern extension
Samrah mine
Samrah mine western extension
Urqabah (PL110)
Dyke mine (PL93)
Samrah east
PL92
PL88
PL96
PL98
PL99
Area of proposed Diamond Drilling
Magnetic, gravity and IP/resistivity survey
Scale 1 : 25,000
0 25 125
Metres
UTM WGS84 Zone 38N
Map compilation by Watts, Griffis and McOuat Limited
Geomatics, Cartography and GIS - Nikolay Pasiekov M.Sc.

3.12.3.2 Hajlan Prospect

Location, History and Status

The Hajlan prospect (MODS 0012) is a single (isolated) mineral occurrence located in the north-western Ad Dawadimi Terrane in the Eastern Arabian Shield at 44° 50' 08.77" E and 23° 58' 17.08" N. The prospect consists of extensive ancient workings that were sampled by Shaffner in the early to mid-1950s as part of a general regional reconnaissance program. This is the first modern mention of the prospect which is believed to have been worked for silver. During 1981, follow-up exploration by the BRGM included geophysical surveys (magnetometer and scintillometer) and detailed mapping and sampling which led to a 5-hole percussion drilling program totaling 601.5 m. The focus continued to be on silver as base metals seemed to be of little interest. Wide zones of lower grading silver mineralization was intersected averaging between 3 and 60 g/t, as well as Zn-Pb values. No resource estimate was made at that time. Follow-up work in 1983 included geochemical wadi sediment sampling on a 100 m by 100 m grid, rock chip sampling and additional radiometric surveying –Th, Zr, Y, Nb and Sn were evaluated indicating that the work lack focus and that the project managers were perhaps lacking in any real direction. Despite this, wadi sediment geochem sampling discovered significant Pb-Zn anomalies NW of the rhyolite but found no comparable values in the area drilled. This target area remained essentially untested in 1991. Additional sampling completed in 2003 and reported by the SGS in 2007 confirmed silver values as high as 91.8 g/t, Zn values to 3.02%, Pb to 4.14% and up to 0.31 g Au/t. The highest Cu value was 700 ppm. Pb-Zn-Ag-Cu are closely correlated which would be expected within a high-sulphidation epithermal system. The SGS recommended additional work, but it is unclear whether any additional work was completed.

Geology

Mineralization occurs within and around a nearly circular rhyolite breccia stock approximately 1.7 km in diameter intruding the Abt schist (Figure 116). Very little technical information is readily available on the prospect as the work seems to have been reported in BRGM quarterly reports that were not made public. The prospect is classified as a silver occurrence in the MODS as a result of the initial reconnaissance work, samples from which produced assays up to 570 g Ag/t with associated gold and copper. A resource of 30-40,000 t averaging 93 g Ag/t, 0.2% Cu and 0.31 g Au/t was estimated at that time.

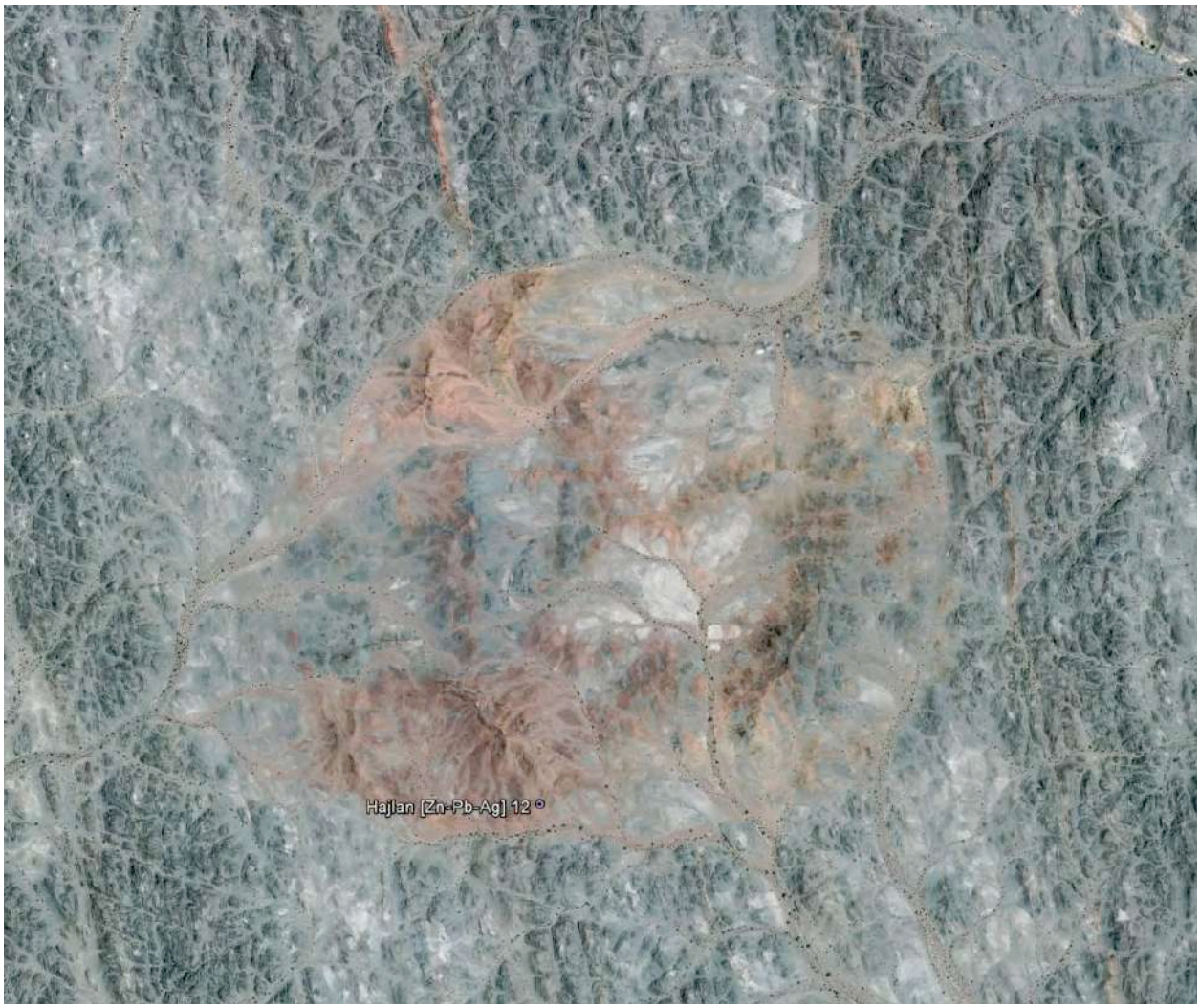


Figure 116: Satellite view of the Hajlan rhyolite breccia stock - a circular 1,700 m wide body intruding meta-volcanic and metasedimentary Abt Schist. The oxidation of sulphide zones is very clear in this image. The location of the main zinc lead silver prospect (ancient mine) is located at lower centre (purple dot). Note leakage of metallic minerals, now oxidized, into the schist along a fracture zone at upper-left.

Recommendations

In its review carried out between 1989 and 1992, WGM assessed the initial reconnaissance work as adequate, and recommended follow-up exploration. WGM believes that the exploration of the Hajlan body must be systematic and target polymetallic mineralization, probably using an epigenetic model not dissimilar from Mahd adh Dhahab. WGM's review of the satellite imagery shows clearly the unusual circular feature that is the rhyolite breccia body (Figure 116). The rhyolite is broken into blocks of varying sizes that are defined by shallow drainages that formed along fracture lines. The largest blocks are about 100 m wide and 300 m long. red-brown gossan has formed extensively along fracture zones within the bodies. Rusty pathways along the NNW foliation in the country rocks indicates that leakage of mineralizing fluids occurred, especially to the NNW, for as much as 2.3 km from the margin of the rhyolite body. It is interesting that the ancient workings tend to occur along NE-trending fractures. There is no clear preferred orientation to

gossanous zones within the rhyolite. At approximately 1,700 m in diameter, the body has mine-making dimensions, but it is clear that exploration needs to be systematic and focus on exploring and testing individual structures to outline individual nodes of mineralization which are likely to be vein or stockwork-type in geometry.

3.12.4 OTHER EPITHERMAL TARGETS

3.12.3.1 Al Buqariyah Area

Location, History and Status

The Al Buqariyah Prospect (MODS 4994) has been mined as a source of Pyrophyllite after being discovered by the BRGM during 1975. It is located 26 km east-northeast of Yanbu between Wadi Thamar and Wadi al Far'ah. After being explored as a source of clay, the area was reassessed for gold in 1989 through geological mapping and geochemical sampling programs covering portions of the Yanbu al Bahr quadrangle. Bellivier et al (1994) reported that the detection threshold for gold using emission spectrography was 10 ppm which would have been completely inadequate for exploration purposes, and WGM questions why the survey was performed with such an inadequate analytical technique when fire assaying has always been the international standard. During 1991, seven holes were drilled to assess the quality of the clay, and two important conclusions came out of this work:

2) hydrothermal activity was responsible for the clay's formation; and,
3) the alteration might overlie or be related to a mineralized stockwork.

Follow-up exploration in 1992 comprised helicopter reconnaissance of the area and the recognition of a possible Tertiary epithermal system. Follow-up analysis of the pyrophyllite-bearing drill core was made for the epithermal geochemical indicators arsenic, antimony, mercury, barium and thalium, and the results were supportive of an epithermal association. Gold values in the drill core were erratic, the highest value being 1 g/t. The BRGM concluded that the prospect had possibilities for epithermal gold mineralization and commenced an exploration program in 1993 dedicated to assessing this potential. This work consisted of a topographic survey, 1:2,500 scale geological mapping which was compiled at 1:12,000 scale, bedrock chip sampling (468 samples), wadi sediment geochemical sampling (238 samples), pitting (41) and trenching (one at 120 m long), and geophysical surveying (magnetometer, electrical sounding and gravity). A total of 99 samples were petrographically studied. The area was subdivided into the Al Buqariyah East and West Prospects, with the eastern prospect being more strongly altered argillically and the more highly favoured target. The petrographic work failed to identify alteration of a clear epithermal character. Wadi sediment geochemical sampling failed to identify interesting anomalies – the gold values ranged from 5 to 8 ppb with the highest values in areas of argillic or tourmaline alteration. Most indicator elements were found in very low concentrations – mercury was not present. Thalium showed weak enrichment locally supporting the hydrothermal origin for some of the alteration. Magnetic surveying indicated the presence

of a weakly elevated zone spatially associated with the zone of argillic alteration and several single-point anomalies suggesting the presence of hidden intrusions at depth. Electrical sounding indicated low resistivities in the subsurface, consistent with the argillic alteration extending to depth. Based on the foregoing results, the BRGM recognized the presence of an epithermal system and recommended that 20 percussion holes be drilled on a 400 m x 400 m grid to delineate the kaolin-pyrophyllite deposit with the lowermost 10 m in each hole analysed for gold and indicator elements.

The BRGM also recommended that the initial drilling be followed by a series of 250 m deep cored drill holes to test the more promising zones based on favourable As-Sb-Mo-Bi associations and high thalium values. The BRGM returned to the Al Buqariyah area in 1993, including the prospects at nearby Jabal al Majrad (MODS 4857, 4945-4949), Abu Rowbah and Wadi Mahallah (4859), late last being about 57 km to the SSE. During this program, the BRGM focused on the Al Buqariyah Prospect and its surrounding area. The intention of examining the wider region was to allow the BRGM to acquire a better understanding of the setting of the alteration at Al Buqariyah which was the main focus of the exploration. Wadi Mahallah is also associated with a copper-bearing gossan (0726). The renewed exploration program was composed of a review of the total field magnetometer data and wadi sediment data from surveys previously completed across the Yanbu al Bahr quadrangle. The purpose of the review was to characterize the various felsic to intermediate plutons present in the area, and to categorize geochemical anomalies having an epithermal character. At the Jabal al Majrad prospect, a topographic survey was completed and used as a basis for detailed geological mapping and chip sampling of the area of hydrothermal alteration. Wadi sediment sampling (32 sites) was also completed in a 5.25 km^2 area surrounding the prospect. These and 69 chip samples were analysed. At Abu Rowbah, chip sampling was completed (69 samples) together with systematic sampling of two profiles and 63 wadi sediment samples were collected over a 6 km2 area for geochemical analysis. At Wadi Mahallah, four 8-10 kg samples of “mineralization” were taken from the prospect for analysis and study.

Geology

The Al Buqariyah Prospect is hosted within the Abathir Formation, a felsic volcanic sequence consisting of rhyolite, ignimbrite and crystal tuff with subordinate andesite to dacite and clastic sedimentary rocks. The prospect is located very close to the western margin of the exposed shield. The felsic rocks locally contain quartz-eye porphyry and they are locally silicified and argillically altered. Boulders of “explosion breccia” were found in the wadis. The area is affected by a pervasive 015^o-striking subvertical schistosity which is locally rotated as a result of ENE (065^o) trending strike-slip faults. Hydrothermal alteration preferentially affects basis to intermediate tuffs and flows. Six alteration styles were recognized, but only one was of potential interest as a result of epithermal activity. An area of tourmalinization (+ pyrite) was discovered in the south-central part of the belt. These rocks included hydraulic mosaic breccia with tourmaline cement, tourmaline impregnations along bedding laminations in tuff and tourmaline rosettes associated with quartz. Hydraulic breccia/stockwork occurs in a SSE-trending zone that is 100-200 m wide and can be traced for 1.5 km along strike. Several bedrock geochemical anomalies characterized by an As-Sb-Mo-Bi association

are found in areas of tourmalinization, and this was attributed to the potential for the area to be underlain by a granitic intrusion. Northeast striking limonitic quartz vein material generally contained low base metal values however one sample carried 9,820 ppm Cu.

The Jabal al Majrad area contains kaolin and pyrophyllite-bearing alteration, and associated isolated B, As, Mo, Sb and Bi geochemical anomalies. The area is underlain by felsic to basic volcanic rocks of the Abathir Formation, a member of the Al Ays Group, which are intruded by granodiorite plutons. Most of the alteration observed was in tuff and andesitic to rhyolitic flows. A black, fine grained, jasperoid facies was noted along the western contact of the main granodiorite body – it's origin and significance were not clear to the BRGM. Thallium was anomalous with values as high as 5 ppm found when drill core from the 1991 program was reanalysed. No significant gold or base metals were present in any samples, however the overall geology and geochemistry suggested potential for an epithermal system.

The Abu Rowbah geology was very similar to that at Jabal al Majrad and metal contents were also very low. The favourable Abathir Formation rocks comprising epidotized lapilli tuff, mafic feldspar porphyritic lava and crystal tuff, occur in a narrow zone within the Jabal Gharib Batholith. Strong propylitic alteration and localized silicification are present.

At Wadi Mahallah, the same volcanosedimentary units of the Abathir Formation form a 170o/50oE monocline within which lapilli tuff is kaolinized and sericitized in zones spatially associated with small intrusions. The tuff is locally silicified with disseminated pyrite where it is cut by a feldspar-porphyritic dike. No significant results were found at Wadi Mahallah however the work was described as too superficial to have any significance at this time. Hematite is commonly associated with argillic alteration. Advanced argillic alteration (kaolin) is preferentially developed within the tuff locally.

Based on the second season of field work, the BRGM concluded that the alteration and pyrite mineralization was controlled by lithology (stratigraphy), but definitely had a genetic relationship with the granodiorite plutons. An epithermal association was indicated in all areas. Stream sediment geochemistry was not a useful exploration tool in that it failed to detect gold or indicator element anomalies although boron anomalies did delineate areas of tourmaline alteration. Various indicator anomalies were detected (e.g. Ba, As, Mo, Sb) however these did not define targets of specific interest to the BRGM. The northern part of the Jabal al Majrad area was deemed to be the most interesting area for follow-up (Bellivier et al, 1996). The BRGM recommended reserve estimates of the pyrophyllite resources and the use of 1:10,000 scale detailed geological mapping to search for features known to be associated with epithermal systems, such a hydraulic breccia zones.

Recommendations

WGM agrees that the area has potential for an epithermal gold deposit even though the current geochemical results show little direct evidence of gold mineralization. Epithermal systems are vertically

zoned and the capping rocks typically contain little evidence of the underlying mineralization. The silicified breccia zones represent an excellent geological target for systematic follow-up drilling. WGM does not agree with the BRGM's recommendation for percussion drilling as this has little value in gold exploration. Experience in many parts of the world, including Saudi Arabia, has shown that the results of percussion drilling are usually not representative of mineralization in the ground.

Epithermal systems typically consist of an inner zone that is centred on the hydrothermal conduit and contains a variety of silica species that are indicative of vertical positioning in respect to the fossil water table (boiling level) within the hydrothermal system. Above this, silica and jasperoid caps can occur which are barren and which show little or no physical or chemical evidence for the underlying mineralization. Mercury levels can be anomalous, but care must be taken in the sampling and analysis of samples for mercury as geochemical loss can occur depending on the level of weathering and the digestion method used when the sample is analysed. Usually a very weak digestion is sufficient which may be inappropriate for other metals. The presence of large zones of advanced argillic alteration can be a favourable sign, however, this alteration is the result of cold, descending acid hot spring solutions that are barren of gold, or at least are incapable of depositing gold. These alteration zones, which commonly carry substantial amounts of brassy bright pyrite, are not exploration targets in themselves. The target is the silicified stockwork/breccia zone within this clay-altered envelop, and it must be drilled at the correct elevation with respect to the ancient water table in the hot spring system. All breccia zones in the target areas should be geologically mapped in detail to identify the best geological targets, and then systematically tested by diamond drilling on 100-200 m profiles using angled holes (say -60 degrees). As there is no direct evidence for gold mineralization on surface, the holes should test the zone at a depth of approximately 200-300 m below surface. Silica textures should be carefully documented. The black, fine grained, jasperoid facies in the Jabal al Majrad area along the western contact of the granodiorite is of specific interest as a target and should be drill-tested. IP surveying along this contact zone could be useful in delineating the silicified, sulphide-bearing zone at depth.

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4.0 CONVERTING EXPLORATION POTENTIAL TO MINERAL DEVELOPMENT

The discovery of new mineral deposits is a difficult and lengthy undertaking, and it is not made any easier by the need for mines to maintain production in the face of challenging commodity prices, such as exist in 2015-2016. In response to this challenge, many companies have ceased exploration, or significantly reduced exploration expenditures, as a cost-cutting tool. In making this decision, however, mining companies accept the long-term risk to maintaining their very existence in the face of diminishing resources and reserves. The focus can become a matter of concentrating on high quality projects or deposits that are not challenged by metallurgical complexities or by market specifications that place the mineral producer at a competitive disadvantage. While this is not much of a challenge for precious metal or base metal producers, it is a major concern for producers of many industrial minerals and specialty metals such as rare earths, tin, tungsten, molybdenum, niobium, tantalum, etc.

Explorers always prefer giant ore deposits that can sustain long-lived operations and allow the amortization of exploration, development and infrastructure costs. Such deposits can also allow lower cost production through bulk-mining methods and economies of scale. These deposits include porphyry-type copper, copper-gold and copper-molybdenum deposits, porphyry-gold deposits, iron ore-copper-gold ("**IOCG**") deposits, sedimentary exhalative ("**SEDEX**") deposits, laterite nickel deposits and banded iron formation deposits. Explorers can also focus on smaller high-value deposits that can sustain operations despite commodity cycles such as Mississippi Valley-Type ("**MVT**") and Irish-Type carbonate replacement zinc-lead-silver deposits, volcanogenic massive sulphide ("**VMS**") deposits. Unfortunately, giant deposits represent less than 1% of all deposits types, and the odds of finding a giant are greatly outweighed by the probability of fining a median-sized deposit.

Just as giant deposits are rare, they can also be extremely difficult to find. There is a presumption in some quarters that porphyry copper deposits are geologically simple yet the reality is that they can be quite complex and well hidden. Nature provides geologists with a vast landscape in which a mineral deposit is minuscule. Company managers prefer deposits that are relatively easy to find, and for this reason many companies do not search for MVT deposits – the sulphides do not respond well to conventional geophysical surveying, yet the opportunities created by a well-understood and predictable geological model, geochemistry and a tabular geometry are overlooked. The exploration strategies of large companies favour very large deposits because one measure of success is for the discovery to improve company revenues by at least 10%. However, for every large company with such high standards, there are at least 1,000 junior companies that simply want any discovery! Junior companies are opportunists. They are mobile, high-energy predators that will seize any opportunity. They welcome opportunities to discuss their projects and demonstrate their success, and unlike many large and secretive companies, junior explorers know they don't have all the answers. They are reliant on external experts and they tend to forge a very symbiotic and co-operative relationship with geological surveys.

Over the past decade, well accredited studies[8] of the minerals industry in mature mining jurisdictions such as Canada, Scandinavia and Australia, have pointed to the close relationship between successful exploration and the availability of a solid geoscience foundation on which exploration programs are planned and executed. The building blocks of this information base are assembled from work carried out by sovereign geological surveys combined with the work carried out by the Private Sector which is filed and comes into the public domain. The capacity of both Government and Private Sector to fund this work will vary with economic cycles, but both parties have a vital role in the research and development that sustains the industry overall. It comes as no surprise that regimes such as Canada and Australia, where geoscience and exploration information is readily available, are favoured destinations for investors. Even though excellent work is being done in Russia, for example, lack of access to such information and other barriers are sufficient to divert the flow of investment capital to more favourable destinations.

The trend in exploration over the last few decades is to make use of increasingly accurate, multidisciplinary data in a more holistic and integrated approach involving a very wide skill set. It has become vital to understand the intricate nature of the deposit models on which we base exploration programs; how the deposit type was formed and preserved, and how it can be detected in a variety of terrains. Given the need to explore for more deeply buried deposits, especially in mature exploration areas, understanding the subtle features that constitute an ore-field halo is also vital. Mineral deposits can hide, even close to surface, and the explorer is well advised to treat exploration models with the degree of latitude that they deserve.

The discovery of the Balboa copper deposit in Panama is a case in point for using models with a great degree of latitude, assisted by the development of new technologies. For more than 400 years, western explorers had recognized and exploited the copper deposits in this region of Panama. Balboa is the most westerly of 6 shallowly dipping tabular porphyry copper deposits. It was found by a company looking in an area that had not been explored previously, and using improved ZTEM electromagnetic surveying instrumentation which detected a previously unknown anomaly. The lesson is simple, you can't make a discovery if you are not searching, if the tools are wrong or you stop too soon. All procedures in the exploration tool box are worth considering: geology, prospecting, geochemistry, remote sensing and geophysics. Most deposits have complex signatures and they might well be overlooked if only one type of survey was used.

Deposits have been missed because the associated anomaly did not fit the model. Many discoveries have been made as a result of the misinterpretation of anomalies by those who explored before. Deposits have been missed because the anomaly was tested and explained, but the deposit was off-set from the anomaly (e.g. Texasgulf's discovery of the Kidd Creek VMS deposit). Companies have also found mines, and even new deposit types, as a result of follow-up work on an anomaly that did not fit the exploration model. The very last and lowest priority anomaly to be examined was not in an area of sandstone cover and it did not

[8] Studies by such organizations at the Prospectors and Developers Association of Canada, the Fraser Institute, the Australian Institute for Mining and Metallurgy, the Canadian Institute for Mining and Metallurgy and the Mining association of Canada.

fit the geological model, and yet the quality of the anomaly demanded follow-up. With winter arriving very soon, a team of student geologists was sent to the site and within minutes had discovered boulders of massive pitchblende mineralization.

Exploration must be a sustained effort, and prominent mining areas have faded in importance as result of neglect and the inability of explorers to develop and embrace new models. The Witwatersrand Basin in South Africa sustained the national economy for more than 100 years following the discovery of its gold in 1886 (Phillips, 2014). Production reached a peak of 1,000 tonnes a year during 1970, but has steadily declined since. Gold output has averaged about 20 tonnes a year over the last decade and production will probably end in 2022. The steady decline in production is attributable to exploration failure – no new mine has been discovered since 1951. This fact lies in sharp contrast to the Kirkland Lake gold camp in Canada. After nearly 100 years of mining, and the production of 37 million ounces (1,200 tonnes of gold) from 27 mines in the area, a junior company named Kirkland Lake Gold made a 9-million ounce discovery within the very centre of the former producing area by simply exploring a different geological model.

The effectiveness of a geological model can be measured in how successful companies are when using it. For example, the model for orogenic gold deposits has been substantially refined since the mid-1980s, and it is well known to most exploration geologists. This mineral potential assessment made wide use of the orogenic model to define prospective gold belts in the Kingdom. Ma'aden has been effective in the Mansourah area by deploying its exploration programs along the Nabitah Fault Zone which is a key geological prerequisite for orogenic gold in the KSA. Internationally, exploration companies have enjoyed significant success in exploring along similar structures in areas of Proterozoic and Archean Shield, recognizing that being on or adjacent to such structures is vital to success, and that the chances of success rapidly decrease away from such structures. Other deposit models are also useful tools for exploration, but many require additional inputs before the target can be easily defined. VMS-type models offer a proven approach to the exploration for copper-lead-zinc-silver deposits. However, the effective use of the VMS model requires substantially greater geological and lithogeochemical in-puts than are required for orogenic gold, and geophysical surveying can be an important tool in the delineation of VMS-type targets for drilling. Understanding the nature of the target in all its complications is one of the most important aspects of effective exploration. This understanding guided Kirkland Lake Gold, mentioned previously, and it also guided Kefi Minerals in its recent discovery of the Jibal Qutman gold deposit near Bishah. Explorationists are seriously handicapped if the model is not well understood, or the model is based on a single "type-location" which is dependent on a geological setting that is unique or even controversial - ***trying to imagine another Norilsk or Sudbury nickel deposit is extremely difficult.***

Mines are discovered by geologists who bring to a project all of the same positive and negative personality characteristics that surface in any commercial enterprise. Exploration success can best be achieved by in geologists who are optimists. Some might say that success can only be achieved by those for whom the cup is always half-full, never half-empty, but this is too simplistic. Exploration is high-risk endeavor best undertaken by those who are well informed and capable of mitigating risk through the use of staged exploration programs using established industry standard practices. Exploration needs to be managed by realists who are optimistic, but it is no place for those who cannot see beyond risk and the possibility of failure.

Unfortunately, the outcome of many of the exploration projects carried out in the Kingdom have been constrained by factors that may not have been completely in the control of project managers. It is difficult to imagine a set of circumstances that would impel exploration geologists to turn away from so many excellent exploration targets so early in the exploration process. Yet this is what has happened repeatedly during the last five decades. The preceding pages of this Mineral Project Assessment are filled with examples of projects that were abandoned much too early. Most of these were gold prospects or VMS-type polymetallic targets or nickel-copper occurrences. In some cases, the exploration of specialty metal prospects has ended too soon, and it is impossible to know whether potential economic viability exists or not. In the case of the rare earth metals, specific prospects require additional exploration while other prospects have no economic potential under any foreseeable market conditions. In the case of porphyry copper mineralization, there is simply too little information at this time to make any meaningful assessment of economic viability, or even if this metallogenic model has any true potential in the Arabian Shield, although evidence suggests that it does. Some projects have been promoted repeatedly for decades because they are viewed as success stories, yet one can only ask the question, 'if they were such great projects, why are they not now in production?' – Ghurayyah is a good example.

Wood (2014) stated that "exploration is a bet that the money invested will create rather than destroy wealth". In citing the exploration success of Newcrest, Wood attributes the company's strong record to four factors:

- strong Board support for "organic growth," i.e., growth through discovery;
- a team of technically strong and creative geologists, focused on discovery;
- a willingness on the part of the team and of the company to accept risk; and,
- necessity – it was clear in mid-1991 that Newcrest had to discover additional ore within the next three years if Newcrest was to survive, and the company's exploration team was given a directive to discover 2 Moz of gold over the next three years.

Wood also emphasized the commitment of senior management to continuity of effort and the importance of persistence. In mid-1992, the company produced 600,000 ounces of gold worth about US $2.4 billion per year and it had a market capitalization of A $152 million. By mid-2007, 15 years later, Newcrest's market capitalization was A $7 billion, and the wealth created by its mineral production increased to more than A $160 billion. Newcrest grew through persistent and well funded efforts of highly skilled autonomous teams of exploration geologists that were dedicated to the task of finding new orebodies. The methods they used were not substantially different from those being used by many other companies, however

Newcrest explored for deposits in areas where others had not gone. It developed a strategy for ensuring targets were adequately tested before moving on to newer prospects. The potential for a project to fail must be not only recognized, but accepted as integral to the exploration process. It is knowing when to move on that avoids what Wood describes as "Gambler's Ruin". Saudi Arabia offers a huge number of under-explored targets that are prime for the approach taken by Newcrest. This strategy is rare in large companies, but it is common in junior and smaller companies. Citadel Resources was the catalyst for action at Jabal Sayid after Ma'aden held the licence for more than 20 years. Kefi Minerals seized the opportunity it recognized at Jibal Qutman and a mine was discovered within a few short years. Both Citadel and Kefi Minerals were new-comers to Saudi Arabia. These events reinforce the need for the Kingdom to find a means to attract junior companies, however the difficulties experienced by many in simply acquiring exploration licences has been a major factor in preventing the activity that is required to generate a vibrant exploration community. Junior companies are predators. They are led by hunters, not managers. In junior companies, creative thinking is encouraged. They have a low tolerance for bureaucratic red tape. Risk-taking is expected.

Successful explorers recognize that exploration is not a science, however, it must be based on science because only the scientific endeavours of organizations like the Saudi Geological Survey can provide the reliable geoscience information on which explorationists can base their decisions. Explorationists are tasked with one simple job – finding a mine. Newcrest recognized the simple fact that it would cease to exist if it did not find new mines. Survival has a way of focusing one's attention. Newcrest's geologists were dedicated to this sole purpose. Project turn-over is vital to achieving these goals. While persistence is important, geologists need to work within a system that requires a prospect to prove itself within a specific period of time or within a specific, structured exploration framework. This structure avoids on-going unwarranted investments. Many successful companies require a project to prove itself within three exploration stages as follows:

1) regional reconnaissance to identify areas within which to focus;
2) detailed exploration programs dedicated to transforming anomalous areas to specific individual targets for drilling; and,
3) diamond core drilling.

If the program does not generate positive results at the end of the third program, the prospect is abandoned. The measure of success, however, must be realistic because it is extremely rare for a project to generate a mine-making discovery or drill hole intersection during the first exploration program. The lead author of this study was responsible for the discovery of the Moz Holt-McDermott Gold Mine in Canada that came only after 3 previous drilling campaigns had failed, prompting the mine manager to comment, "*This mine was made, not found*."

It requires great skill to recognize opportunity even when the analytical data is not as good as one might have expected. It is important that the amount of drilling be proportional to the size or number of targets being tested, and it is vital that such decisions be made by the team leader and not by corporate headquarters or those controlling the company's finances. Newcrest recognized this fact.

Prospectors and junior resource companies usually lack the technical knowledge and financial resources required to develop a prospect into an operating mine. Nevertheless, they have an almost endless capacity to accept risk, and a proven ability to turn significant profits by adding value to early level mineral properties, often by doing no more than generating some interesting results and making larger companies aware of the potential. Citadel Resources acted in this manner when it acquired Jabal Sayid. The potential for such rewards is sufficient to support a multi-billion dollar investment cycle in Canada that is centred on junior explorers.

According to Dietrich, former Manager of Evaluations for Noranda Inc., a major Canadian mining conglomerate, turning an inception-level prospect into an operating mine can be compared to a series of manufacturing steps. However, he differentiates it from manufacturing in that the mobility of capital is higher, the enterprise is much more speculative, risk is higher and product pricing is beyond the control of the operator. Exit costs for investors are negligible and therefore capital flows will quickly reverse should circumstances changes, a fact that many Governments have faced when they changed the rules to the detriment of investors. Within this framework it is therefore necessary to understand what projects will best support the ultimate goal, and to differentiate between those with a low probability for success and those for which the chances are better.

All mineral deposits can be characterized by various target valuation models. The earlier that this is done the more likely the owner will be able to make quantitative decisions about the viability of its project. The physical processes inherent in a valuation model include determining the following major factors:

- if the resource potential is sufficient to support a mine over a reasonable life-span;
- potential cut-off grades and metallurgical challenges;
- mining and processing options and the potential capital and operating costs for each;
- likely market requirements, if any, and potential revenue streams based on commodity price forecasts;
- the impact of local supply, infrastructure and human resource requirements; and,
- the impacts of environmental and societal factors as well as taxes and royalties.

Through the use of some form of a scoping study or preliminary economic assessment to convert technical information into economic terms, the project owners should be able to acquire a vision of the mining operation, and then ask the following simple question:

“Does this mining project resemble other successful mines that exist in comparable jurisdictions?”

The answer should be positive, following which the owner/operator can then proceed with some confidence that a substantial amount of project risk has been eliminated. The sooner this valuation metric is achieved, the better if the company is to avoid pouring money into a project that will ultimately fail. The hurdle that a project must clear depends on the ambitions and requirements of the company. A major company may

require a project to add to its revenue stream by at least 10% whereas a small company may simple wish to make a profit. The bar by which projects are measured therefore is relative, not absolute. The same argument can be made for governments seeking to develop their minerals sector. If they wish to be a top tier producer, they must focus on those projects most likely to achieve that goal, and push aside those projects that have little potential for success. This not the same as abandoning those projects because they will continue to exist, and in time they may become economically feasible due to changing market conditions or technological innovations that solve technical challenges. All explorers, whether Private Sector or Government Agencies, must be aware of the downstream commercial hurdles demanded of their projects such that they can focus on a portfolio of mineral properties that have the greatest probability of success.

This Mineral Potential Assessment has identified orogenic and disseminated (porphyry-type) gold projects, VMS-type base metal projects, Ni-Cu-PGE projects and the carbonate-hosted zinc-lead-silver projects as those having the greatest chance for success and making a measurable contribution to the national economy of Saudi Arabia. The base case studies contained in this assessment, which used a 50% confidence level as a predictor, showed that the in-ground value of these deposits totals US $110 Billion using long-term commodity prices supplied to WGM by McKinsey. As stated in this report, WGM believes that both gold and VMS-type base metals potential are underestimated using the EMINERS software required for its analysis, and that evidence in the Saudi context shows that the 10% confidence level may more closely reflect the actual potential that will be realized with long-term, continuing exploration. If that is true, the in-situ value of the identified resources increases to $385 Billion.

The realization of the potential outlined in this Mineral Potential Assessment requires the participation of a strong, well funded Saudi Geological Survey ("**SGS**"). In the absence of a strong and diverse mineral exploration sector, of which junior explorers are a vital component, many projects have been left to the SGS to demonstrate the fundamental economic viability of the model to the international exploration community. The SGS have carried the burden of being a geoscience information collector as well as being an explorer. This demands that the SGS performing two roles that have divergent goals and require very different skills. For this reason, in most countries the geological surveys do not involve themselves in mineral exploration programs. They draw a clear line between the role of the Private Sector and themselves. That line is typically drawn between geoscience programs that seek to characterize or monitor the natural environment, and exploration programs that are dedicated solely to the discovery of an economically viable mineral deposit. In practical terms, this differentiation can be based on scale, with geoscience typically being regional and requiring surveys at 1:50,000 scale or greater, and mineral exploration being focused and requiring work at scales of 1:20,000 scale or less. Specifically, any work dedicated to a mineral target or group of targets should be considered as exploration. Programs dedicated to the general understanding of a mineral belt should be thought of as geoscience.

As stated already, this division of roles is important. **The recommendations for future exploration programs as contained in this Mineral Potential Assessment are not intended for the SGS. They are intended for independent explorers, whether they are domestic companies or foreign investors.** In some cases, there is a specific role for the SGS to play in providing regional information through geochemical sampling programs and airborne geophysical surveys. Some of this work has already been

done, and it is vital that the SGS be adequately funded for such capital intensive programs. In those rare occasions where the SGS steps into a role of explorer, it must be limited to demonstrating an untested geological model or geoscience technique. The SGS must resist being drawn into exploration because this requires skills, experience and judgements pertaining to economic potential that the Survey is not well equipped to handle.

Part of the role of the SGS involves providing geoscience and exploration information to potential investors. Both the SGS, potential investors and the authors of this report suffer from a lack of information concerning large areas that have been explored by State-sponsored companies such as Ma'aden and Aramco. WGM has been surprised, in fact shocked to learn that even the President of the Geological Survey does not have access to the reports filed by companies relating to work completed on exploration licences. As pointed out by one of the expert reviewers of this report, successful mining jurisdictions understand the vital need to ensure the free circulation of geoscience and exploration information within the investing community. A way must be found to ensure that all such information finds its way into the records of the SGS to allow the work done in the past to become part of the Kingdom's exploration heritage – its foundation of knowledge for future explorers. In Canada, some companies have completely opened their data vaults to all parties, and sponsored a contest whereby others in the industry can try to predict the location of the next major ore shoot. This encourages wide-ranging exchanges of ideas and generates new exploration concepts.

The circulation and practical use of geological and mineral sector knowledge can best be achieved through the efforts of a National Geoscience Database, provisions for which are identified and discussed in other components of the Comprehensive Mining Strategy Project of which this report is one part. Only by knowing was has been done in the past can new programs be developed to investigate what has not been explored, and to avoid repeating the failed programs of the past. Repeating failed programs is not only a waste of money, it reinforces negative thinking. The new Kirkland Lake Gold Mine, which will produce in excess of 9 Moz of gold, was not found as a result of negativity or by repeating past efforts. It was discovered by trying a different approach to a well-tested model.

This Mineral Potential Assessment has identified tremendous wealth that can be unlocked through investments in exploration. Such activities are licensed and monitored by the Deputy Ministry for Mineral Resources ("**DMMR**"). Although positive changes were made approximately 10 years ago to enable greater competition and fairness in the activities of Ma'aden and other exploration licence holders in the Kingdom, WGM's interviews of those applying for licences (including some of its own clients) indicate that the licensing process has failed to live up to the expectations of those seeking to invest. The administrative process has also impacted those seeking mining licences, however these applications do require significantly greater scrutiny than those for exploration projects. At this time, the granting of exploration licences is subject to an excess of approvals for what is generally a very low-impact activity in respect to the environment and society. The Government, as represented by the DMMR, must ensure a legal and regulatory framework that is well defined, transparent and free of road-blocks, and which assists and supports those who invest in exploration. Most importantly, the process of granting exploration licences

that requires minutes or hours in other countries should not take years in Saudi Arabia. The recognition of significant mineral potential, as predicted in this Mineral Potential Assessment Report, means very little if the path between investors and prospects is blocked. A clear and unencumbered path is needed to facilitate the granting, renewal and transfer of exploration licences.

As clearly stated in this report, the development of Saudi Arabia's mineral potential will require substantial, sustained investments guided by experienced industry professionals. The DMMR and the SGS have vital roles to play, not by trying to do all the exploration recommended in this report, but by providing a stable and efficient regulatory environment, and by building the essential geoscience framework within which private sector investors can participate in the exciting challenge of developing the Kingdom's mineral sector.

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APPENDICES

Formation and Lithology Legends for Geological Figures

Legend

Quaternary
- Qa: Quaternary alluvium
- Qat: Quaternary alluvial terraces
- Qb: Quaternary flood basalt
- Qc: Quaternary coral reef limestone
- Qe: Quaternary eolian sand sheets and dunes
- Qf: Quaternary alluvial fan and flood plain deposits
- Qg: Quaternary gravel sheets and terraces
- Qk: Quaternary khabra deposits
- Qm: Quaternary marine and coastal plan deposits
- Qs: Quaternary sabkhah deposits
- Qt: Quaternay talus deposits
- Qu: Quaternary sand, gravel, and silt deposits

Quaternary-Neogene
- QNb: Quaternary-Neogene flood basalt
- QNbc: Quaternary-Neogene basaltic cinder cones
- QNp: Quaternary-Neogene pediment, cobble, pebbles, conglomerate, sand, and gravel sheets

Neogene
- Nb: Neogene flood basalt
- Nbe: Neogene erdoed basalt and gravel
- Nbu: Buwanah evaporitic, fossiliferous, and calcareoud deposits
- Ngb: Neogene gabbro and granophyre dike
- Npl: Neogene gypsiferous sand, sandy clay, and conglomerate
- Nrc: Raghama formation, conglomerate, sandstone, marl, and limestone
- Nrg: Raghama formation, gypsum, dolomite, and anhydrite
- Nrl: Raghama formation, limestone, marlstone, and gypsum
- Nrr: Raghama formation, basal reef limestone, calcareous siltstone, and sandstone
- Nru: Raghama formation, undivided

Paleogene
- PAka: Azlam formation, basal sandstone and fossilliferous argillaceous limestone

Ordovician
- Oss: Saq sandstone, Sajir member

Cambrian-Ordovician
- OEr: Ram, and Umm Sahm sandstones

Cambrian
- Eq: Quweira sandstone
- Es: Siq sandstone
- Esr: Saq sandstone, Risha member

Al Ays group <745->700 Ma
- ayb: Basaltic rocks
- ayfi: Fashghan formation, silicic rocks
- ayfs: Fashghan formation, sedimentary rocks
- ayjv: Umm Jabuh formation, volcanosedimentary rocks
- ayls: Clastic sediments, limestone, and tuff
- aytu: Thaa formation, undifferentiated rocks
- ayu: Al Ays undifferentiated rocks
- ayvs: Volcanosedimentary rocks, undivided

Al Bad' granite super suite 585-565 Ma
- abd: Daghalah granite

Al Qunnah formation >745 Ma
- aqvs: Metapyroclastic, and metasedimentary rocks

Bayda group (Age uncertain)
- baac: Amud formation, volcanic conglomerate
- baas: Amud formation, sandstone and tuffaceous sandstone
- baat: Amud formation, andesitic and silicic tuff
- bada: Dacite and rhyodacite
- baha: Hasha formation, andesite, basalt, tuff, and pyroclastic rocks
- bahb: Hasha formation, andesite and basalt lavas, tuffs, and agglomerates
- bahc: Hasha formation, arkosic sandstones and conglomerates
- bahd: Hasha formation, dacite and rhyodacite lavas
- bahf: Hijr formation, silicic pyroclastic rock and rhyolite flows
- baik: Jarasah formation, agglomerate siltstone,

Imdan complex 748-~660 Ma
- imb: Gabbro (748 Ma
- imd: Diorite (660 Ma)
- img: Granodiorite (660 Ma)
- imt: Tonalite

Jar-Salajah complex 745-695 Ma
- jsbd: Gabbro and diorite
- jsdg: Adamellite, granodiorite, quartz diorite, and tonalite
- jsdi: Diorite
- jsdq: Diorite and quartz diorite
- jst: Tonalite (725 Ma)
- jsta: Amphibole tonalite
- jstt: Tonalite and trondhjemite (731 Ma)

Jibalah group (age uncertain)
- jbd: Mataar and Dhaiqa formations (~599 Ma)
- jbmc: Misyal formation, conglomerate and siltstone
- jbru: Rubtayn formation, polymictic conglomerate and sandstone
- jbsr: Salih formation, rhyolite flows overlain by siltstone and conglomerate
- jbu: Jibalah group, undifferentiated rocks

Marabat suite ~621-608 Ma
- qama: Atiyah monzogranite
- qambm: Abu Suar complex, monzogranite
- qamdi: Abu Suar complex, diorite
- qamhd: Hadb complex, diorite
- qamhm: Habd complex, monzogranite (608 Ma)
- qamkm: Kara Dakha complex, monzogranite
- qamks: Kara Dakha complex, syenogranite
- qamld: Liban complex, diorite to quartz diorite
- qamlm: Liban complex, monzogranite (621 Ma)
- qamls: Liban complex, syenogranite
- qamsb: Ashsha'b complex, gabbro
- qamsm: Ashsha'b complex, monzogranite
- qamss: Ashsha'b complex, syenogranite
- qamwb: Warid complex, gabbro
- qamwg: Warid complex, granodiorite and quartz monzonite
- qamwm: Warid complex, monzogranite
- qamws: Warid complex, syenogranite

Midyan suite-Dabbagh complex 630-570 Ma
- abyn: Numran alkali granite
- abyr: Raydan alkali granite (630 Ma)

Muraykhat formation (Age uncertain)
- mybu: Muraykhat gabbro

Muwaylih suite ~725-710 Ma
- mwhn: Hayyan complex, norite, gabbro, anorthosite, and magnetite-ilmenite lenses
- mwsg: Shaghab complex, diorite, quartz diorite, gabbro, Norite, and tonalite
- mwyb: Buwaydah complex, gabbro
- mwyd: Buwaydah complex, diorite
- mwyg: Buwaydah complex, granodiorite
- mwyt: Buwaydah complex, tonalite

Nabt complex (Age uncertain)
- nabu: Nabt abbro, diorite, and quartz diorite

Ra'al granite 635 Ma
- rngl: Ra'al leucocratic granite, adamellite, and monzonite
- rngn: Ra'al granitic gneiss
- rngr: Ra'al granite
- rngrs: Ra'al monzogranite and syenogranite

Rithmah complex (Age uncertain)
- rtdq: Rithmah quartz diorite

Thalbah group <660->620 Ma
- thsh: Hashim formation, conglomerate, litharenite, and siltstone
- thsr: Ridam formation, conglomerate, containing granite boulders
- thsz: Zhufar formation, litharenite, conglomerate, and shale

Other Proterozoic units
- fatt: Fara' trondhjemite (743 Ma)
- gqm: Granodiorite and quartz monzonite
- njgd: Najah granodiorite >725 Ma
- xmo: Orthogneiss and orthoschist
- xmp: Paraschist, paragneiss, and phyllonite

Unassigned Proterozoic rocks
- ub: Unassigned gabbro
- ubd: Unassigned gabbro and diorite
- ubn: Unassigned gabbronorite
- ug: Unassigned granite
- ugd: Unassigned granodiorite
- ugm: Unassigned monzogranite
- ugsy: Unassigned granodiorite and syenite
- ur: Unassigned rhyolite
- usg: Unassigned syenogranite
- ut: Unassigned tonalite

MODS Records (2014)

Precious Metals
- Gold

Faults
- Normal faults
- Strike-slip faults
- Thrust faults

Compiled from: SGS sources and MODS (2015)

end

ternary

- Qa: Quaternary alluvium
- Qat: Quaternary alluvial terraces
- Qe: Quaternary eolian sand sheets and dunes
- Qg: Quaternary gravel sheets and terraces
- Qgs: Quaternary gravel, sand, boulder Scree
- Ql: Quaternary loessic sand and silt
- Qs: Quaternary sabkhah deposits
- Qu: Quaternary sand, gravel, and silt deposits
- Qvy: Quaternary colluvial deposits

ternary-Neogene

- QNb: Quaternary-Neogene flood basalt

gene

- Nb: Neogene flood basalt
- Nbc: Neogene basaltic cinder cones
- Nbr: Neogene rhyolitic tuff and breccia
- Nla: Neogene laterite

brian-Ordovician

- OEw: Wajid undifferentiated sandstones
- OEwd: Wajid sandstone, Dibsiyah formation
- OEwh: Wajid sandstone, Shum formation
- OEwi: Wajid sandstone, Ilman formation
- OEwj: Wajid sandstone, Juwayl formation
- OEwk: Wajid sandstone, Khusayyan formation
- OEws: Wajid sandstone, Sanamah formation

lafoor suite ~610 Ma

- aodi: Diorite
- aogm: Monzogranite
- aogr: Monzogranite and granodiorite
- aoj: Jasl monzodiorite
- aoqm: Quartz monzonite
- aotg: Granodiorite and tonalite

unaynah formation <620 Ma

- ajsc: Polymictic conglomerate
- ajss: Sandstone and siltstone

Nimas complex 815-795 Ma

- andb: Diorite and gabbro
- andq: Quartz diorite
- andt: Diorite and tonalite
- antt: Tonalite and trondhjemite

Sutayyan complex (Age uncertain)

- stad: Agmatite, diorite, and gabbro
- stdb: Diorite and gabbro
- stdi: Diorite
- stdm: Diorite and monzogranite
- stdq: Quartz diorite
- stdt: Diorite and tonalite
- stgd: Granodiorite
- stgt: Granodiorite and tonalite
- sttg: Hornblende-biotite granodiorite
- sttt: Tonalite and trondhjemite

Sha'ib group (Age uncertain)

- sbam: Amphibolite
- sbga: Paragneiss, greenstone, greenschist, and amphibolite
- sbgs: Paragneiss, quartzose gneiss and schist, quartzite, and marble (700-665 Ma)
- sbma: Massive andesite
- sbms: Graywacke, tuffaceous graywacke, quartzite shale, and marble
- sbva: Andesitic rocks and flows, pyroclastic flows, breccias, and tuff
- sbvm: Mafic volcanic rocks
- sbvs: Metavolcanic and metasedimentary rocks
- sbvt: Basaltic and andesitic flow, and pyroclastic rocks

i Ghayy group 630-607 Ma

- byaa: Arfan formation, andesite and rhyolite (608 Ma)
- byal: Arfan formation, strotomatolatic and clastic limestones, marble, and carbonate breccia

Haml suite ~640-620 Ma

- hlga: Alkali-feldspar granite (615-600 Ma)
- hlgg: Monzogranite and granodiorite
- hlgr: Monzogranite and syenogranite
- hlgs: Syenogranite (615-600 Ma)

Ibn Hashbal suite 640-615 Ma

- ihga: Alkali-feldspar granite (628-617 Ma)
- ihgr: Biotite monzogranite (641 Ma)
- ihgx: Biotite monzogranite and mafic inclusions

Kawr suite ~650-620 Ma

- kwdb: Diabase and gabbro
- kwga: Alkali-feldspar granite (636-604 Ma)
- kwgm: Monzogranite (620 Ma)
- kwgr: Monzogranite and syenogranite
- kwgs: Syenogranite

Khadra belt 745-730 Ma

- ktam: Amphibolite
- ktbd: Basalt, andesite, and dacite
- ktbd: Basalt, dacite, andesite tuff, and graywacke siltstone
- ktcd: Dacitic, rhyolitic, and rhyolitic rocks
- ktcs: Chlorite-sericite schist, sericite-chlorite schist, and chlorite schist
- ktds: Diabase
- kths: Biotite-hornblende schist, graywacke, andesitic and dacitic graywacke
- ktm: Melange
- ktqd: Hornblende-biotite quartz diorite
- ktsc: Conglomeratic graywacke, siltstone, and shale
- ktss: Sedimentary rocks, undivided
- ktsu: Sedimentary, volcanic, and ultramafic rocks
- ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff
- ktvd: Metamorphosed dacitic flow and pyroclastic rocks
- ktvf: Felsic volcanic rocks, undivided
- ktvi: Lithic breccia and tuff, flow rocks, and minor sedimentary rocks
- ktvr: Rhyolit, lithic tuff, ash-flow tuff, and flow
- ktvs: Volcanic and sedimentary rocks, undivided
- ktvt: Dacite tuff and basalt flow, and andesite

Khaniq formation (Age uncertain)

- kknf: Felsic volcanic and volcaniclastic rocks

Malahah belt >730 Ma

- mlcs: Carbonaceous siltstone and shale
- mld: Diabase and metadiabase
- mlda: Metadacite, pyroclastic and volcaniclastic rocks
- mlgc: Graywacke, phyllite, and conglomerate
- mlms: Schist, slate, metagraywacke, metatuff, and marble
- mlv: Basalt, andesite, and dacite
- mlvm: Meta-andesite, metabasalt and breccia

Mushrifah complex ~730 Ma

- smdb: Diorite and gabbro
- smdi: Diorite
- smdt: Diorite and tonalite
- smt: Tonalite
- smtn: Tonalite and granodiorite

Nabitah gneiss suite 660-623 Ma

- nbab: Abss granodiorite and tonalite gneiss (651 Ma)
- nbkd: Khamis Mushayt granodiorite gneiss (657 Ma)
- nbkq: Khamis Mushayt and Al Qa'ah granodiorite and granite gneiss
- nbkt: Khamis Mushayt and Al Qa'ah tonalite and granodiorite gneiss
- nbmg: Musayrah granodiorite and granite (623 Ma)
- nbmy: Umm al Hashiyah granodiorite and monzogranite migmatite
- nbt: Tathlith gneiss (652 Ma)

Nasaf suite ~645 Ma

- nzt: Ziraq complex, tonalite

Rawdah formation >730 Ma

- ktra: Basalt, andesite, lithic tuff, and agglomerate

Tayyah belt >815 Ma

- tyam: Amphibolite
- tybd: Basalt, andesite, and dacite
- tycg: Conglomeratic arkose and volcanic graywacke
- tyss: Sedimentary rocks
- tyva: Andesitic rocks
- tyvb: Basalt and volcaniclastic rock
- tyvd: Dacitic volcaniclastic rocks
- tyvm: Mafic volcanic rocks, undivided
- tyvs: Volcaniclastic graywacke, shale and siltstone

Thalath complex ~640-630 Ma

- lab: Gabbro
- labm: Metagabbro
- ladb: Diorite and gabbro

Wadbah suite ~605 Ma

- wbdi: Diorite and tonalite
- wbdt: Biotite-hornblende tonalite and granodiorite
- wbdx: Granodiorite and tonalite agmatite
- wbdh: Biotite-hornblende granodiorite and monzogra

Wozariyah formation >730 Ma

- ktwz: Volcaniclastic, shale, siltstone, and marble

Other Proterozoic units

- bgg: Biotite granodiorite and monzogranite
- dgb: Gabbro and diorite undivided
- hjt: Hijrat trondhjemite 655 Ma
- hkub: Hakran serpentinite and gabbro
- hpry: Hima rhyolite
- ltt: Julayhi tonalite ~705 Ma
- ndgr: Najd granite ~590 Ma
- qwgt: Al Qawba tonalite and granodiorite
- rxtn: Arin tonalite 674 Ma
- skn: Shonkinite
- xmo: Orthogneiss and orthoschist
- xmp: Paraschist, paragneiss, and phyllonite
- xmu: Peridotite, serpentinite, metagabbro in fault zo

Unassigned Proterozoic rocks

- ub: Unassigned gabbro
- ubm: Unassigned metagabbro
- ubt: Unassigned gabbro and tonalite
- ubu: Unassigned gabbro and metagabbro
- uda: Unassigned dacite
- udi: Unassigned diorite
- udr: Rhyolite dikes, sills, and plugs
- udt: Unassigned diorite and tonalite
- ufd: Unassigned felsic to granitic dikes
- ug: Unassigned granite
- ugd: Unassigned granodiorite
- ugg: Unassigned granite and granodiorite
- ugm: Unassigned monzogranite
- ugt: Unassigned granodiorite and tonalite
- uma: Unassigned albite microgranite
- umd: Unassigned mafic dikes and sills
- unu: Unassigned ultramafic rocks
- upx: Unassigned pyroxenite
- uqp: Unassigned quartz porphyry
- usg: Unassigned syenogranite
- usn: Unassigned syenite and syenite gneiss
- ut: Unassigned tonalite

MODS Records (2014)

Precious Metals

- Gold

Faults

- Normal faults

y
Quaternary alluvium
Quaternary alluvial terraces
Quaternary basaltic cinder cones
Quaternary caliche
Quaternary eolian sand sheets and dunes
uaternary alluvial fan and flood plain deposits
Quaternary gravel sheets and terraces
Quaternary khabra deposits
Quaternary playa lake deposits
Quaternary sabkhah deposits
Quaternary sand, gravel, and silt deposits
Quaternary colluvial deposits
y-Neogene
Quaternary-Neogene flood basalt
leogene flood basalt
leogene gravel and sand terraces
n
Saq sandstone, Hilwan membar
Saq sandstone, Sajir member
Ordovician
Cambrian-Ordivician undifferentiated sandstones
Saq sandstone, Risha member
ite 585-565 Ma
Abanat suite, Fawwarah alkali-feldspar granite
Alkali-feldspar granite
Flourite granite (peraluminous granite and aplite)
Biotite granite and leucogranite
Peralkalic and alkalic granite
Porphyritic biotite albite-orthoclase granite
Aalkali-feldspar granophyre
Hornblende perthite granite
Qitan porphyritic biotite-muscovite syenogranite
Qitan biotite-muscovite syenogranite
Rhyolite porphyry
Salma alkali-feldspar granite
Silsilah aplite
Alkali-feldspar quartz syenite
ion ~650-635 Ma
Basalt, andesite and related tuff, and volcanic sandstone
Meta-andesite and volcaniclastic sediments
Rhyolitic tuff, ignimbrite, rhyolite, and andesite
Gneiss, schist, metavolcanic and metasedimentary rocks
Tuff, siltstone, graywacke, sandstone, and andesite
d Sufran formations >740 Ma
Sufran felsic volcanic rocks
Banana and Sufran mafic volcanic rocks
Banana gneissic and shistose rocks
Banana and Sufran andesite and basalt
Banana and Sufran orthogneiss, gneissic and shistose rocks
y group 630-607 Ma
Numan formation, graywacke, conglomerate, and sandstone
Shihbah formation, sandstone, limestone, and conglomerate
Bani Ghayy group, undivided
Volcanic and sedimentary rocks
Volcanic sandstone, conglomerate, rhyolite, andesite, and tuffite
h complex ~835 Ma
Bi'r Tuluhah gabbro-serpentinite
d Qarnayn formations (Age uncertain)
Buqaya and Qarnayn formations, undivided
Buqaya formation, volcaniclastic and metagraywacke
omplex 840-830 Ma
Bi'r Umq gabbro-serpentinite
mation >695 Ma
Dhiran meta-andesite
mplex 816-803 Ma
Gabbro
Granite, quartz monzonite, monzotonalite, and diorite
Tonalite (803)
oup (Age uncertain)
Shuwayt formation, basalt, andesite, and pyroclastic rocks
Naslah formation, volcanic and sedimentary rocks
Naslah formation, silicic rocks
Naslah formation, mafic volcanic rocks
Naslah formation, rhyolite to rhyodacite
Naslah formation, sedimentary rocks
Naslah formation, sandstone, siltstone, graywacke, basalt, and andesite
Sharqan formation, siltstone, sandstone, and conglomerate
oup ~750 Ma
Kharzah formation, silicic rocks
Kharzah formation, mafic volcanic rocks

Humaymah suite 645-630 Ma
hyb: Gabbro and layered gabbro
hyga: Alkali-feldspar granite
hygc: Calc-alkalic granite
hygd: Granodiorite
hygl: Biotite granite, and leucogranite
hygm: Monzogranite
hygr: Granite
Idah suite 632-610 Ma
idbu: Gabbro
iddi: Diorite
iddt: Diorite, quartz monzonite, quartz diorite, and trondhjimite
idga: Alkali-feldspar granite
idgc: Calc-alkalic, alkalic granite and granodiorite
idgd: Granodiorite (620-614 Ma)
idgg: Granite, granodiorite, and microgranite
idgl: Biotite granite and leucogranite
idgm:Monzogranite (632 Ma)
idgo: Granite, orthogneiss
idgr: Monzogranite and syenogranite
idgs: Syenogranite
idgt: Tonalite and granodiorite
idim: Microsyenite
idmd: Monzodiorite
idmq: Quartz monzodiorite
Isamah formation ~840 Ma
isva: Andesite, basalt, and pyroclastic rocks
isvb: Biotite gneiss, leptinite, quartzite, and amphibolite
isvd: Hypabyssal diabase, diorite, and gabbro
isvs: Volcanic and sedimentary rocks, undivided
isvt: Tuff, conglomerate, marble, chert, jasper, rhyolite, and andesite
Jibalah group (age uncertain)
jbc: Conglomerate, sandstone, siltstone, and limestone
jbj: Jifn formation, sandstone, siltstone, conglomerate, and andesite
jbo: Granite, orthogneiss
jbs: Sandstone
jbss: Umm Al 'Aisah formation, polymictic conglomerate, sandstone, and limestone
jbsv: Umm Al 'Aisah formation, conglomerate, limestone, shale, andesite, and basalt
jbu: Jibalah group, undifferentiated rocks
jbv: Rhyolite, trachyte, andesite, granophyre, and conglomerate
Jidh suite ~700-640 Ma
jdbd: Gabbro, diorite, and microdiorite
jdbu: Gabbro
jddi: Diorite
jddq: Diorite and quartz diorite
jddu: Gabbro and diorite
jdgb: Granite, trondhjemite, diorite, and gabbro
jdgc: Calc-alkalic granite
jdgd: Granodiorite (647 Ma)
jdgg: Granite and granodiorite
jdgl: Biotite granite, and leucogranite
jdgm: Monzogranite (646 Ma)
jdgo: Granite, orthogneiss
jdgr: Calc-alkalic, alkalic granite and granodiorite
jdgs: Biotite granite, leucogranite, syenogranite and syenite
jdgt: Granodiorite, monzogranite, and tonalite
jdgy: Alkalic to calc alkalic granite and granite porphyry
jdlg: Leucogranite
jdqm: Quartz monzonite, monzotonalite, and diorite
jdqs: Quartz syenite and syenogranite
jdtq: Granodiorite, tonalite, quartz diorite, and diorite
Jurdhawiyah group 610-595 Ma
jhc: Conglomerate and sandstone
jhi: Saharat porphyritic andesite
jhl: Lapilli tuff beds
jhm: Muqawqi andesite
jhs: Volcanic sandstone, conglomerate, rhyolite, andesite, and tuffite
jhsr: Shabah rhyodacite and rhyolite
jhst: Shabah formation, andesitic tuff
jhu: Jurdhawiyah group, undivided
Khishaybi suite ~640 Ma
ksgd: Granodiorite
ksgl: Biotite granite, leucogranite
ksgm: Monzogranite
ksgo: Granite, orthogneiss
ksgr: Granite
ksgs: Syenogranite
ksgt: Granodiorite, tonalite, and trondhjemite
Kilab suite ~650 Ma
kbgm: Monzogranite (651 Ma)
kbgt: Granodiorite and tonalite
Laban complex ~650 Ma
lndq: Diorite and quartz diorite
lnsd: Samirah quartz monzodiorite

Shammar group ~630 Ma
szk: Kuara formation, conglomerate, volcanic sandstone, rhyo ignimbrite, andesite, basalt, and pyroclastics
szm: Malha formation, rhyolite, ignimrite rhyolitic tuff and brec conglomerate and volcanic sandstone
szu: Volcanic and sedimentary rocks
Siham group <750->695 Ma
sihd: Hypabyssal diabase, diorite, and gabbro
sin: An Nayzah formation, schist, gneiss, amphibolite, quartzit marble, meta-andesite, and granodiorite
sis: Madin formation, tuff, siltstone, graywacke, sandstone, and andesite
sisc: Conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
siva: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
sivb: Urta formation, basalt, andesite, tuff, and volcanic sandstone
sivd: Rhyolite, dacite, andesite, and pyroclastics
sivn: Metamorphosed schist, gneiss, amphibolite, metarhyolite and jasper
Sumayir formation ~830 Ma
bisb: Basalt, and minor jasper (831 Ma)
bisg: Greenstone, chert, gabbro, serpentinite and carbonate rocks
bism: Sumayir formation, undivided
Suwaj suite 685-659 Ma
swbu: Gabbro
swdd: Dumaym diorite
swgd: Granodiorite
swgh: Granophyre
swgo: Granite, orthogneiss
swkq: Khaytan quartz diorite
swmt: Muzafir tonalite (684 Ma)
Syn- to post-Banana formation 740-685 Ma
bxbu: Gabbro
bxdi: Diorite
bxgd: Granodiorite
bxgm: Monzogranite
bxgp: Sheared porphyritic monzogranite
bxgy: Feldspar granophyre
bxqg: Quartz diorite and granodiorite
bxqm: Muwashsham quartz monzodiorite
Syn- to post-Hulayfah group ~720 Ma
hxg: Granite, trondhjemite, diorite, and gabbro
Syn- to post-Isamah formation <840 Ma
isxb: Gabbro
isxd: Diorite and quartz diorit
isxj: Granite, trondhjemite, diorite, and gabbro
isxm: Microgranite
isxo: Granite, orthogneiss
isxt: Granodiorite and tonalite
isxt: Granodiorite and tonalite
Syn- to post-Shammar group 625 Ma
szg: Granite and granodiorite
szxa: Alkali-feldspar granite
szxb: Gabbro and serpentite
szxg: Granite
szxm: Microgranite
szxo: Granite, orthogneiss
szxt: Granodiorite
szxy: Granophyre
Tamran formation >810 Ma
tam: Tamran formation, undivided
tamf: Felsic volcanic rocks
tamm: Mafic volcanic rocks
tams: Sedimentary rocks, undivided
Wasit formation 590-560 Ma
wsry: Wasit rhyolite and related tuff
Zarghat formation (Age uncertain)
zhvs: Volcanic and sedimentary rocks, undivided
Other Proterozoic units
ibtg: Bari granodiorite 776 Ma
xmp: Paraschist, paragneiss, and phyllonite
xmu: Peridotite, serpentinite, metagabbro in fault zones
Unassigned Proterozoic rocks
uam: Unassigned amphibolite
uap: Unassigned aplite, aplite granite, and aplite pegmatite
ub: Unassigned gabbro
ubd: Unassigned gabbro and diorite
ubm: Unassigned metagabbro
ubs: Unassigned gabbro and serpentite
uda: Unassigned dacite
udi: Unassigned diorite
udp: Unassigned diabase dikes and plugs
udr: Rhyolite dikes, sills, and plugs
udy: Unassigned dacite and rhyolite
ug: Unassigned granite
ugg: Unassigned granite and granodiorite
ugp: Unassigned granite porphyry
ugy: Unassigned granophyre and rhyolite

Qa: Quaternary alluvium
Qat: Quaternary alluvial terraces
Qc: Quaternary coral reef limestone
Qe: Quaternary eolian sand sheets and dunes
Qf: Quaternary alluvial fan and flood plain deposits
Qg: Quaternary gravel sheets and terraces
Qk: Quaternary khabra deposits
Qm: Quaternary marine and coastal plan deposits
Qs: Quaternary sabkhah deposits
Qt: Quaternay talus deposits
Qu: Quaternary sand, gravel, and silt deposits

Quaternary-Neogene

QNb: Quaternary-Neogene flood basalt
QNbc: Quaternary-Neogene basaltic cinder cones
QNp: Quaternary-Neogene pediment, cobble, pebbles, conglomerate, sand, and gravel sheets

Neogene

Nb: Neogene flood basalt
Nbe: Neogene erdoed basalt and gravel
Ngb: Neogene gabbro and granophyre dike
Nrc: Raghama formation, conglomerate, sandstone, marl, and limestone
Nrg: Raghama formation, gypsum, dolomite, and anhydrite
Nrl: Raghama formation, limestone, marlstone, and gypsum
Nrr: Raghama formation, basal reef limestone, calcareous siltstone, and sandstone
Nru: Raghama formation, undivided

Paleogene

PAka: Aztam formation, basal sandstone and fossiliferous argillaceous limestone
PAtm: Mira formation, undivided

Cretatious

Kaz: Aruma formation, Zallum member

Silurian

Sq: Qusaiba formation, undivided
Su: Uqlah formation

Ordovician-Silurian

OSt: Tabuk group, undivided

Ordovician

Oqh: Qasim formation, Hanadir member
Oqk: Qasim formation, Kahfah member
Oqq: Qasim formation, Quwarah member
Oqr: Qasim formation, Ra'an member
Os: Sarah formation
Oss: Saq sandstone, Sajir member

Cambrian-Ordovician

OEr: Ram, and Umm Sahm sandstones

Cambrian

Eq: Quweira sandstone
Es: Siq sandstone
Esr: Saq sandstone, Risha member

Abu Safiyah complex ~700 Ma

asga: Alkali-feldspar granite
asmz: Monzonite
asqs: Quartz diorite and syenite

Admar suite ~630 Ma

adgg: Monzogranite and granodiorite

Al Ays group <745 >700 Ma

ayfs: Fashghan formation, sedimentary rocks
ayjf: Jizl formation, felsic volcanic rocks
aymt: Matran formation, mafic volcanic rocks
aymv: Metavolcanic rocks
aysc: Sericite and chlorite schist
aytu: Thaa formation, undifferentiated rocks
ayu: Al Ays undifferentiated rocks
ayvs: Volcanosedimentary rocks, undivided

Al Bad' granite super suite 585-565 Ma

abd: Daghalah granite

Al Qunnah formation >745 Ma

aqvs: Metapyroclastic, and metasedimentary rocks

Asmar complex (Age uncertain)

axtd: Asmar diorite and quartz diorite

Bayda group (Age uncertain)

baac: Amud formation, volcanic conglomerate
baas: Amud formation, sandstone and tuffaceous sandstone
baat: Amud formation, andesitic and silicic tuff
bada: Dacite and rhyodacite
baha: Hasha formation, andesite, basalt, tuff, and pyroclastic rocks
bahb: Hasha formation, andesite and basalt lavas, tuffs, and agglomerates
bahc: Hasha formation, arkosic sandstones and conglomerates
bahd: Hasha formation, dacite and rhyodacite lavas
bahf: Hijr formation, silicic pyroclastic rock and rhyolite flows
bahr: Hasha formation, rhyolite and rhyodacite lavas
bajk: Jarasah formation, agglomerate siltstone, litharenite and basalt
bajt: Jarasah formation, silicic and andesitic tuff
baka: Khawr formation, andesitic and basaltic lavas, tuffs, and agglomerates
bakc: Khawr formation, conglomerate and arkosic sandstone
bakd: Khawr formation, dacitic lavas and tuffs
bakl: Khawr formation, litharenite and volcanic rocks
barl: Riman formation, litharenite, siltstone, and conglomerate
bas: Sedimentary rocks, undivided
bau: Bayda group, undifferentiated rocks
bauu: Unnab formation, andesite, silicic tuff, litharenite and siltstone
bavf: Felsic volcanic rocks
bavs: Volcanosedimentary rocks, undivided

Duba complex ~725-710 Ma

mwbg: Duba complex, granodiorite
mwbt: Duba complex, tonalite

Ghawjah formation >710 Ma

gju: Andesitic lavas, porphyritic amphibolite and pyroclastic rocks

Hadiyah group ~695 Ma

dysm: Siqam formation, basalt, andesite, tuff and clastic sediments (697 Ma)
dytu: Tura'ah formation, undifferentiated

Imdan complex 748-~660 Ma

imb: Gabbro (748 Ma
imd: Diorite (660 Ma)
img: Granodiorite (660 Ma)
imt: Tonalite

Jar-Salajah complex 745-695 Ma

jsbd: Gabbro and diorite
jsta: Amphibole tonalite

jbe: Meddan formation, rhyolite and andesite flows and pyroclastic rocks
jbf: Farra'ah formation, rhyolite flows and breccia, and interbedde conglomerate
jbm: Muraykhah formation
jbmc: Misyal formation, conglomerate and siltstone
jbr: Rahabah formation, argillite, siltstone, sandstone and conglomerate
jbru: Rubtayn formation, polymictic conglomerate and sandstone
jbsr: Salih formation, rhyolite flows overlain by siltstone and conglomerate
jbu: Jibalah group, undifferentiated rocks
jbz: Zumurrud formation
jbzm: Mashhad formation
jbzn: Nadah formation
jbzu: Zumurrud, Nadah, and Mashhad formations, undivided

Marabat suite ~621-608 Ma

qama: Atiyah monzogranite
qambm: Abu Suar complex, monzogranite
qamdi: Abu Suar complex, diorite
qamhd: Hadb complex, diorite
qamhm: Habd complex, monzogranite (608 Ma)
qamkm: Kara Dakha complex, monzogranite
qamks: Kara Dakha complex, syenogranite
qamld: Liban complex, diorite to quartz diorite
qamlm: Liban complex, monzogranite (621 Ma)
qamls: Liban complex, syenogranite
qamsb: Ashsha'b complex, gabbro
qamsm: Ashsha'b complex, monzogranite
qamss: Ashsha'b complex, syenogranite
qamwb: Warid complex, gabbro
qamwg: Warid complex, granodiorite and quartz monzonite
qamwm: Warid complex, monzogranite
qamws: Warid complex, syenogranite

Midyan suite 630-570 Ma

abym: Massah complex, alkali granite, monzogranite, and granodiorite (629 Ma)
abyu: Alkali granite, unassigned

Midyan suite-Dabbagh complex 630-570 Ma

abyda: Alkali-feldspar granite (577 Ma)
abyn: Numran alkali granite
abyq: Qaraqir alkali granite
abyr: Raydan alkali granite (630 Ma)

Muwaylih suite ~725-710 Ma

mwhn: Hayyan complex, norite, gabbro, anorthosite, and magnetite-ilmenite lenses
mwmg: Maharish complex, granodiorite
mwmt: Maharish complex, tonalite
mwsd: Shaghab complex, riebeckite dacite
mwsg: Shaghab complex, diorite, quartz diorite, gabbro, Norite, and tonalite
mwyb: Buwaydah complex, gabbro
mwyd: Buwaydah complex, diorite
mwyg: Buwaydah complex, granodiorite
mwyt: Buwaydah complex, tonalite

Nabt complex (Age uncertain)

nabu: Nabt abbro, diorite, and quartz diorite

Naghr formation (Age uncertain)

jbn: Sandstone, conglomerate, siltstone, mudstone, and limestone

Ra'al granite 635 Ma

rngr: Ra'al granite

MODS Records (2014)

Major Metals

Copper

Steel Metals

Iron

Compiled from: SGS sources and

Legend

Quaternary

- *Qa: Quaternary alluvium*
- *Qat: Quaternary alluvial terraces*
- *Qb: Quaternary flood basalt*
- *Qe: Quaternary eolian sand sheets and dunes*
- *Qgs: Quaternary gravel, sand, boulder Scree*
- *Ql: Quaternary loessic sand and silt*
- *Qu: Quaternary sand, gravel, and silt deposits*

Quaternary-Neogene

- *QNb: Quaternary-Neogene flood basalt*
- *QNbb: Quaternary-Neogene Buqum flood basalt*
- *QNbc: Quaternary-Neogene basaltic cinder cones*

Ablah group 640-615 Ma

- *bljr: Jerub formation, andesitic, dacitic and rhyolitic pyroclastic rocks*
- *bltf: Thurat formation, conglomeratic volcanic wacke, stromatolitic marble, sandstone, and siltstone*

Al Harmah complex ~635 Ma

- *atg: Granodiorite and monzongranite*
- *atgd: Granodiorite*

Al Junaynah formation <620 Ma

- *ajsc: Polymictic conglomerate*
- *ajss: Sandstone and siltstone*

Alawah tonalite ~630 Ma

- *awt: Alawah tonalite*

An Nimas complex 815-795 Ma

- *andb: Diorite and gabbro*
- *andi: Diorite*
- *andq: Quartz diorite*
- *andt: Diorite and tonalite*
- *antt: Tonalite and trondhjemite*

As Sutayyan complex (Age uncertain)

- *stdb: Diorite and gabbro*
- *stdi: Diorite*
- *stdq: Quartz diorite*
- *stgt: Granodiorite and tonalite*
- *sttg: Hornblende-biotite granodiorite*

Bidah belt layered rocks ~855-815 Ma

- *bbam: Bidah amphibolite and biotite schist*
- *bbhw: Hawiyah formation, metamorphosed basaltic and andesitic volcaniclastic rocks*
- *bbhwd: Hawiyah formation, quartz porphyry, and porphyritic rhyolite sills and dikes*
- *bbkm: Khumrah greenstone*
- *bbmb: Bidah metabasalt, meta-andesite, and mafic pyroclastic rocks*
- *bbsg: Bidah graywacke, carbonaceous chert, argillite, and slate*
- *bbsm: Bidah sedimentary and metasedimentary rocks, undivided*
- *bbss: Bidah sedimentary rocks, undivided*
- *bbvb: Bidah amygdaloidal basalt flows, greenstone, and chlorite schist*
- *bbve: Bidah epiclastic and volcaniclastic rocks*
- *bbvf: Bidah mafic and felsic volcanic rocks, undivided*
- *bbvm: Bidah mafic volcanic rocks, undivided*

Buwwah suite 855-815 Ma

- *bwbt: Biotite-hornblende tonalite*
- *bwbu: Gabbro and metagabbro*
- *bwdi: Diorite*
- *bwdt: Diorite and tonalite*
- *bwt: Tonalite (815 Ma)*

Digham formation >730 Ma

- *ghm: Digham polylithologic layered rocks*

Hadhaq complex ~782-720 Ma

- *hdgg: Monzogranite gneiss*
- *hdtg: Granodiorite gneiss*

Hali group 795-780 Ma

- *hos: Quartzite, metasiltstone, conglomerate, feldspathic graywacke, and marble*

Ibn Hashbal suite 640-615 Ma

- *ihga: Alkali-feldspar granite (628-617 Ma)*
- *ihgr: Biotite monzogranite (641 Ma)*

Khadra belt 745-730 Ma

- *ktam: Amphibolite*
- *ktbd: Basalt, dacite, andesite tuff, and graywacke siltstone*
- *ktqd: Hornblende-biotite quartz diorite*
- *ktss: Sedimentary rocks, undivided*
- *ktva: Andesitic and dacitic rocks and flows, pyroclastic flows, breccias, and tuff*
- *ktvd: Metamorphosed dacitic flow and pyroclastic rocks*
- *ktvr: Rhyolit, lithic tuff, ash-flow tuff, and flow*
- *ktvs: Volcanic and sedimentary rocks, undivided*
- *ktvt: Dacite tuff and basalt flow, and andesite*

Khaniq formation (Age uncertain)

- *kknf: Felsic volcanic and volcaniclastic rocks*

Lakathah complex ~640-620 Ma

- *lkbu: Gabbro*
- *lksy: Syenite*

Muwayh formation (Age uncertain)

- *mayv: Mafic to felsic volcanic rocks*

Nabitah gneiss suite 660-623 Ma

- *nbab: Abss granodiorite and tonalite gneiss (651 Ma)*
- *nbkq: Khamis Mushayt and Al Qa'ah granodiorite and granite gneiss*
- *nbmg: Musayrah granodiorite and granite (623 Ma)*
- *nbmy: Umm al Hashiyah granodiorite and monzogranite migmatite*

Qiya complex 780-760 Ma

- *qgn: Qiya granite gneiss*

Rawdah formation >730 Ma

- *ktra: Basalt, andesite, lithic tuff, and agglomerate*

Shwas belt >815 Ma

- *shkf: Khutnah formation, feldspathic and lithic graywacke*
- *shkv: Khutnah formation, metamorphosed sedimentary rocks, volcaniclastic wacke and conglomerate*
- *shqa: Qirshah formation, andesitic rocks*
- *shqc: Qirshah formation, conglomerate, arkose, and siltstone*
- *shqd: Qirshah formation, andesite and dacite*
- *shqr: Qirshah formation, rhyolitic rocks*
- *shqv: Qirshah formation, metabasalt, andesite, and rhyolite*
- *shqz: Qirshah formation, quartizite*

Tayyah belt >815 Ma

- *tybd: Basalt, andesite, and dacite*
- *tycg: Conglomeratic arkose and volcanic graywacke*
- *tyss: Sedimentary rocks*
- *tyva: Andesitic rocks*
- *tyvb: Basalt and volcaniclastic rock*
- *tyvd: Dacitic volcaniclastic rocks*
- *tyvm: Mafic volcanic rocks, undivided*
- *tyvs: Volcaniclastic graywacke, shale and siltstone*

Thalath complex ~640-630 Ma

- *lab: Gabbro*
- *labm: Metagabbro*

Wadbah suite ~605 Ma

- *wbdx: Granodiorite and tonalite agmatite*
- *wbdh: Biotite-hornblende granodiorite and monzogranite*

Wozariyah formation >730 Ma

- *ktwz: Volcaniclastic, shale, siltstone, and marble*

Other Proterozoic units

- *bgg: Biotite granodiorite and monzogranite*
- *dgb: Gabbro and diorite undivided*
- *hkub: Hakran serpentinite and gabbro*
- *qwgt: Al Qawba tonalite and granodiorite*
- *xmu: Peridotite, serpentinite, metagabbro in fault zones*

Unassigned Proterozoic rocks

- *uap: Unassigned aplite, aplite granite, and aplite pegmatite*
- *ub: Unassigned gabbro*
- *ubm: Unassigned metagabbro*
- *ubn: Unassigned gabbronorite*
- *uda: Unassigned dacite*

Legend
Quaternary
Qa: Quaternary alluvium
Qb: Quaternary flood basalt
Qbc: Quaternary basaltic cinder cones
Qbn: Quaternary basanite, and nephiline Hawaiite
Qch: Quaternary caliche
Qg: Quaternary gravel sheets and terraces
Qs: Quaternary sabkhah deposits
Qsk: Quaternary sabkhah and khabra deposits
Qu: Quaternary sand, gravel, and silt deposits
Quaternary-Neogene
QNb: Quaternary-Neogene flood basalt
QNbn: Quaternary-Neogene basanite and nepheline Hawaiite
Neogene
Nb: Neogene flood basalt
Nbc: Neogene basaltic cinder cones
Nbh: Hammah Neogene Alkali olivine flood basalt
Nbr: Rahat alkali olivine basalt and basanite
Nbt: Neogene trachyphonolitic volcanic rocks
Ngb: Neogene gabbro and granophyre dike
Nlc: Neogene lacustrine sediments
Ar Rahah monzogranite and granodiorite ~630 Ma
argd: Ar Rahah granodiorite
argm: Ar Rahah monzogranite
Arj group ~785 Ma
rjsv: Sayid formation, silicic volcanic rocks (703 Ma)
rju: Sayid and Jabal Azlam formation, undifferentiated
rjz: Jabal Azlam formation, volcaniclastic rocks and andesite
Birak group >805 Ma
brq: Qahah formation, mafic to felsic epiclastic rocks, conglomerate, and volcanic rocks
Bi'r Tuluhah complex ~835 Ma
nubm: Bi'r Tuluhah gabbro-serpentinite
B'ir Umq complex 840-830 Ma
biu: B'ir Umq gabbro-serpentinite
Dhukhr complex 816-803 Ma
dhbu: Gabbro
dhgd: Granodiorite
dhgq: Granite, quartz monzonite, monzotonalite, and diorite
dhtt: Tonalite (803)
Furayh group (Age uncertain)
fud: Dawnak formation, sandstone, graywacke, conglomerate, and siltstone
fug: Ghuwayt formation, basalt, andesite, and pyroclastic rocks
fun: Naslah formation, volcanic and sedimentary rocks
funf: Naslah formation, silicic rocks
funm: Naslah formation, mafic volcanic rocks
funr: Naslah formation, rhyolite to rhyodacite
funs: Naslah formation, sedimentary rocks
funv: Naslah formation, sandstone, siltstone, graywacke, basalt, and andesite
fuq: Qidirah formation, andesite, basalt, conglomerate, and tuff
fus: Sharqan formation, siltstone, sandstone, and conglomerate
Ghamr group ~750 Ma
gkgs: Gharmati formation, sandstone
gkgt: Gharmati formation, tuffaceous rocks
gkkc: Kharzah formation, conglomerate and sandstone
gkkf: Kharzah formation, silicic rocks
gkkm: Kharzah formation, mafic volcanic rocks
gkks: Kharzah formation, sedimentary rocks
gkku: Kharzah formation, undivided
gkkv: Kharzah formation, basaltand andesite flows and mafic volcaniclastic rocks
gkmi: Mislah formation, intermidiate volcanic and volcaniclastic rocks
gkmp: Mislah formation, silicic lavas and pyroclastic rocks
gkms: Mislah formation, sedimentary rocks
gkvb: Basalt to andesite
gkvr: Rhyolite to rhyodacite
Habid formation (Age uncertain)
hbf: Graywacke, siltstone, conglomerate, and tuff
Hadb ash Sharar suite ~590-575 Ma
hhbu: Habd ash Sharah complex, Qam gabbro
hhga: Dayahin alkali-feldspar granite (590 Ma)
hhgd: Assharah Quartz monzodiorite
hhgm: Assharah monzogranite
Hufayriyah complex 780-760 Ma
hfgt: Granodiorite
hftt: Tonalite (760 Ma)
Jibalah group (age uncertain)
jbj: Jifn formation, sandstone, siltstone, conglomerate, and andesite
jbss: Umm Al 'Aisah formation, polymictic conglomerate, sandstone, and limestone
Mahd group ~775 Ma
mhj: Haf formation, Juraysiyah mafic and felsic volcanic rocks
mhvb: Basalt and andesite
mhvm: Haf formation, Za'anah mafic volcanic rocks
mhvr: Rhyolite and rhyodacite
mhvs: Haf formation, volca
mhvs: Volcanic and sedime
mhvt: Tulaymisah formatio
mhz: Haf formation, Zur vo
Mughah complex (Age uncerta
gmxl: Leucocratic gneiss
gmxs: Schist and gneiss
Ram Ram complex 770-750 Ma
rrg: Ram Ram granodiorite
Samran group 825-745 Ma
sah: Shayban formation, q
Subh suite 659 Ma
sfga: Subh alkali-feldspar g
Sumayir formation ~830 Ma
bisb: Basalt, and minor jas
bisg: Greenstone, chert, ga
bism: Sumayir formation, u
Suwaylih suite ~620 Ma
yssk: Alkali-feldspar syenit
Syn- to post-Shammar group 6
szxg: Granite
szxm: Microgranite
Tamran formation >810 Ma
tam: Tamran formation, un
tamf: Felsic volcanic rocks
tamm: Mafic volcanic rocks
tams: Sedimentary rocks,
tamv: Volcanic rocks, undiv
Other Proterozoic units
ibtg: Bari granodiorite 776
xmu: Peridotite, serpentinit
Unassigned Proterozoic rocks
ub: Unassigned gabbro
ubs: Unassigned gabbro a
ubu: Unassigned gabbro a
udi: Unassigned diorite
udq: Unassigned diorite an
ug: Unassigned granite
uga: Unassigned alkali-felc
ugg: Unassigned granite a
ugy: Unassigned granophy
umz: Unassigned monzoni
MODS Records (2014)
Precious Metals
Gold
Faults
Normal faults

Legend

Quaternary

- Qa: Quaternary alluvium
- Qb: Quaternary flood basalt
- Qe: Quaternary eolian sand sheets and dunes
- Qs: Quaternary sabkhah deposits
- Qt: Quaternay talus deposits
- Qu: Quaternary sand, gravel, and silt deposits

Quaternary-Neogene

- QNb: Quaternary-Neogene flood basalt
- QNp: Quaternary-Neogene pediment, cobble, pebbles, conglomerate, sand, and gravel sheets

Neogene

- Nb: Neogene flood basalt
- Nbt: Neogene trachyphonolitic volcanic rocks
- Nby: Neogene rhyolite
- Nsn: Neogene sedimentary rocks, undivided

Cambrian-Ordovician

- OEr: Ram, and Umm Sahm sandstones

Cambrian

- Es: Siq sandstone
- Esr: Saq sandstone, Risha member

Abu Safiyah complex ~700 Ma

- asbu: Gabbro
- asga: Alkali-feldspar granite
- asgh: Microgranite and granophyre
- asmz: Monzonite
- asqs: Quartz diorite and syenite
- asry: Rhyolite
- assy: Syenite

Admar suite ~630 Ma

- adga: Alkalic granite
- adgg: Monzogranite and granodiorite
- adgm: Monzogranite

Al Ays group <745->700 Ma

- ayak: Graywacke, phyllite, and conglomerate
- ayau: Anmauth formation, undifferentiated rocks
- ayb: Basaltic rocks
- ayd: Dikes and small intrusions of diabase, basalt, and rhyolite
- ayfi: Fashghan formation, silicic rocks
- ayfs: Fashghan formation, sedimentary rocks
- aygr: Al Ghamra formation, rhyolite, dacite, andesite, and tuff
- ayib: Basalt and quartz andesite
- ayjf: Jizl formation, felsic volcanic rocks
- ayjk: Kura and Jizl formations, felsic volcanic rocks
- ayju: Judayfah formation, undifferentiated rocks
- ayjv: Umm Jabuh formation, volcanosedimentary rocks
- aymg: Mayghabat formation, volcanosedimentary rocks
- aymr: Metasedimentary rocks and metarhyolite
- aymt: Matran formation, mafic volcanic rocks
- aymu: Murshid formation, undifferentiated rocks
- aymv: Metavolcanic rocks
- ayng: Gneiss and schist
- aynt: Waterlaid tuff
- aynv: Abu An Na'am formation, volcanic breccia
- ayrl: Rhyolitic lava
- ayrt: Rhyolite and tuff
- ays: Sedimentary rocks, undivided
- aysc: Sericite and chlorite schist
- aysi: Silicic rock
- aysv: Sahbalah formation, andesite, dacite, and tuff
- aytu: Thaa formation, undifferentiated rocks
- ayu: Al Ays undifferentiated rocks
- ayva: Andesite and trachyandesite flow, agglomerate, tuff, sills, and plugs
- ayvf: Felsic volcanic rocks
- ayvs: Volcanosedimentary rocks, undivided

Al Bad' granite super suite 585-565 Ma

- abd: Daghalah granite

Al Qunnah formation >745 Ma

- aqvs: Metapyroclastic, and metasedimentary rocks

Bayda group (Age uncertain)

- bahf: Hijr formation, silicic pyroclastic rock and rhyolite flows
- barl: Riman formation, litharenite, siltstone, and conglomerate
- bas: Sedimentary rocks, undivided
- bau: Bayda group, undifferentiated rocks
- bavf: Felsic volcanic rocks
- bavs: Volcanosedimentary rocks, undivided

Hadiyah group ~695 Ma

- dyas: Aghrad formation, conglomerate and sandstone
- dysm: Siqam formation, basalt, andesite, tuff and clastic sediments (697 Ma)
- dytj: Tura'ah formation, Jammazin member
- dytq: Tura'ah formation, Qaraqah member
- dyts: Tura'ah formation, sandstone and conglomerate
- dytu: Tura'ah formation, undifferentiated

Hamra Badi complex 585-565 Ma

- hbga: Hamra Badi alkali-feldspar granite

Jar-Salajah complex 745-695 Ma

- jsbd: Gabbro and diorite
- jsdi: Diorite
- jsdq: Diorite and quartz diorite
- jst: Tonalite (725 Ma)
- jsta: Amphibole tonalite

Jibalah group (age uncertain)

- jbb: Badayi formation
- jbm: Muraykhah formation
- jbru: Rubtayn formation, polymictic conglomerate and sandstone
- jbs: Sandstone
- jbu: Jibalah group, undifferentiated rocks
- jbz: Zumurrud formation
- jbzm: Mashhad formation
- jbzn: Nadah formation
- jbzu: Zumurrud, Nadah, and Mashhad formations, undivided

Khanzirah complex (Age uncertain)

- khga: Alkalic granite
- khgc: Calc-alkalic granite and granodiorite
- khgh: Granophyre
- khgm: Biotite-muscovite monzogranite

Marabat suite ~621-608 Ma

- qamwg: Warid complex, granodiorite and quartz
- qamws: Warid complex, syenogranite

Mardabah complex (Age uncertain)

- mrm: Monzodiorite

Muraykhat formation (Age uncertain)

- mybu: Muraykhat gabbro

Nabt complex (Age uncertain)

- nabu: Nabt abbro, diorite, and quartz diorite

Ra'al granite 635 Ma

- rngn: Ra'al granitic gneiss
- rngr: Ra'al granite
- rngrs: Ra'al monzogranite and syenogranite

Rithmah complex (Age uncertain)

- rtdq: Rithmah quartz diorite
- rttx: Rithmah granodiorite and tonalite

Shufayyah complex ~715 Ma

- sugd: Adamellite, granodiorite, tonalite, and dior
- sugt: Calc-alkalic granite and granodiorite

Wask-Ess mafic-ultramfic rocks (~780 Ma)

- webd: Gabbro and diorite
- weum: Mafic-ultramfic rocks, undifferentiated

Za'am group 760-710 Ma

- zafb: Fashghan formation, basaltic rocks
- zafs: Fashghan formation, silicic rocks (711 Ma)
- zafu: Fashghan formation, undifferentiated rocks
- zamg: Mayghabat formation, undifferentiated roc
- zanv: Nasrah formation, volcanic rocks
- zau: Zaam group, undivided

Other Proterozoic units

- fatt: Fara' trondhjemite (743 Ma)
- fxg: Al Far granodiorite ~700 Ma
- gqm: Granodiorite and quartz monzonite
- rwga: Radwa peralkalic granite 517 Ma
- xmo: Orthogneiss and orthoschist
- xmp: Paraschist, paragneiss, and phyllonite

Unassigned Proterozoic rocks

- ub: Unassigned gabbro
- ubd: Unassigned gabbro and diorite
- uda: Unassigned dacite
- udm: Unassigned diorite and quartz monzonite
- udq: Unassigned quartz diorite
- udz: Unassigned diorite, quartz diorite, and mon
- ug: Unassigned granite
- ugm: Unassigned monzogranite
- ugn: Unassigned schist, gneiss, and amphibolite
- ugq: Unassigned granodiorite and quartz diorite
- ugsy: Unassigned granodiorite and syenite
- ugy: Unassigned granophyre and rhyolite
- uqp: Unassigned quartz porphyry
- ur: Unassigned rhyolite
- usg: Unassigned syenogranite

Compiled from: SGS sources and

gend

aternary

- *Qa: Quaternary alluvium*
- *Qat: Quaternary alluvial terraces*
- *Qe: Quaternary eolian sand sheets and dunes*
- *Qf: Quaternary alluvial fan and flood plain deposits*
- *Qg: Quaternary gravel sheets and terraces*
- *Qk: Quaternary khabra deposits*
- *Qs: Quaternary sabkhah deposits*
- *Qu: Quaternary sand, gravel, and silt deposits*

ogene

- *Nb: Neogene flood basalt*
- *Ng: Neogene gravel and sand terraces*

dovician

- *Osh: Saq sandstone, Hilwan membar*

mbrian-Ordovician

- *OEs: Cambrian-Ordivician undifferentiated sandstones*

nat suite 585-565 Ma

- *aagp: Peralkalic and alkalic granite*

formation ~650-635 Ma

- *afvb: Basalt, andesite and related tuff, and volcanic sandstone*
- *afvs: Gneiss, schist, metavolcanic and metasedimentary rocks*

ana and Sufran formations >740 Ma

- *bsva: Banana and Sufran andesite and basalt*

i Ghayy group 630-607 Ma

- *byu: Bani Ghayy group, undivided*
- *byvs: Volcanic and sedimentary rocks*
- *byx: Volcanic sandstone, conglomerate, rhyolite, andesite, and tuffite*

Tuluhah complex ~835 Ma

- *nubm: Bi'r Tuluhah gabbro-serpentinite*

ayh group (Age uncertain)

- *fug: Ghuwayt formation, basalt, andesite, and pyroclastic rocks*
- *funv: Naslah formation, sandstone, siltstone, graywacke, basalt, and andesite*
- *fus: Sharqan formation, siltstone, sandstone, and conglomerate*

shi formation ~630 Ma

- *hivt: Rhyolite, rhyolitic tuff, conglomerate, volcanic sandstone, and andesite*

ayfah group >720 Ma

- *huav: Afna formation, andesite, basalt, pyroclastics, tuffite, marble, and conglomerate*
- *hud: Hypabyssal diabase, diorite and gabbro*
- *hut: Tuffite, conglomerate, marble, chert, jasper, and pyroclastics*

naliyah formation 590-560 Ma

- *hmry: Humaliyah rhyolite and tuff*

naymah suite 645-630 Ma

- *hygd: Granodiorite*
- *hygl: Biotite granite, and leucogranite*
- *hygr: Granite*

n suite 632-610 Ma

- *idgc: Calc-alkalic, alkalic granite and granodiorite*
- *idgd: Granodiorite (620-614 Ma)*
- *idgo: Granite, orthogneiss*
- *idgr: Monzogranite and syenogranite*
- *idgs: Syenogranite*
- *idgt: Tonalite and granodiorite*
- *idim: Microsyenite*

nah formation ~840 Ma

- *isva: Andesite, basalt, and pyroclastic rocks*
- *isvb: Biotite gneiss, leptinite, quartzite, and amphibolite*
- *isvd: Hypabyssal diabase, diorite, and gabbro*
- *isvt: Tuff, conglomerate, marble, chert, jasper, rhyolite, and andesite*

alah group (age uncertain)

- *jbj: Jifn formation, sandstone, siltstone, conglomerate, and andesite*
- *jbo: Granite, orthogneiss*
- *jbss: Umm Al 'Aisah formation, polymictic conglomerate, sandstone, and limestone*
- *jdgb: Granite, trondhjemite, diorite, and gabbro*
- *jdgl: Biotite granite, and leucogranite*
- *jdgo: Granite, orthogneiss*
- *jdgr: Calc-alkalic, alkalic granite and granodiorite*
- *jdgs: Biotite granite, leucogranite, syenogranite and syenite*
- *jdgt: Granodiorite, monzogranite, and tonalite*
- *jdqm: Quartz monzonite, monzotonalite, and diorite*

Jurdhawiyah group 610-595 Ma

- *jhc: Conglomerate and sandstone*
- *jhl: Lapilli tuff beds*
- *jhs: Volcanic sandstone, conglomerate, rhyolite, andesite, and tuffite*
- *jhu: Jurdhawiyah group, undivided*

Khishaybi suite ~640 Ma

- *ksgo: Granite, orthogneiss*
- *ksgr: Granite*

Mardamah group <655-620 Ma

- *mum: Maraghan formation, lithic graywacke, sandstone, siltstone, shale, and marble*
- *muz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite*

Nafi and Hillit formations and Dukhnah gneiss >695 Ma

- *nku: Nafi and Hilli, and Dukhnah gneiss*

Shammar group ~630 Ma

- *szk: Kuara formation, conglomerate, volcanic sandstone, rhyolite, ignimbrite, andesite, basalt, and pyro*
- *szm: Malha formation, rhyolite, Ignimrite rhyolitic tuff and breccia, conglomerate and volcanic sandston*
- *szt: Tuff, conglomerate, marble, chert, jasper, and rhyolite*
- *szu: Volcanic and sedimentary rocks*

Siham group <750->695 Ma

- *sihd: Hypabyssal diabase, diorite, and gabbro*
- *sivb: Urta formation, basalt, andesite, tuff, and volcanic sandstone*
- *sivd: Rhyolite, dacite, andesite, and pyroclastics*

Suwaj suite 685-659 Ma

- *swgd: Granodiorite*
- *swgo: Granite, orthogneiss*

Syn- to post-Banana formation 740-685 Ma

- *bxbu: Gabbro*
- *bxgd: Granodiorite*

Syn- to post-Hulayfah group ~720 Ma

- *hxg: Granite*
- *hxg: Granite, trondhjemite, diorite, and gabbro*
- *hxgg: Granite and granodiorite*

Syn- to post-Isamah formation <840 Ma

- *isxb: Gabbro*
- *isxd: Diorite and quartz diorit*
- *isxg: Ganodiorite and granite*
- *isxj: Granite, trondhjemite, diorite, and gabbro*
- *isxm: Microgranite*
- *isxo: Granite, orthogneiss*
- *isxt: Granodiorite and tonalite*
- *isxt: Granodiorite and tonalite*

Syn- to post-Shammar group 625 Ma

- *szg: Granite and granodiorite*
- *szxa: Alkali-feldspar granite*
- *szxb: Gabbro and serpentite*
- *szxg: Granite*
- *szxm: Microgranite*
- *szxo: Granite, orthogneiss*
- *szxt: Granodiorite*
- *szxy: Granophyre*

Tamran formation >810 Ma

- *tamm: Mafic volcanic rocks*
- *tams: Sedimentary rocks, undivided*

Other Proterozoic units

- *xml: Sheared limestone*
- *xmp: Paraschist, paragneiss, and phyllonite*

Compiled from: SGS sources and

egend

uaternary

- Qa: Quaternary alluvium
- Qat: Quaternary alluvial terraces
- Qe: Quaternary eolian sand sheets and dunes
- Qg: Quaternary gravel sheets and terraces
- Qk: Quaternary khabra deposits
- Qs: Quaternary sabkhah deposits
- Qu: Quaternary sand, gravel, and silt deposits

uaternary-Neogene

- QNb: Quaternary-Neogene flood basalt

eogene

- Nb: Neogene flood basalt
- Nhc: Hasak formation, conglomerate
- Nlc: Neogene lacustrine sediments

retatious

- Km: Khurma sandstone and conglomerate

fif formation ~650-635 Ma

- afvr: Rhyolitic tuff, ignimbrite, rhyolite, and andesite
- afvs: Gneiss, schist, metavolcanic and metasedimentary rocks
- afvt: Ttuff, siltstone, graywacke, sandstone, and andesite

l Khushaymiyah suite 610-595 Ma

- kygt: Tonalite and granodiorite

r Rahah monzogranite and granodiorite ~630 Ma

- argm: Ar Rahah monzogranite

ani Ghayy group 630-607 Ma

- byac: Arfan formation, boulder conglomerate
- byag: Arfan formation, graywacke sandstones and siltstones
- byal: Arfan formation, strotomatolatic and clastic limestones, marble, and carbonate breccia
- byas: Arfan formation, sandstone, wacke, grit, siltstone, and conglomerate
- byav: Arfan formation, basaltic, andestitic, and rhyolitic volcanic rocks
- bymc: Majayrib formation, boulder conglomerate and graywacke conglomerate
- bymg: Majayrib formation, tuffaceeous graywacke sand stones and siltstones
- byml: Majayrib formation, limestone
- bymr: Majayrib formation, porphyritic rhyolite flows, sills, and tuffs
- byms: Majayrib formation, tuffaceous graywacke siltstones
- bymv: Majayrib formation, basaltic, andesitic, and rhyolite volcanic rocks
- byn: Numan formation, graywacke, conglomerate, and sandstone
- bys: Shihbah formation, sandstone, limestone, and conglomerate

hukhr complex 816-803 Ma

- dhtt: Tonalite (803)

hamr group ~750 Ma

- gkkf: Kharzah formation, silicic rocks
- gkks: Kharzah formation, sedimentary rocks

adb ash Sharar suite ~590-575 Ma

- hhgm: Assharah monzogranite

adhaq complex ~782-720 Ma

- hddn: Diorite gneiss (782 Ma)
- hdgn: Mylonitic orthogneiss
- hdts: Granodiorite gneiss

aml suite ~640-620 Ma

- hld: Diorite
- hlgc: Calc-alkalic and alkalic granite
- hlgd: Granodiorite (632 Ma)
- hlgm: Monzogranite (620 Ma)
- hlgp: Porphyroblastic granodiorite
- hlgs: Syenogranite (615-600 Ma)
- hlmd: Monzodiorite
- hlsa: Alkali-feldspar syenite and alkali-feldspar (615-600 Ma)
- hlsy: Syenite (615-600 Ma)
- hlt: Tonalite

umaymah suite 645-630 Ma

- hyb: Gabbro and layered gabbro
- hybm: Melanocratic gabbro

Jidh suite ~700-640 Ma

- jddi: Diorite
- jddq: Diorite and quartz diorite
- jdgc: Calc-alkalic granite
- jdgd: Granodiorite (647 Ma)
- jdgg: Granite and granodiorite
- jdgm: Monzogranite (646 Ma)
- jdgt: Granodiorite, monzogranite, and tonalite
- jdgy: Alkalic to calc alkalic granite and granite porphyry

Jurdhawiyah group 610-595 Ma

- jhu: Jurdhawiyah group, undivided
- jhvm: Mafic volcanic rocks

Kawr suite ~650-620 Ma

- kwgm: Monzogranite (620 Ma)

Laban complex ~650 Ma

- lnbu: Clinopyroxene-hornblende gabbro

Mardamah group <655-620 Ma

- rmuz: Zaydi formation, conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite

Mughah complex (Age uncertain)

- gmxl: Leucocratic gneiss
- gmxn: An Nayzah schist and gneiss, amphobolite, quartzite, metarhyolite, and meta-andesite
- gmxs: Schist and gneiss

Muwayh formation (Age uncertain)

- mayv: Mafic to felsic volcanic rocks

Naim complex 746 Ma

- natx: Naim granodiorite and tonalite gneiss

Qettan formation (Age uncertain)

- qte: Sandstone, conglomerate, mafic to felsic volcanic rocks, and limestone

Rharaba complex (Age uncertain)

- rhb: Rharaba gabbro

Sarjuj formation (Age uncertain)

- sjf: Basalt, andesite, mafic agglomerate, and mafic breccia

Siham group <750->695 Ma

- sia: Aysari formation, andesitic flows and tuffs
- siab: Aysari formation, basaltic flows and tuffs
- siac: Aysari formation, graywack conglomerate grits and tuffs
- sial: Aysari formation, calc-arenite marble
- siar: Aysari formation, rhyolitic flows and tuffs
- siba: Bahjah formation, andesitic flows and tuffs
- sibb: Bahjah formation, basaltic flows and tuffs
- sibg: Bahjah formation, graywacke, sandstone, and siltstones
- sibl: Bahjah formation, calc-arenite marble
- sibr: Bahjah formation, rhyolitic flows and tuffs
- sibs: Bahjah formation, shale and tuffs
- sif: Farthan formation, undivided
- sifa: Farthan formation, andesitic flows and tuffs
- sifb: Farthan formation, basaltic flows and tuffs
- sifg: Farthan formation, graywack conglomerate grits and tuffs
- sifl: Farthan formation, calc-arenite marble
- sijl: Juwayr formation, calc-arenite marble
- sijq: Juwayr formation, quartizite and mica schist
- sin: An Nayzah formation, schist, gneiss, amphibolite, quartzite, marble, meta-andesite, and granodiorite
- sina: Nawm formation, andesitic flows and tuffs
- sinb: Nawm formation, basaltic flows and tuffs
- sins: Nawm formation, carboneceous shale and tuffs
- sis: Madin formation, tuff, siltstone, graywacke, sandstone, and andesite
- sisc: Conglomerate, lithic sandstone, graywacke, siltstone, and rhyolite
- sits: Tandub formation, shale and tuffs
- siva: Andesite, basalt, pyroclastic, rhyolite, microdiorite, and sediments
- sivb: Clinopyroxene-hornblende gabbro
- sivc: Tandub formation, shale and tuffs
- sivd: Rhyolite, dacite, andesite, and pyroclastics

Zafrah suite ~740 Ma

- zxbn: Gabbronorite
- zxdb: Metagabbro and metadiorite
- zxum: Serpentinite, listwanite, and talc shists

Other Proterozoic units

- fhd: Fuhud porphyritic microdiorite ~650 Ma
- hkub: Hakran serpentinite and gabbro
- hrgm: Gharamil monzogranite
- ibtg: Bari granodiorite 776 Ma
- mvf: Mukhayyat felsite
- snd: Sawan dolomite
- xmo: Orthogneiss and orthoschist
- xmp: Paraschist, paragneiss, and phyllonite
- xmu: Peridotite, serpentinite, metagabbro in fault zon

Unassigned Proterozoic rocks

- ub: Unassigned gabbro
- ubm: Unassigned metagabbro
- ubu: Unassigned gabbro and metagabbro
- udi: Unassigned diorite
- ug: Unassigned granite
- ugg: Unassigned granite and granodiorite
- ugm: Unassigned monzogranite
- ugp: Unassigned granite porphyry
- unu: Unassigned ultramafic rocks
- uqs: Unassigned quartz syenite and syenogranite
- ut: Unassigned tonalite

MODS Records (2014)

Major Metals

- Copper
- Zinc

Guides for Metals

- Gossan

Faults

- Normal faults
- Thrust faults

egend

Compiled from: SGS sources and MODS

uaternary

- Qa: Quaternary alluvium
- Qat: Quaternary alluvial terraces
- Qc: Quaternary coral reef limestone
- Qe: Quaternary eolian sand sheets and dunes
- Qf: Quaternary alluvial fan and flood plain deposits
- Qg: Quaternary gravel sheets and terraces
- Qgs: Quaternary gravel, sand, boulder Scree
- Qs: Quaternary sabkhah deposits
- Qsk: Quaternary sabkhah and khabra deposits
- Qt: Quaternay talus deposits
- Qu: Quaternary sand, gravel, and silt deposits

uaternary-Neogene

- QNb: Quaternary-Neogene flood basalt

eogene

- Nah: Hadat Ash Sham formation
- Nb: Neogene flood basalt
- Nbc: Neogene basaltic cinder cones
- Nbh: Hammah Neogene Alkali olivine flood basalt
- Nbr: Rahat alkali olivine basalt and basanite
- Nbs: Sita alkali basalt and trachyte
- Nd: Dafina sandstone, conglomerate, and shale
- Ngb: Neogene gabbro and granophyre dike
- Nk: Khulaysiyah formation
- Nsk: Khulays formation
- Nsn: Neogene sedimentary rocks, undivided
- Nss: Shumaysi formation, sandstone, mudstone, conglomerate, and limestone
- Nu: Ubhur formation, sedimentary rocks, undivided
- Nus: Usfan formation, sandstone, ferruginous, conglomerate and fosiliferous limestone

aleogene

- PAq: Qam Al Himar formation, purple sandstone and minor conglomerate
- PAsb: Buraykah formation

l Hawiyah granite suite 630-560 Ma

- ahh: Halgah complex, Bahitah monzogranite and syenogranite
- ahl: Layyah granite and granodiorite

t Ta'if group >810 Ma

- tih: Muhrim formation
- tim: Misarrah formation
- tiw: Wuhayt formation, undifferentiated rocks
- tiwa: Wuhayt formation, amphibolite and quartzofeldspathic schist

ahrah formation (Age uncertain)

- zfb: Sericite-chlorite schist and quartz-feldspar-sericite-chlorite schist epidote-tremolit

irak group >805 Ma

- brl: Labunah formation, mafic and minor felsec volcanic rocks, with cherty rocks and marble
- brlb: Labunah formation, basalt and chert
- brlm: Labunah formation, marble
- brq: Qahah formation, mafic to felsic epiclastic rocks, conglomerate, and volcanic rocks
- brqa: Qahah formation, andesitic and dacitic to rhyolitic tuffs, and breccias
- brs: Suri formation, basaltic and rhyolitic lava and volcaniclastics

ighbij complex 825-800 Ma

- kmd: Dighbij quartz diorite

atima group ~680 Ma

- ffb: Baqar formation, conglomerate, arenite, and silststone
- ffd: Daf formation, felsic volcanic and volcaniclastic rocks, and siliclastic sedimentary rocks
- ffs: Shubayrim formation, conglomerate, arenite, silststone
- ffu: Fatima group, undivided

urayh group (Age uncertain)

- fuq: Qidirah formation, andesite, basalt, conglomerate, and tuff
- fuqd: Qidirah formation, dacitic lithic tuff (633 Ma)
- fuqr: Qidirah formation, rhyodacite and tuff (663 Ma)

hamr group ~750 Ma

- gkma: Mislah formation, andesitic and dacitic lava and volcaniclastics, and basaltic rocks

ada granodiorite 750 Ma

- agd: Hada granodiorite

Khuls suite 563

- klgw: Waqqas monzogranite

Mahd group ~775 Ma

- mhj: Haf formation, Juraysiyah mafic and felsic volcanic rocks
- mhz: Haf formation, Zur volcanic and sedimentary rocks

Makkah suite ~870-770 Ma

- dmdb: Milh complex, diorite and gabbro (817 Ma)
- dmdq: Milh complex, diorite and quartz diorite
- dmtt: Milh complex, tonalite
- sqdb: Makkah suite, Sharqah complex, gabbro, norite, and diorite

Milhah formation >715 Ma

- mzvm: Volcanic and sedimentary rocks

Misr complex 700 Ma

- gsym: Monzogranite and gabbro
- gsys: Syenite and gabbro

Nu'man complex (Age uncertain)

- ngn: Monzogranite gneiss

Qudayd suite 780-745 Ma

- qdgn: Qudayd orthogneiss

Rabigh suite ~805 Ma

- rabd: Bustan complex, gabbro, diorite, and quartz diorite
- rabg: Bustan complex, granodiorite and quartz monzodiorite
- rabm: Bustan complex, monzogranite and quartz monzodiorite
- rabt: Bustan complex, tonalite and granodiorite (807 Ma)
- rahb: Hajar complex, gabbro
- rahq: Hajar complex, quartz diorite
- raht: Hajar complex, tonalite

Samran group 825-745 Ma

- saa: Amudan formation, sericite-chlorite schist, andesite, rhyolite, and basaltic rocks
- saf: Fayidah formation
- sah: Shayban formation, quartzofeldspathic and lithic volcaniclastics, and mafic volcanic rocks
- sahc: Shayban formation, graywacke and conglomerate
- sahs: Shayban formation, chloritic schist, amphibole, sericite, marble and quartzite
- sak: Kashab formation
- sam: Madrakah formation
- san: Nida formation, chloritic schist, amphibole, sericite, marble and quartzite

Shayma Nasir group (Age uncertain)

- nsrt: Talha formation, basaltic to andesitic lava, volcaniclastics, rhyolite, and conglomerate
- nsru: Uaibikh formation, Andesitic to dacitic lava, volcaniclastics, basalt, rhyolite, and conglomerate
- nsrw: Tuwayyimah formation

Shufayyah complex ~715 Ma

- sudb: Diorite and gabbro
- sudi: Diorite

Subh suite 659 Ma

- sfga: Subh alkali-feldspar granite

Sulayman formation (Age uncertain)

- zfs: Mafic tuff, lapilli tuff, greenschist, and chlorite-quartz schist

Suwaylih suite ~620 Ma

- yssk: Alkali-feldspar syenite, quartzsyenite and monzonite
- yssm: Monzonite, quartz monzonite, and syenite

Thamrah suite 870-775 Ma

- rmnb: Nasir gabbro
- rmsb: Ash Shaaf gabbro
- rmum: Tharwah complex, serpentinite, peridotite, and gabbro (870 Ma)

Zibarah group (Age uncertain)

- zfj: Jumum formation, amphibolite, amphibole schist, and quartz-feldspar paragneiss
- zfm: Madiq formation, basalt and basaltic tuff

Other Proterozoic units

- gugs: Umm Gerad granite 585 Ma
- igd: Hishash granodiorite
- igt: Hishash granite
- kngr: Hanak granite 596 Ma
- mtt: Samd tonalite
- ryg: Rumayda biotite granite

MODS Records (2014)

Precious Metals

- Gold

Major Metals

- Copper
- Zinc