ربع قرن من معرفة جيولوجية أرضنا
25 Years of Understanding Our Geology

هيئة المساحة الجيولوجية السعودية
Saudi Geological Survey

SCIENTIFIC
NEWSLETTER
NOVEMBER 2024 I ISSUE 11

The Arabian Shield Regional Geological Survey Program (RGP): A World's Largest Geological Survey Program

Compiled and prepared by Mahrous Abu El-Enen

Introduction

As part of "Saudi Arabia's Vision 2030", several programs have been launched, including the National Industrial Development and Logistics Program (NIDLP). The NIDLP aims to transform the Kingdom into a leading industrial powerhouse and a global logistics hub by maximizing the value achieved from the mining and energy sectors. This transformation has already opened new horizons for investment in mining, attract foreign and domestic investors, and stimulate economic growth while diversifying revenues in the Kingdom. A key component of NIDLP's strategy is the Regional Geological Survey Program (RGP). The Saudi Geological Survey (SGS) supervises critical initiatives, including the RGP, to improve the efficiency and effectiveness of geological surveys and exploration efforts nationwide.

The RGP is one of the largest initiatives in terms of nature and scale, both in scope and output, and it aims to build a comprehensive geoscientific dataset for the Arabian Shield. This dataset will help attract national and international mining enterprises. As a key component of Saudi Arabia's Vision 2030, the RGP supports the goal of establishing mining as a third pillar of the national economy. Led by the Saudi Geological Survey (SGS), the RGP focuses on surveying and mapping approximately 600,000 km² of the mineral-rich Arabian Shield in western Saudi Arabia over an eleven-year period. Its primary objective is to obtain reliable, high-precision, and detailed geological data to uncover potential mineral resources. In doing so, the RGP will invigorate the Kingdom's mining sector and attract significant investment from domestic and global stakeholders.

The RGP initiative includes conducting high-precision and detailed geological surveys in the Arabian Shield to support the mineral exploration programs by generating reliable and comprehensive geological survey data. The RGP consists of several key components, including the High-Precision Airborne Geophysical Survey (GPAS), the High-Resolution Regional Geochemical Survey (GSAS), and the Detailed Geological Mapping (GMAS) of the Arabian Shield. This is in addition to the Arabian Shield Stratigraphic Commission (ASSC) focuses on the lithostratigraphy of the Arabian Shield, while the Geoscience Data Analytic Centre-Saudi Arabia (GDAC-SA) works to identify new, high-potential mineral targets (Fig. 1). Technical supervision of the RGP's subdisciplines by the technical partner ensures quality control, quality assurance, and technical evaluation of the geological data produced by the contractors. Capacity building and knowledge transfer are also central to the RGP's mission, facilitated through training programs and educational resources.

The data collected through the RGP is made accessible to investors via online portals of the National Geological Database (NGD). This facilitates the growth of the exploration sector by producing high-quality, pre-competitive geoscience data for the public domain, thereby catalyzing a deeper understanding of the mining potential in the Kingdom of Saudi Arabia (KSA). This is in addition to supporting the Mining Vision Initiative by providing up-to-date geological information to further develop the Kingdom's mining sector.

1. Airborne Geophysical Survey (GPAS)

The existing legacy airborne geophysical coverage in the Arabian Shield originates from surveys carried out between the 1960s and 1980s using single magnetometers and/or low-volume radiometric systems. However, advances in airborne systems over the last 30 years

have significantly improved resolution and accuracy, rendering the legacy data far less precise compared to what modern systems can achieve today.

The High-Resolution Geophysical Survey of the Arabian Shield project (GPAS) is divided into sequential phases to ensure a robust and consistent geophysical methodology. Phase 1 comprises the acquisition, processing, and interpretation of more than 2 million line-km of magnetic gradiometer and radiometric data. The survey covers almost 700,000 km^2 and was undertaken by Sander Geophysics Arabia Ltd and Xcalibur Multiphysics Pty in 3 major blocks: Sander flew Block 1 (northeast), while Xcalibur handled Blocks 2 (northwest) and 3 (south). Independent technical supervision at every stage is provided by the RGP Technical Partner consortium. The primary objective of GPAS is to assemble a modern, fit-for-purpose, high-resolution, baseline airborne geophysical dataset for use in geological mapping, mineral exploration, and environmental applications.

The GPAS Phase-1 delivers high-resolution magnetic gradiometry and radiometric data, acquired at 300 m line spacing, 3,000 m tie-line spacing, and 60 m (nominal) altitude above ground. The new magnetic dataset reveals both surficial and buried lithologies (often hidden by thin sediment cover) and unmapped structures that were previously undetectable through surficial mapping and remote sensing studies (Fig. 2). Additionally, the dataset serves as a powerful tool for identifying anomalies associated to natural mineral resources. The radiometric dataset reveals lithological variations, particularly those related to K-U-Th geochemistry (e.g., intrusions).

The GPAS acquisition began in September 2021 and is scheduled for completion in early 2025. Up to nine fixed-wing survey aircraft have been deployed for data collection. Despite challenges from weather and logistical factors, 80 percent of the Arabian Shield has been surveyed to date. Final data products have been released to the National Geological Database (NGD) for priority areas comprising approximately 90 map sheets at a 1:100,000 scale.

The compiled products include line data, raster grids and GeoTIFF images, PDF maps, and GIS projects, as well as technical and interpretation reports. This data can enhance the geological understanding of the Arabian Shield at scales as detailed as 1:20,000 scale. In addition to geological mapping and mineral exploration, the data has various potential applications, including geothermal studies (such as Curie depth models), hydrology (mapping buried faults and dikes that may partition aquifers), and geohazards (e.g., radiological radon risk maps).

GPAS Phases 2 and 3 are set to begin in 2025, featuring detailed airborne surveys incorporating electromagnetic, gravity/gravity gradient, and/or magneto-telluric surveys over mineral belts and selected target areas. These will be conducted using fixed-wing aircraft and/or helicopters (heliborne).

2. High-Resolution Geochemical Survey of the Arabian Shield (GSAS)

Geochemical surveys for mineral exploration in the Saudi Arabian Shield have a history that dates back to the

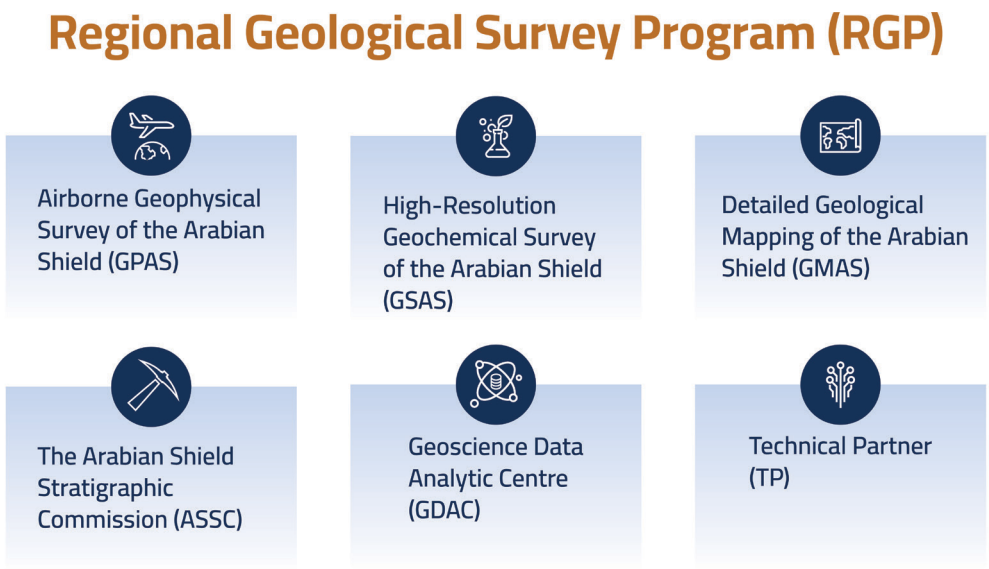

Figure 1. Components of the Regional Geological Survey Program (RGP).

1960s. These surveys focused on various types of mineralization and provided orientation data on the most effective sample types and fraction sizes for analysis. Following this, a systematic geochemical survey was established after 2000 as part of the Regional Geochemical Reconnaissance Program by the SGS.

The RGP's High-Resolution Geochemical Survey of the Arabian Shield (GSAS) is conducted through stream sediment and heavy mineral concentrate samples for more than 85,000 samples. This extensive survey covers a total area of approximately 600,000 Km^2 and is being conducted by the China Geological Survey (CGS). The six-year GSAS project started in late 2020. The primary objective of the scale stream-sediment geochemical survey is to enhance the effective utilization of exploration geochemistry within the Arabian Shield region. This process includes the systematic sampling of stream sediments at a density of 1 sample/6.25 Km^2, using a 1:50,000 topographic map scale. Results are reported and plotted on a 1:250,000 map quadrangle scale. These samples were analysed to determine the concentrations of 76 elements, along with loss on ignition (LOI), using various methods on fractions ranging from 2 mm to 0.25 mm.

The CGS significantly enhanced the geochemical survey capabilities of the GSAS by introducing advanced techniques and modern technologies into this extensive and challenging project. The field team was divided into several groups, each deployed across different quadrangles. Field data is collected using a digital recording system, which uses handheld devices that combine GPS, data recording, smartphone, and camera functionalities. The Geochem Master software, running on an Android platform, is used to pre-plot sample sites, guide samplers to field locations, and record field site and sample information. These data can be quickly uploaded to a field database, allowing project managers immediate access to project progress. The CGS, with its extensive staff resources and experience from similar projects in arid terrains in the People's Republic of China (PRC), has successfully conducted the sampling within a stringent timeline.

The stream sediments were collected from low-order drainage channels that formed during a less arid climate. A systematic sampling procedure has been established across the Arabian Shield, considering the various landscape types. In the field, stream sediment collected from drainage channels is sieved to < 2 mm. During sample preparation, the samples are further sieved to remove the fraction < 0.25 mm, which helps mitigate the effects of windblown contamination. The sediment samples were analyzed in CGS laboratories for 76 chemical elements, in addition to LOI, using various analytical techniques. Subsequently, element concentrations were presented through various styles of geochemical maps produced from the data on 1:250,000 scale quadrangles. These include sample site location maps, single-element classified symbol maps, single-element color contoured maps (Fig. 3), and multi-element anomaly maps. Furthermore, the survey contributed to the updated Geochemical Atlas of the Arabian Shield, which aims to support mineral exploration, environmental monitoring, geoscience, and land use decision-making.

The up-to-date geoscientific data generated from the GSAS project will be utilized to produce geochemical maps at different scales, pinpointing prospective mineral exploration targets. The geochemical survey data serves multiple purposes:

- Supporting the mining sector: It provides up-to-date geochemical data for development within KSA.

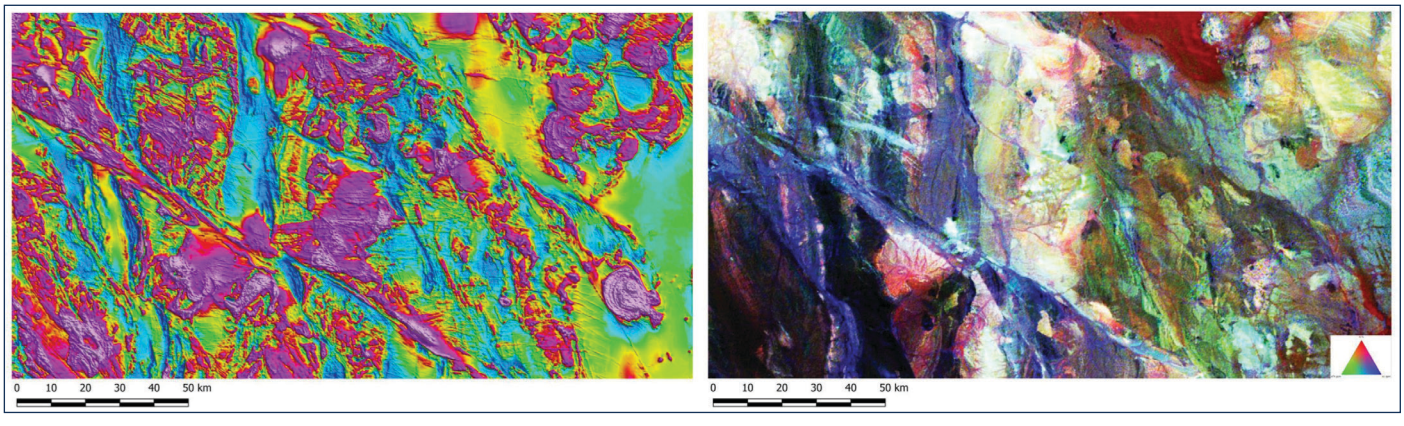

Figure 2. New pole-reduced magnetic field and ternary radiometric data collected and processed from Block 1 survey (RGB = K-eTh-eU).

- Systematic assessment of mineral resources: This involves generating geochemical maps and conducting complementary research, which enhances the effective application of geochemistry in metallic exploration.
- Promoting environmental sustainability: The project provides preliminary information to government and private sector stakeholders, enabling informed decision-making regarding urban and agricultural planning, and environmental aspects, such as the distribution of elements that may pose risks to ecosystems and human health, including arsenic, mercury, lead, and radioactive elements.
- Prioritizing identification, remediation, and development of any potentially contaminated land.
- Determining and managing geochemical factors that influence biodiversity.
- Enhancing our understanding of the interplay between the environment and potential health impacts.

A key outcome of the GSAS Project, which includes field information and chemical analysis data, is housed within the National Geoscience Database (NGD). After rigorous quality assurance/quality control (QA/QC) procedures, the analytical data undergo statistical analysis using both single- and multi-element statistical methodologies. This comprehensive database, containing both field and analytical data, will be used to generate 1:250,000 scale map quadrangle reports and maps. Ultimately, the project will result in the creation of a geochemical atlas of the Arabian Shield in Saudi Arabia.

3. Detailed Geological Mapping of the Arabian Shield (GMAS)

The Arabian Shield was previously systematically mapped between 1963 and 2000 using a series of assembled maps at a 1:250,000 scale. These maps were based on source data collected during reconnaissance for the purpose of geological mapping and mineral exploration at a scale of 1:100,000. Subsequently, to focus on the geological evolution of the Arabian Shield, seamless regional syntheses of the previous geological maps have been done at scales of 1:500,000, 1:750,000, and 1:1,000,000. These compilations aimed to correct the conflicts of structures and geological contacts at map boundaries, as well as to reduce the repetition of geological rock units.

The Detailed Geological Mapping of the Arabian Shield (GMAS) project aims to generate a consistent new geological dataset through geological mapping the entire Arabian Shield, which occupies an area of approximately 600,000 Km^2 along the western region of the Kingdom of Saudi Arabia. The detailed geological mapping is based on a 1:50,000 scale during the fieldwork, with the final compilation at a scale of 1:100,000 . The 11-year project started in early 2023 and follows an annual cycle that includes preliminary map generation – field data collection – interpretation – field verification – laboratory work – reinterpretation – generation of intermediates maps for different map sheets. In the final year of the project, a consistent geological model will be generated for the entire project areas of the Arabian Shield, along with the final products. The entire data flow, from the field data collected and interpretation to the final product is conducted in a digital environment

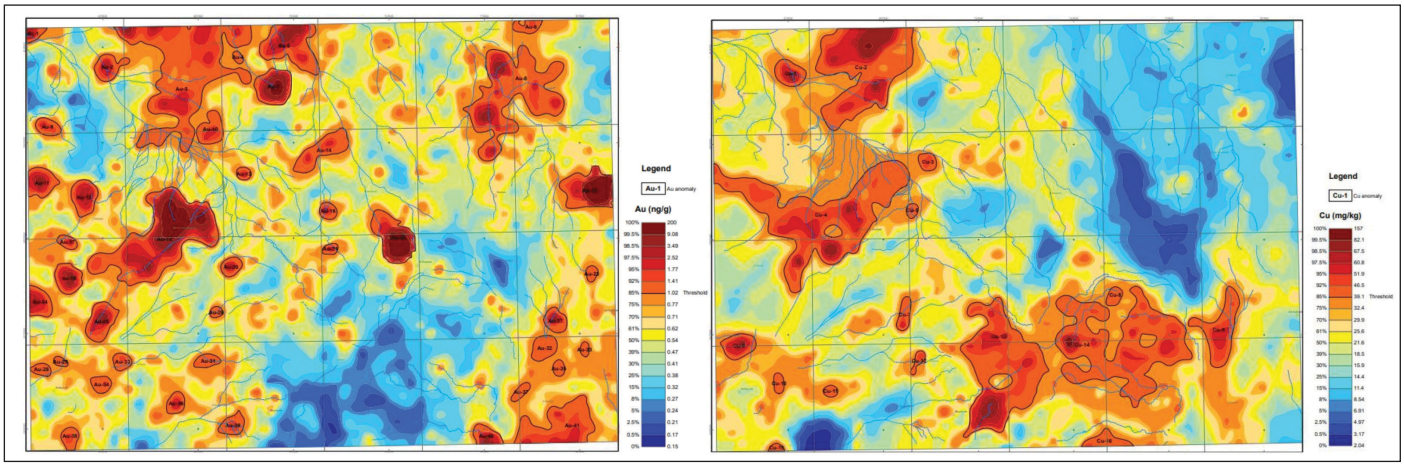

Figure 3. Au- and Cu-geochemical anomalous distribution map outputs of a quadrangle from the Arabian Shield.

and is compiled into the National Geological Database (NGD).

Previously unavailable data types and legacy data are interpreted together in a geographic information system. The resulting geological models are visualized in the form of preliminary geological maps (Fig. 4) and described in accompanying explanatory notes. These maps will undergo ground-truthed and amended to form the basis for seamless geological maps of the entire Arabian Shield, segmented into 271 map sheets at a scale of 1:100,000. Results of the newly released airborne geophysical survey, which cover the entire Arabian Shield (RGP's GSAS project), along with data collected from the regional geochemical survey (RGP's GSAS project) and data collected by satellite-based spectrometers (ASTER, GF-5), are particularly importance for this project. This data will facilitate the analysis of the spatial distribution of materials with the same or similar properties, significantly reducing the time needed for field verification compared to the previous methods. Assuming that these data represent specific lithologies, geological maps are compiled by integrating this data with legacy data. The latter provides, among other things, are the stratigraphic information.

The correctness of the geological models is checked by fieldwork. Geologists gather a comprehensive data

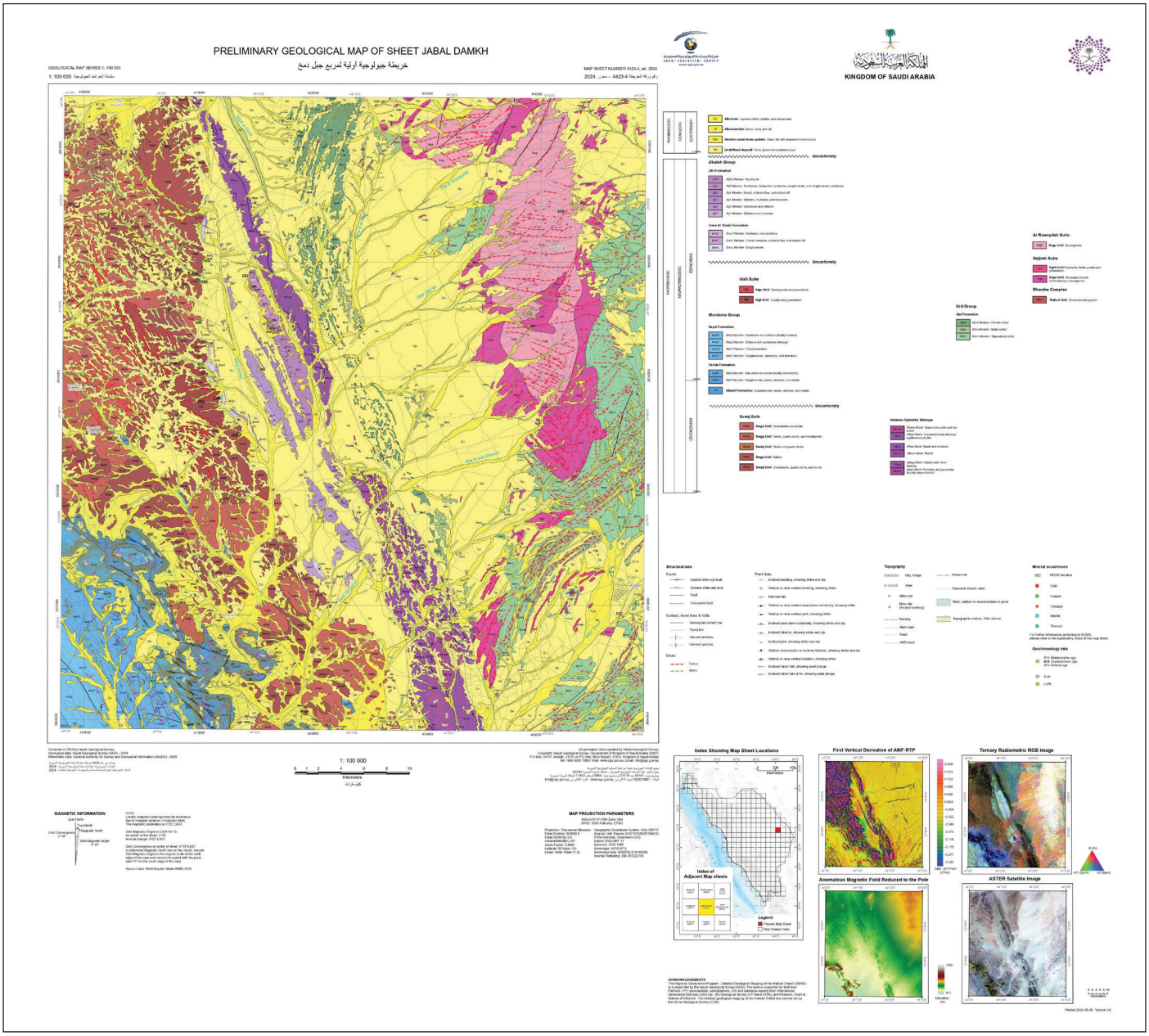

Figure 4. One of the preliminary 1:100,000 scale maps of the GMAS project.

set in the field, which will be integrated into the National Geological Database (NGD) and become available as a stand-alone product for interested investors and prospectors. This database will contain over a million data sets collected from around 200,000 observation points. SGS has commissioned the China Geological Survey to carry out the project under the supervision of SGS geologists and experts from the technical partnership that includes the Geological Survey of Finland (GTK) and the British consulting firm International Geoscience Services (IGS) Ltd. Laboratory work supports and refines the interpretation of the information obtained in the field. This includes 1,250 isotope age determinations, ca. 27,000 petrographic thin sections, ca. 19,000 bulk-rock chemical analyses, and mineral chemical analyses of ca. 2,000 polished thin sections. These analyses not only assist in identifying stratigraphic units but also in the further elucidation of the geological development and evolution of the Arabian Shield.

The project is expected to lead to a widespread improvement in geological knowledge and understanding of the Arabian Shield, particularly with regard to the identification and delineation of the economic occurrences of both metallic and non-metallic resources. Furthermore, detailed geological mapping of the Arabian Shield will provide essential multidisciplinary information for various land-use planning initiatives and for large-scale projects undertaken by both government and private sectors. This information will be crucial for infrastructure development, groundwater studies, and avoiding geological hazards associated with both stable and active structural elements.

4. The Arabian Shield Stratigraphic Commission (ASSC)

The Arabian Shield was previously mapped geologically using informal stratigraphic schemes that were developed to make fieldwork easier and allow for what were believed to be reliable correlations between different areas of the shield. To improve this process, the Arabian Shield Stratigraphic Commission (ASSC) was established in 2023 to support the Geological Mapping of the Arabian Shield (GMAS) regarding lithostratigraphy. The main role of the ASSC is to provide an up-to-date and realistic lithostratigraphic framework and expert scientific oversight for the geological mapping of the Arabian Shield.

The ASSC is composed of members (Fig. 5), including international and national academic experts, senior staff from the Saudi Geological Survey, and the Technical Partner from the International Geoscience Services (IGS), all of whom have extensive knowledge and experience in the geology of the Arabian Shield. The commission is organized into five task groups: tectonostratigraphic and lithostratigraphic, geochronology, the Arabian Shield stratigraphic database and digital library, and research, mentorship, and training.

Field transects covering the Arabian Shield's middle, north, and south sectors have been carried out by the ASSC. Several meetings were held to review the current state of the Arabian Shield's lithostratigraphy and tectonostratigraphy. These meetings aimed to address any

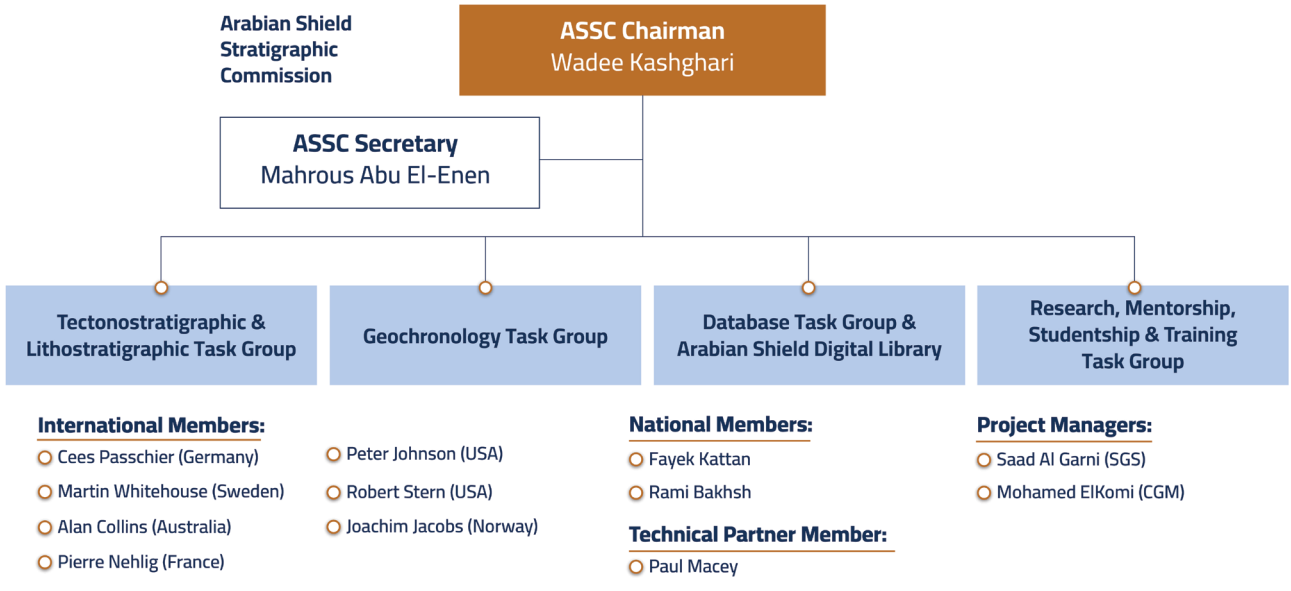

Figure 5. The Arabian Shield Stratigraphic Commission membership.

issues, consider suggestions, and discuss recommendations that could assist the mapping contractor with the GMAS project.

Additionally, the Arabian Shield Lithostratigraphic and Lithodemic Code (ASLLC) was assigned specifically for the current GMAS and published as special publication by SGS. The preliminary lithostratigraphy and geochronology databases of the Arabian Shield have been compiled, and age reliability for the Arabian Shield geochronology has been verified.

A workshop involving the mapping contractor, technical partners, clients, and ASSC members was held to transfer the stratigraphic products and discuss the ASSC's recommendations. The mapping contractor's results will be evaluated yearly over the next four years within the framework of the ASLLC's lithostratigraphy. The ASSC members have contributed their expertise through workshops, on-the-job training, the development of scientific skills, and the understanding of application-oriented methodologies.

5. Geoscience Data Analytic Centre-Saudi Arabia (GDAC-SA)

The Geoscience Data Analytics Centre-Saudi Arabia (GDAC-SA) focuses on both mineral exploration and the environmental, social, and economic impacts associated with the mineral resources sector in Saudi Arabia. GDAC-SA's vision is to be a leader in mineral resources, artificial intelligence, cumulative effects analysis, and various scientific laboratory analytical tools related to the mining sector and its impact assessment.

The objectives of the GDAC-SA are as follows:

1. To support Saudi Arabia in becoming a leading center of excellence in artificial intelligence.
2. To assist in diversifying the Kingdom's economy by identifying new world-class mineral deposits.
3. To ensure the Kingdom has a strong understanding of the environmental, social, and economic impacts associated with mineral resource extraction.
4. To establish world-class geoscientific laboratories that align with the Kingdom's data collection needs.

The GDAC-AS will be powered by an AI/Big Data analytics platform, a state-of-the-art facility, a Research and Training Institute as well as key research and innovation laboratories. The Center aims to promote and advance modern technology and the application of artificial intelligence in various fields of earth sciences. This includes advanced geological exploration, improved data integration among earth science disciplines, and cumulative effects analysis. The Center will address the economic, environmental, and social development needs of Saudi Arabia. Furthermore, it is expected to position Saudi Arabia as a center for regional earth science innovation and international earth science exchanges, establishing the country as a leader in geological artificial intelligence technology.

GDAC-SA aims to support advanced exploration and environmental science across the region and beyond. Its AI platform is designed to identify high potential areas of prospectivity and provide the ability to perform more targeted, deeper analysis using a range of existing and emerging techniques. The platform will be attract mining investors, geologic and earth scientists, scientific researchers, universities, and other related organizations through GDAC-SA's products and services, such as scientific consultants, the development of new analytic methods and AI software, high-quality geospatial-data, and laboratory paid services. Additionally, GDAC-SA is expected to represent the kingdom as a leader in geosciences and earth sciences research, AI research, and open data. It will improve the skills of AI technical personnel in geoscience within Saudi Arabia and build a high-level research and application team specializing in AI across various earth sciences fields.

6. The Technical Partner Consortium (TP)

To achieve successful outcomes in the RGP multidisciplinary program, effective technical supervision is essential. This involves integrating various working philosophies and methods into a single and standard system that ensures compatibility among data sources. Therefore, the technical partner, a consortium of the Geological Survey of Finland (GTK) and the British consulting firm International Geoscience Services (IGS) Ltd, has been contracted as the independent technical supervision of the RGP and other initiatives, including the National Core Library (NCL) and the National Geological Database (NGD). The technical partner's primary role is to provide consultative and supportive services, focusing on the overall technical content and quality control of the RGP-NCL, NGD, and their deliverables.

Certain functions in terms of supervision and quality control are standardized. These include the scope of work with specific standards for each of the subdisciplines; preparing templates and workflow procedures; evaluating products; ensuring quality control of data acquisition method; monitoring progress; early identification of challenges that could affect progress; recommendations for sign-off; and checking the training component of actions.

The methodologies used to perform quality assurance/quality control work are standardized whenever possible. They use checklists and reporting templates to ensure consistency of application among team members. Where possible, scripts are used to improve efficiency and minimize errors. All quality control reports within a discipline adhere to a standard format or template. The consultant's technical leader provides the ultimate approval for all reports produced by the team, following an internal evaluation by the relevant team leader.

Thus, the technical partner project is essential for ensuring the high-quality performance of the RGP's projects and initiatives. It facilitates well-informed decision-making, aligns goals, manages risks effectively, adheres to best practices, and optimizes resource use. Additionally, it encourages creativity and problem-solving, improving the overall quality and success of the RGP's projects.

SGS Launches Expanded NGD Geological Data Packages in Its 25th Anniversary

By Mustafa A. Makki

In celebration of its 25th anniversary in October 2024, the Saudi Geological Survey (SGS) has launched the second phase of geological data packages under its General Geological Survey Initiative, available on the National Geological Database Portal (NGD). This milestone reaffirms SGS's commitment to strengthening Saudi Arabia's mining sector by providing reliable, high-quality geological data that supports mineral exploration and encourages local and foreign investment. These efforts align with the goals of Saudi Vision 2030, contributing

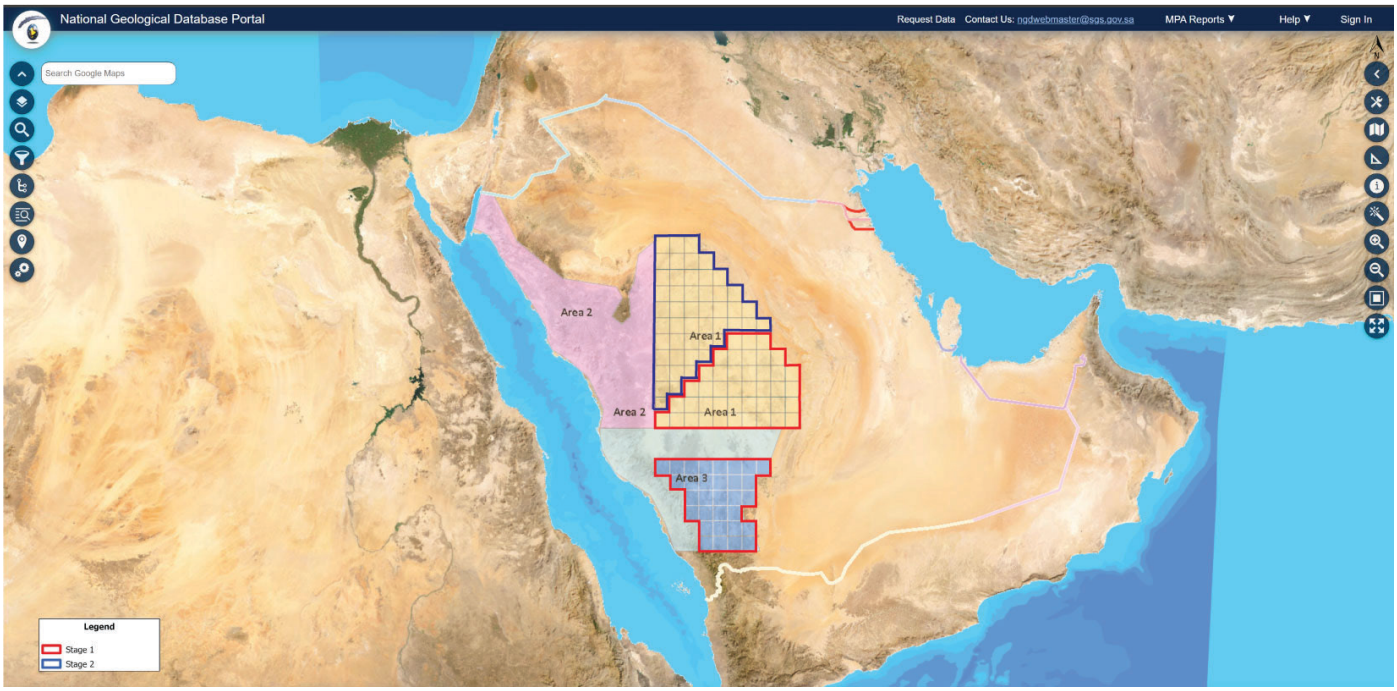

Figure 1. Coverage areas for stages one and two of the RGP airborne geophysical survey. Stage one covers 30% of the Arabian Shield, while stage two covers an additional 30%, bringing the total coverage to 60%.

to economic growth and income diversification in the Kingdom.

The newly released Geophysical Airborne Magnetic Survey data package now covers 30% of the Arabian Shield's area, specifically targeting the northeastern section (Fig. 1). This complements previously published data, which accounted for 30% of survey coverage in the central, eastern, and southeastern parts of the Shield. With the completion of this second phase, SGS has now surveyed a total of 60% of the Arabian Shield since the initiative's launch. Across both phases, the total distance of surveyed flight lines has reached 1,164,531 kilometers. The collected geophysical data has been carefully prepared for technical interpretation and organized into 121 sheets at a 1:100,000 scale. In the second phase, 48 survey sheets were generated in the central and northern regions of the Shield, while the first phase produced 73 grids covering the southern, southeastern, central, and eastern areas.

In the domain of surface geochemistry, the first phase of the Surface Geochemical Survey successfully covered approximately 40% of the Arabian Shield, analyzing 20 geological quadrangles at a 1:250,000 scale to provide geochemical data on stream sediments (Fig. 2). Through the NGD Portal, a total of 35,585 samples have been made available, covering more than two million chemical analyses for 57 elements from the periodic table. In the second phase, SGS published data for an additional 17,696 surface samples from 9 geological quadrangles at the same scale, contributing over one million chemical analyses for 57 elements. This extended the survey to an additional 20% of the Shield, focusing on the southern and southeastern regions. By the end of this phase, nearly 60% of the Arabian Shield had been covered by the Surface Geochemical Survey.

Additionally, SGS has made preliminary geological data for mineral exploration boreholes available, which indicates the availability of high-resolution scanned data of core drilling samples through the National Drilling Library Initiative. The NGD Portal now hosts over 4,000 digitally scanned reports and over 10,000 high-quality digital attachments related to mineral occurrences sites. Currently, 5,650 mineral occurrence sites are registered within the NGD, providing a valuable resource for stakeholders in the mining and mineral exploration sectors.

Marking a quarter-century of progress in October 2024, SGS's expanded data release showcases its ongoing dedication to advancing geological research and fostering investment opportunities. By increasing access to critical geological data, SGS continues to play a pivotal role in unlocking Saudi Arabia's mineral potential in line with Vision 2030.

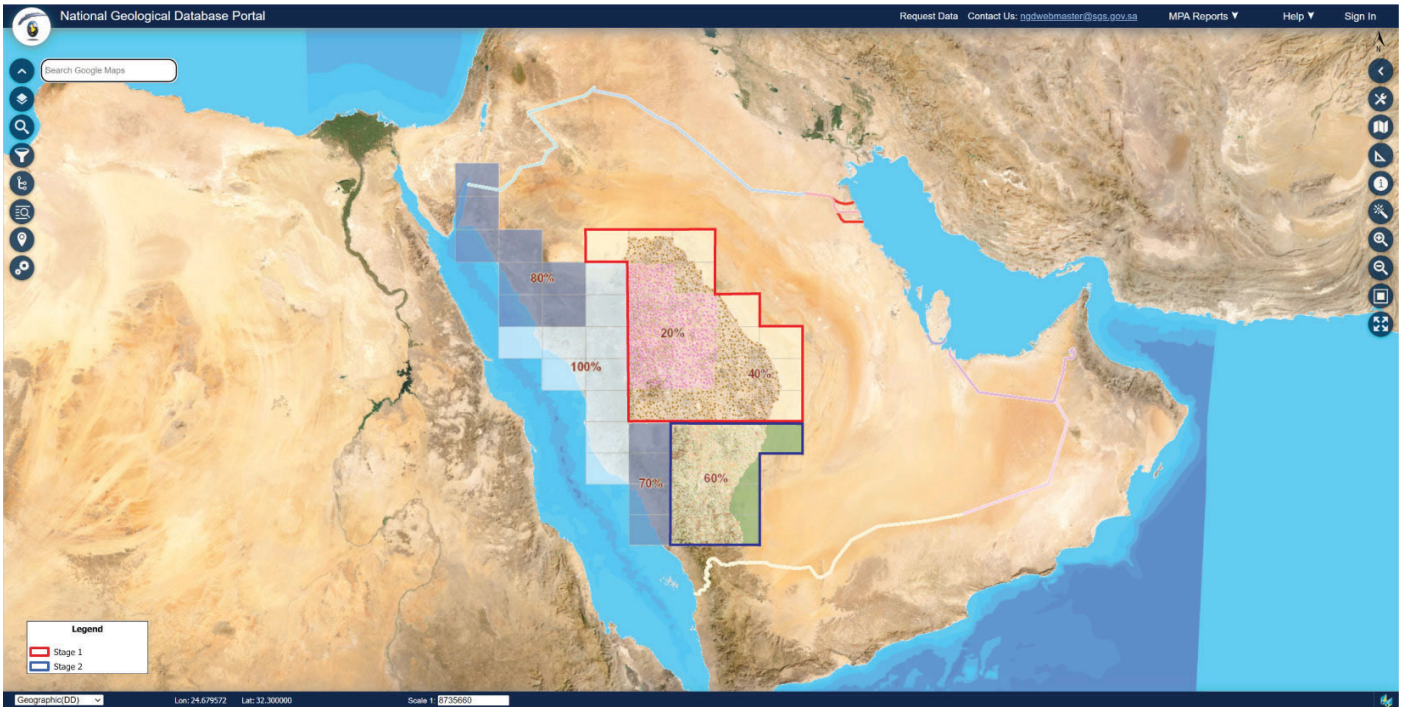

Figure 2. Stream sediment coverage for stage one of the geochemical survey, which encompasses 40% of the Arabian Shield, and 20% in the southeastern part of the Shield during the second stage of the survey, resulting in a total coverage of 60% of the Shield.