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# New Era of Geochemical Surveys in the Kingdom of Saudi Arabia

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Geochemical surveys for mineral exploration in the Arabian Shield in the Kingdom of Saudi Arabia (KSA) have been carried out since the 1960s. At the end of 2021, a significant new initiative commenced with the geochemical Survey Arabian Shield (GSAS) Project. This is part of a Regional Geological Survey Program (RGP) that also includes airborne geophysical surveying and geological mapping to unlock the mineral potential of the Arabian Shield. The RGP is part of the Kingdom's 2030 Vision that aims to transform the mining sector into the third pillar of Saudi Arabian industry. The program led by the Saudi Geological Survey (SGS) focuses on surveying and mapping some 600,000 km$^2$ of the mineral rich Arabian Shield in western Saudi Arabia (Fig. 1) over the next six years. This program will provide a better understanding of the mineral resources of the area, estimated to be worth about $1.3 Trillion (Saudi Press Agency, 2020). The work will provide an invaluable database of geological information to stimulate the mineral exploration sector in KSA.

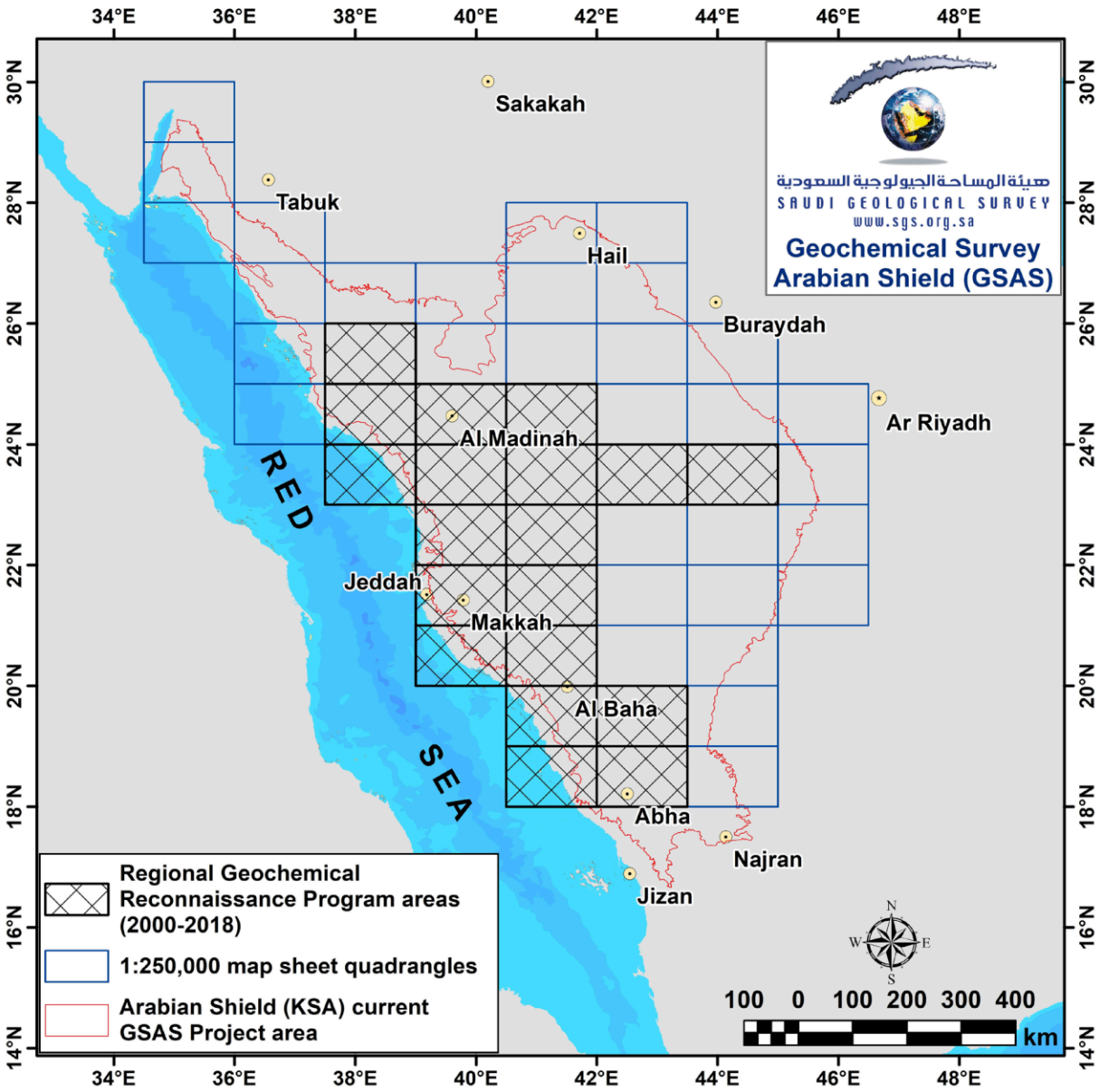


*Figure 1. Map showing the SGS Regional Reconnaissance Geochemical Survey areas (2000-2018) and the current GSAS Project area covering the Arabian Shield, Kingdom of Saudi Arabia.*

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Prior to the formation of SGS in 2000, geochemical surveys in the Arabian Shield were conducted by the United States Geological Survey (USGS) and the Bureau de Recherches Géologiques et Minières (BRGM). These surveys targeted a variety of mineralization types present in the Arabian Shield and provided orientation information regarding the optimal sample media and fraction sizes for analyses. The results of this geochemical exploration work were generally published as internal confidential reports, many of which are stored in the SGS library in Jeddah. These reports indicate contamination of sediment samples by wind-blown detritus is a dominating concern for geochemical sampling in such arid environments.

According to Nehlig (1999), mineral exploration by various organizations and companies operating in the Kingdom of Saudi Arabia for 35 years has led to the discovery of more than 5,300 mineral occurrences. The main mineralization types of the Arabian Shield as listed by them include:

1. Base and precious metal deposits related to submarine volcanism (VMS type);
2. Cr-Ti-Fe-Ni-Cu (PGE) mineralization related to mafic-ultramafic rocks;
3. Sn-W mineralization related to peraluminous post-collisional granites;
4. REE-Th-U mineralization related to granites enriched in high-field-strength-elements and syeno-granites;
5. Porphyry-type Cu-Mo, Cu-Au and W-Mo mineralization;
6. Epithermal gold and base-metal sulfide mineralization;
7. Mesothermal gold veins relating to faulting;
8. Sedimentary Pb, Zn, Cu, or Ni-Mo mineralization; and
9. Ti-Au-W residual placers.

Agar (1992) summarizes the metallogeny associated with the Arabian Shield to include:

1. Cu-Ni and Cr mineralization associated with Proterozoic oceanic crust/ophiolite;
2. Base and precious metal deposits associated with formerly active plate margins (arc-type volcanogenic);
3. Shear-zone hosted mesothermal gold mineralisation related to accretionary and strike-slip tectonics; and
4. Sn-W-Ta-Mo-REE mineralisation associated with post-cratonization alkali granite magmatism of Late Proterozoic to Early Phanerozoic age.

The first systematic regional survey program in the Arabian Shield area of KSA commenced in 2000 with the Regional Geochemical Reconnaissance Program based on the collection of stream sediment at a density of one sample per 25 $km^2$. The stream sediments, collected from low-order wadis (stream channels), were dry sieved in the field to yield a <2 mm fraction and further sieved in the SGS laboratory to recover a <2 >0.177 mm (-10+80 mesh) fraction. This fraction was chosen in order to provide optimal contrast for defining anomalous mineral element concentrations (Al-Thekair, 1984; Al-Thekair *et al*., 2005). The samples were pulverized and analyzed for 60 elements using ICP-OES and AAS following a four-acid digestion. By 2020, SGS had completed the sampling of nineteen 1:250,000 map sheet (1.5º of longitude and 1º of latitude) areas (Fig. 1). For eleven of these map sheet areas, geochemical atlases have been published (e.g., Abdalla *et al*., 2015).

The new geochemical survey activity in KSA commenced with the award in 2021 to the China Geological Survey (CGS) of a contract to carry out a geochemical survey of the Arabian Shield, under the guidance of Eng Abdullah M. Shamrani, Chief Executive Officer, Saudi Geological Survey and Dr. Wadee A. Kashghari, Owner and Director of the Regional Geological Program (RGP). The Project is directed by the SGS aided by Technical Partners, experienced geochemists from IGS (International Geoscience Services) Ltd. and the Geological Survey of Finland (GTK). The Geological Survey Arabian Shield (GSAS) Project will cover the 600,000 $km^2$ with predominately stream sediment samples collected at a density of one site per 6.25 $km^2$ (Fig. 2). The project will have a duration of six years with the sampling, the collection of approximately 100,000 sediment samples, to be completed in the first three years. The sampling will be carried out at the 1:50,000 topographic map scale, reporting results and map plotting will be at the 1:250,000 map quadrangle scale (Fig. 1).

The CGS will substantially upgrade the geochemical survey capability of the SGS, introducing new techniques and modern technologies to all the phases associated with this challenging project. Field data is being collected using a digital recording system and handheld devices combining GPS, data recording, smart phone and camera. The CGS Geochem Master software runs on an Android system and will be used to pre-plot sample sites, guide samplers to locations in the field, and be used to record field site and sample information. The information can be rapidly uploaded to a field database giving rapid access to the project managers concerning the progress of the project. The CGS has substantial staff resources and experience from their work in similar arid terrains in the Peoples' Republic of China (PRC) to conduct the sampling within the framework of a demanding schedule.

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*Figure 2. CGS geochemists in the field collecting stream sediments for the GSAS Project. Photographs from China Geological Survey.*

Delayed by the COVID pandemic, the sampling commenced in March 2022, and by the end of the first phase of sampling in June 2022, some 30,000 (representing 35% of the total) stream sediment samples have been collected. The sampling was preceded by a phase of orientation and planning which resulted in the preparation of three procedure manuals to ensure the sampling, sample preparation and chemical analyses are carried out to strictly adhered to protocols (China Geological Survey, In Prep. a, b, c).

It is estimated that stream sediments will be collected from 85-95% of the area using low-order drainage channels established at a time when the climate was less arid. A common systematic sampling procedure has been established across the Arabian Shield area that considers a variety of landscape types. These include mountainous, flat plain, sabkhah, relatively unweathered recent harrat (basaltic lavas) and Nafud (sand dune areas). In the field, stream sediment collected from stream drainage channels is sieved to <2 mm (-10 mesh). During sample preparation, samples are sieved further to remove the <0.25 mm (-60 mesh) fraction as a measure to mitigate the effects of contamination by windblown material. The sediment samples will be analysed in the laboratories of CGS for 76 elements using a variety of analytical techniques (China Geological Survey, In Prep. c).

The creation of a geochemical database of the field and analytical data in the KSA National Geoscience Database (NGD) is a key project deliverable. This database will be used to generate 1:250,000 scale map quadrangle reports and maps culminating at the end of the project with a geochemical atlas of the Arabian Shield within the KSA.

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