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Mineral Potential of the South-eastern //Karas Region: an Overview

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Abstract :- To complement the Southern Namibian Mapping Programme (Nguno and Macey, 2024), an investigation of the mineral potential of the south-eastern //Karas Region was conducted simultaneously with the field work as an incentive for further exploration. Until the year 2000, the former Sperrgebiet (now Tsau//Khaeb National Park) was reserved solely for exploration and mining of precious stones (alluvial diamonds) along the Atlantic seaboard and Orange River, rendering the huge area between Oranjemund and Lüderitz underexplored with respect to other commodities. That such potential exists is indicated by major mining operations just outside its borders, i. e. the Skorpion Zn and the Rosh Pinah Zn-Pb-Ag Mines, which are part of a major base metal province. The Gergarub Zn-Pb-Ag deposit, situated some 15 km northwest of Rosh Pinah on farm Spitskop 111, constitutes such an unexploited resource, within this province. Other past and present mining operations in the project area (Figs 1 and 2) include the Aukam Graphite, Tin and Fluorite Mines, as well as several dimension stone quarries.

Keywords :- Mineral exploration, Mineral potential, Sperrgebiet

Geology of the project area

The oldest rocks in the area belong to the Palaeo- to Mesoproterozoic Namaqua - Natal Metamorphic Province, which forms a ca. 400 km wide mobile belt along the southern and south-western margins of the Archaean Kaapvaal Craton. They encompass pre- (Sperrgebiet and Richtersveld Magmatic Arcs; Fig. 1), syn- (Kakamas and Aus Domains; Fig. 1) and late to post-tectonic (rare element pegmatites) rocks relative to the Namaqua high-grade tectonothermal event at ~1200 m.y. (e. g. Miller, 2008a), which forms part of the Rodinia Supercontinent assembly. West of Helmeringhausen, the Namaqua rocks are overlain by the Mesoproterozoic volcano-sedimentary Konkiep Group of the Sinclair Supergroup (Fig 1).

The Mesoproterozoic basement is intruded by the Neoproterozoic Richtersveld Igneous Suite, a northeasterly trending line of intrusives extending from the Richtersveld in South Africa to southern Namibia, which heralded the break-up of Rodinia and the development of a rift basin, in which the late Neoproterozoic metasedimentary and metavolcanic rocks of the Gariep Supergroup were deposited (Fig. 1). The ubiquitous Gannakouriep dykes intruded pre-Gariep basement as well as basal Gariep units throughout south-western Namibia and adjoining parts of South Africa during the rifting phase, while the alkaline plutons of the Kuboos – Bremen Igneous Province, which extends from the north-western Richtersveld (South Africa) to the Karas Mountains in Namibia, post-date metamorphism and deformation related to the formation of the Gondwana Supercontinent in the Gariep Belt.

In the eastern part of the project area the metamorphic rocks are overlain by the younger sedimentary successions of the Nama Group and Karoo Supergroup (Fig. 1), which during the Jurassic were extensively intruded by dolerite sills and dykes connected to the breakup of Gondwana. Cretaceous to Palaeogene intrusives, including phonolites, carbonatites and rare kimberlites, together with the unconsolidated to semi-consolidated surficial sediments of the Kalahari and Namib Groups, form the youngest stratigraphic units in the area.

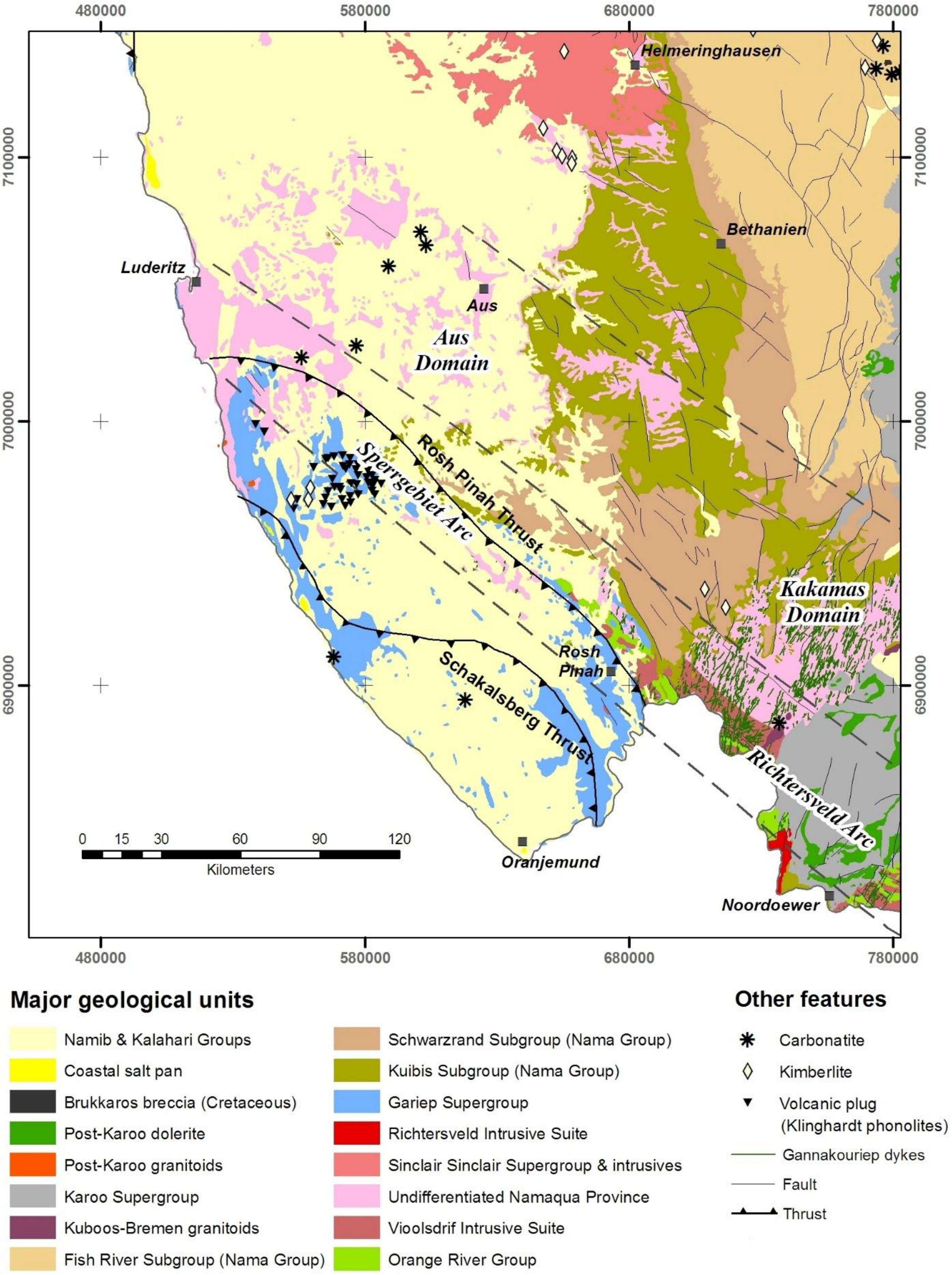

Figure 1. Geological overview of the project area (after 1: 1000 k Geological Map of Namibia, 1980)

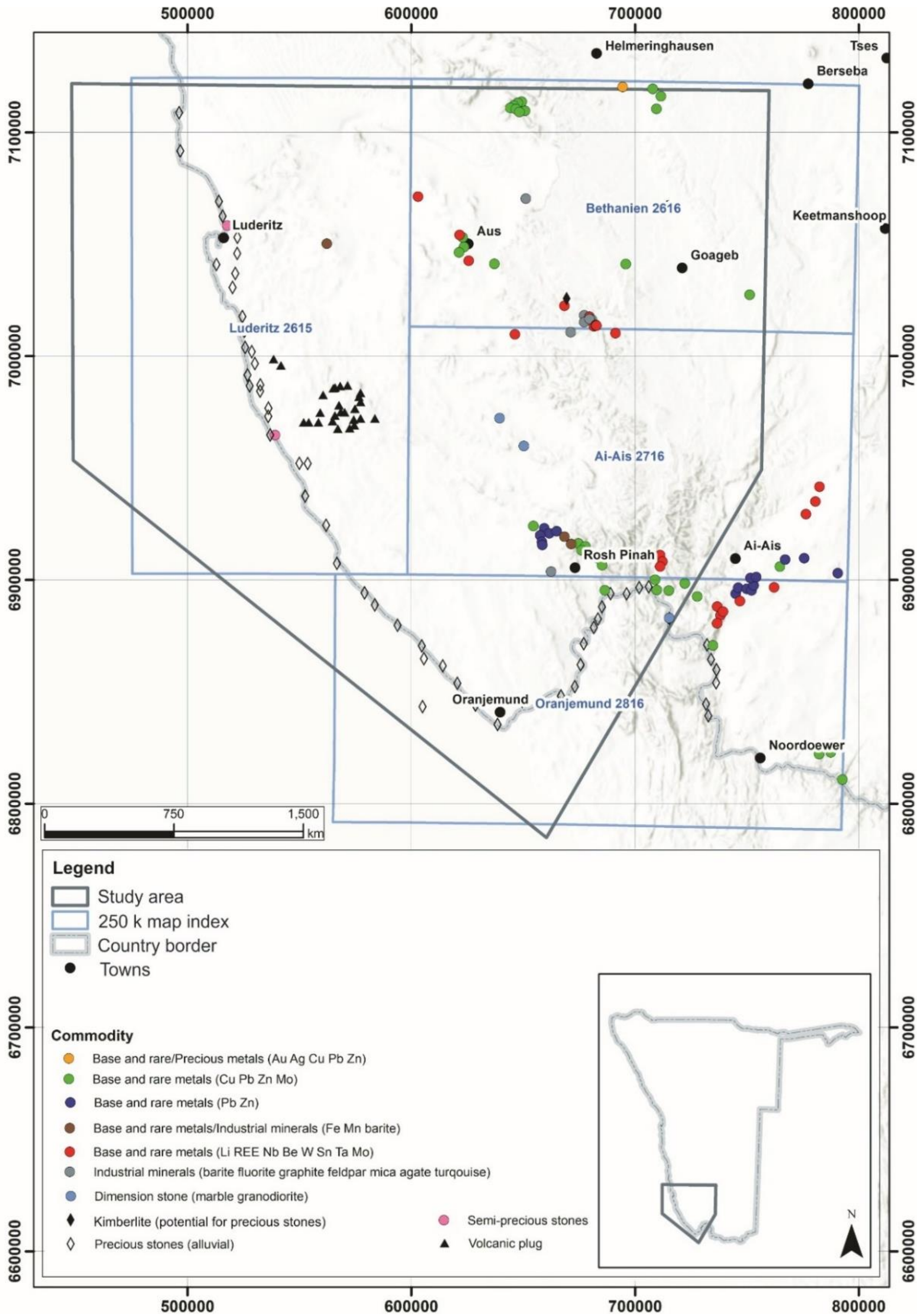

Figure 2. Locality map of the project area showing known mineral occurrences (superimposed on ESRI multi-directional hillshade terrain model)

Mineral potential

Ore deposits related to various plate tectonic settings are summarised by Robb (2020) and Pirajno (2016). Based on tectonic setting, various geological environments encountered in the project area have potential for a range of commodities and mineralisation styles (Fig. 2).

1) Namaqua-Natal Metamorphic Province

In the project area, pre-, syn- and late/post-tectonic rocks relative to the Namaqua Orogeny are present. The Sperrgebiet and Richtersveld Arcs formed in a calc-alkaline island-arc setting along a subduction zone (Macey *et al*., 2017). This setting can be represented by an island arc - inter-arc basin, which has potential for a) island arc-related porphyry copper-(Au, Mo; e. g. Haib, Namibia) and related hydrothermal/epithermal gold (e. g. El Hueso, Chile); b) island arc / incipient rift-related, Kuroko-type (Zn, Cu) volcanogenic massive sulfide (VMS; e. g. Kidd Creek Cu-Zn-Ag, Canada); and c) inactive inter-arc, basin-related podiform Cr (nickel sulfide, Pt) deposits (e. g. Masinloc Chromium, Philippines). Alternatively, it can occupy an island arc – back-arc basin proximal to a continent, which may host a) orogenic gold (e. g. Otjikoto, Namibia); b) podiform chromite and sulfide segregations associated with obducted oceanic spreading centres; c) island arc-related porphyry copper-gold and related hydrothermal precious metal deposits (epithermal gold); d) back-arc basin-related Besshi- (e. g. Otjihase Cu-Zn-Ag-Au, Namibia) and Cyprus-type VMS copper-iron (e. g. Skouriotissa Copper, Cyprus) deposits; and e) granitoid-hosted mineralisation (e. g. Sn, W, Bi, Mo, F) associated with a continental arc (e. g. Red Mountain Molybdenum, Canada).

Although the actual setting of sedimentation remains conjectural, the metasedimentary rocks of the Kakamas Domain indicate provenances from nearby arcs (Sperrgebiet and Richtersveld Arcs; Thomas *et al*., 2016), and are associated with the development of a regional, 'hot orogen'-driven, wide, continental back-arc basin and subsequent high-grade metamorphism and granitic magmatism (Macey *et al*., 2022). Continental back-arc basins are prospective for epithermal gold-silver, Carlin-style gold (e. g. Twin Creeks, USA), and VMS-style Zn-Pb-Cu-Ba.

Prodigious late-stage orogenic pegmatites, which are prospective for tantalum, lithium, tin and fluorite mineralisation, occur throughout the Namaqua Metamorphic Province. Li, Sn and fluorite mineralisation, as well as vein-type graphite (e. g. Aukam Graphite Mine) exposed in trenches and pits near or along hill slopes in the Aukam area, indicate exploration potential of the surrounding flat-lying alluvium-covered terrain, which is stratigraphically positioned below the Nama unconformity and underlain by Namaqua rocks.

2) Sinclair Supergroup

The Sinclair Supergroup (Konkiep Group) was formed in a volcanic-sedimentary arc setting with associated bimodal magmatism on an active continental margin in a subduction zone (Miller, 2008b, and references therein). This Andean-type setting is prospective for porphyry copper-molybdenum and related hydrothermal precious metal deposits (e. g. epithermal gold), as well as for granitoid-hosted tin-tungsten (Llallagua Tin, Bolivia) and polymetallic skarn (e. g. Aberfoyle Tin-Tungsten, Australia).

3) Richtersveld Igneous Suite, Gannakouriep mafic dyke swarm and Gariep Supergroup

The Richtersveld Igneous Suite, the mafic Gannakouriep dykes and the metasedimentary and -volcanic rocks of the Gariep Supergroup are related to successive stages of an extensional plate tectonic regime (Pan-African orogenic cycle). The Richtersveld Suite, a NW-trending line of intrusions, is associated with crustal thinning (intracontinental hotspot activity / incipient rifting) prior to Rodinia break-up; intrusive and supracrustal felsic igneous rocks near the Aurus Mountains and along the margin of the Gariep Belt north-west and north of Rosh Pinah have been correlated with the Richtersveld Suite on the strength of age and petrography (Frimmel, 2008; Thomas *et al*., 2016). The younger Gannakouriep dyke swarm represents syn-sedimentary, rift-related magmatism and heralded continental splitting, while the Gariep Supergroup was deposited in intracontinental rift-related grabens (i. e. failed rift; Frimmel, 2008). The latter is subdivided into the external, continental, parautochthonous Port Nolloth Zone in the east and the largely oceanic, internal Marmora Terrane in the west, separated by the Schakalsberg Thrust (Fig. 1).

Ore deposits associated with an intracontinental hotspot / incipient rift setting (Richtersveld Suite) include a) anorogenic granite-hosted mineralisation (Sn, W, Mo, Cu, Nb, F, etc.; e. g. granites of the Bushveld Complex, South Africa; Robb, 2020); b) pyroxenite / carbonatite - hosted mineralisation (Cu, Fe, Nb, P_2O_5, U, F, Nb, REE, etc.; e. g. Phalaborwa Cu-Fe-P; Robb, 2020); and c) sedimentary exhalative (SEDEX) Pb-Zn-Ba-Ag deposits (e. g. Rosh Pinah Zn-Pb-Ag, Namibia). Intracontinental rift settings provide an environment prospective for VMS mineralisation (e. g. Skorpion Zinc, Namibia) associated with submarine exhalative metal-rich hydrothermal fluid discharge, podiform chromium (NiS, Pt) and banded iron-manganese formation (Kalahari Mn Field, South Africa). Also, failed rifts such as the Gariep, may develop into hydrologically closed intracratonic basins prospective for sediment-hosted stratiform copper (Hitzman *et al*., 2010; e. g. Kamoa Copper, Democratic Republic of Congo).

The Gariep Supergroup was subjected to the Pan-African Orogeny at ca. 530 Ma, which was associated with Andean-type ocean-continent collision and subsequent post-orogenic magmatism (Kuboos-Bremen Igneous Province). Older units locally display Pan-African metamorphic and / or structural overprinting. Mineral deposits formed in this tectonic setting are discussed in chapter 2) above. In addition, continental platforms (accompanying intracontinental rift zones) may be associated with Mississippi Valley-Type (MVT) carbonate-hosted Zn-Pb occurrences (e. g. Berg Aukas Zn-Pb-V, Namibia) attributed to orogenic hydrothermal circulation. Carbonatites of the Kuboos-Bremen Province (e. g. Marinkas Quelle) may be prospective for rare earth elements.

4) Nama Group

The Ediacaran Nama Group, which comprises cratogenic (Kuibis Subgroup), flysch (Schwarzrand Subgroup) and molasse sediments (Fish River Subgroup), was deposited in a foreland basin adjacent to the Damara Orogen to the north and the Gariep Orogen to the west. Most of the strata dip very shallowly (1° or less) towards the east, and were only slightly affected by folding and thrusting along the northern and western basin margins during the final stages of Damara and Gariep orogenesis (Grotzinger and Miller, 2008). In contrast to the older, syntectonic, molasse of the Mulden Group of north-western Namibia, which was deposited adjacent to the Damara and Kaoko Orogens and hosts a variety of base metal deposits (e. g. Tschudi Copper) within carbonaceous arenites, no significant ore bodies are known from the Nama Group to date. This may be ascribed to the absence of mineralising fluid sources and ore forming processes in this southern molasse, or, possibly, to hitherto insufficient exploration. Carbonate rocks of the Nama Group within the project area have been quarried for dimension stones (e. g. Leonardo Potoro, Sandykop and Swartkloofberg marbles; Muyongo *et al*., 2020).

5) Karoo Supergroup

The post-orogenic Karoo Supergroup in the project area consists of the Carboniferous glaciomarine Dwyka Group and the Permian lacustrine-fluviatile Ecca Group, which were deposited in the Karaburg and the Aranos Basin (Fig. 1), the latter being an embayment of the Main Karoo Basin. Correlation with coal-bearing strata in South Africa led to various extensive drilling campaigns since the 1950s, which intersected coal of variable quality at different stratigraphic levels within the Ecca Group (e. g. Miller, 2008c).

6) Cenozoic

The Palaeogene Dicker Willem carbonatite complex, situated some 30 km north-east of Aus, is associated with an intracontinental hotspot/incipient rift setting related to intraplate alkaline magmatism. It lies on a major crustal lineament, which extends from the coast south of Lüderitz in a north-easterly direction and encompasses the intrusives of the Lüderitz Alkaline Province as well as several smaller carbonatites (e. g. Teufelskuppe, Keishöhe) known to be associated with rare earth elements. Similarly, other carbonatite intrusions within the Sperrgebiet (Karingarab, Chameis/Panther) are potentially prospective for REE mineralisation or have already been the target of exploration activities. Further mineralisation styles found in intracontinental rift settings are discussed in paragraph 3) above.

Various partly consolidated to unconsolidated Cenozoic sediments along the Orange River, as well as onshore and offshore along the South Atlantic coast have been exploited for alluvial diamonds and semi-precious stones (agate, turquoise) for more than a century. With onshore diamond deposits almost depleted and only limited mining activities still ongoing along the Orange River, present-day mining and exploration is mainly targeting the nearshore and offshore regions, which requires highly sophisticated and specialised technology.

Implications for exploration

Generally, the most promising tools for successful mineral exploration are geochemical and geophysical surveys, aided by satellite image interpretation of lithology and structure during the reconnaissance stage, to obtain a thorough understanding of the local and regional geology, and the geochemical composition of the area (e. g. Hitzman *et al*., 2012). However, remote sensing applications in the project area have proved largely futile in delineating geological units and structures due to the thick, wind-transported overburden covering much of it. For the same reason, conventional geochemical sampling and geophysical surveys may fail to detect base metal anomalies, thus producing deceptive conclusions with regard to the prospectivity of the area (Meyer and Pedley, 2003). Classic examples of major base metal mineralisation in the Gariep Belt include the Skorpion Zn deposit, concealed by 10 to 20 m of calcrete, silcrete and windblown sand (Jennings *et al*., 2003) and Gergarub Zn-Pb-Ag, a hybrid VMS-SEDEX sulfide deposit (Saayman, 2013), which - buried under 30 to 120 m of alluvial overburden - was only discovered more than 30 years after Rosh Pinah and Skorpion (Schaefer and Terblanche, 2019).

Association of generally tabular to stratiform SEDEX ore bodies and their boundaries with smaller fault-controlled sub-basins near the margins of major depocenters can aid exploration of these types of deposits, as this extensional basin geometry is systematic and predictable (Manning and Emsbo, 2018). Therefore, tools capable of delineating the geometry of depositional basins bounded by basement horsts (e. g. graben structures) are critical for targeting sediment-hosted stratiform copper mineralisation, and may prove successful for VMS/SEDEX systems in the Gariep Belt. In addition, a good understanding of the Cretaceous period of intense weathering that induced deep oxidation of some ore deposits in southern Africa is essential in locating high-grade deposits of supergene origin (Selley *et al*., 2005), such as Skorpion Zinc.

Recommended exploration techniques

- High-resolution airborne magnetic and radiometric surveys to delineate structure and concealed stratigraphic units;
- 3D audio-magneto-telluric (AMT) surveys to identify embayment / graben architecture (e. g. Strangway *et al*., 1973);
- Gravity surveys for mapping out favourable structural basins (Hitzman *et al*., 2012);
- Airborne electromagnetic surveys to detect conductive zones of massive to semi-massive sulfide;
- Systematic RAB/RC scout drilling accompanied by geochemical assaying of the deep overburden to bedrock (successfully employed at Gergarub, as a follow-up in the search for Rosh Pinah-type massive sulfide ore bodies);
- Fluid inclusion studies to identify highly saline, chemically complex, non-orogenic quartz vein-hosted fluid inclusions for the localisation of base metal sulfide prospective areas (Board, 1998);
- Given the strong wind regime and transportation of sand/soil in much of the area, sampling of semi-consolidated material, such as termite mounds for the detection of geochemical anomalies.

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