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Geochemical exploration for base metal sulphide deposits in an arid environment (eastern Namaqua Metamorphic Province), South Africa

by

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ABSTRACT

The massive sulphide deposits at Areachap and Kantienpan Cu-Zn Mine are hosted by a ~1600 Ma old volcano sedimentary succession known as the Areachap Group, in the eastern part of Namaqua Metamorphic Province, South Africa. The deposits were affected by a complex deformation and metamorphic history and represent examples of upper amphibolite to granulite grade metamorphosed volcanic-hosted massive sulphide (VHMS) deposits. The host rocks of both ore deposits are peraluminous-gneisses and the dominant sulphide minerals in the ore zone are pyrite, pyrrhotite sphalerite, and chalcopyrite and trace amounts of galena. Other ore related minerals include barite and anhydrite. The metamorphic minerals in the alteration zones at the Areachap and Kantienpan VHMS deposits are characterized by the presence of plagioclase, almandine and pyrope, enstatite and clinoenstatite, cummingtonite and gedrite, cordierite, sillimanite, and retrograde chlorite and chamosite.

Lithogeochemical methods are widely used in exploration geochemistry to identify the primary alteration zones related to VHMS mineralization, as these zones are often exposed, while the massive sulphide ore body itself may be concealed. Especially in areas that were not affected by high grade metamorphism and intensive deformation. Some of these methods include the variation in the relative abundance of major element concentrations throughout the rock successions, mineral chemistry of silicates and spinel minerals near the ore zone, and normative compositions of the rock successions. However, the application of these methods is limited by complex geology in regional metamorphic terranes, such as the Namaqua Metamorphic Province. Therefore, in addition, three of the more advanced lithogeochemical approaches, known as the Isocon method, the Box Plot and Pearce Elemental Ratios, are combined here and adapted for application in such regions.

Based on the mineral chemistry, it is evident that plagioclase is more Ca-rich adjacent to the ore zone, pyroxene has the highest relative Mg* ratio (Mg* ratio =100 x cationic ratio of Mg / (Mg + Fe + Ca)), the almandine and pyrope components of garnet are high and the spessartine and grossular components are low. In addition, the Mg-rich variety of mica (phlogopite) is more common near the ore zone and the peraluminous nature of the footwall zone is revealed by the presence of gahnite. Cordierite and retrograde chlorites show the highest Mg#'s (Mg# = Mg/ (Mg + Fe)) in the ore zone. In addition to the above, Pearce Element Ratio analyses of cordierite, pyroxene and garnet may be used to define proximity to sulphide mineralization.

Geochemically, the ore zone and alteration zones at Areachap and Kantienpan VHMS ore deposits display a high peraluminous ratio (Al_2O_3 / (Na_2O+K_2O+CaO)) confirming the peraluminous nature of these zones as indicated by the mineral chemistry discussed above. The intervals identified in sampled borehole core with low CaO and Na_2O and with high MgO and K_2O contents represent the alteration zone in the original footwall rocks of the deposit. Isocon studies have shown that the alteration zones at the Areachap and Kantienpan deposits are enriched in Mg, Fe (total), S, Zn, Si, Co and F and depleted in Na, Ca, Sr, Ni, V and La. Elements that behaved relatively immobile include Zr, Ti, P, Mn, Al, Y, and U.

The box plot, alteration index versus the chlorite-carbonate-pyrite index, was originally proposed to illustrate the combined effects of hydrothermal and diagenetic alteration and is based on characteristic primary mineral reactions in regions not affected by regional metamorphism. It is demonstrated here that these primary mineral reactions are preserved in a unique set of metamorphic minerals, and that the box plot can be modified for high-grade metamorphic rock types. When samples with very high Mg contents (MgO>>K_2O, AI>90% and CCPI>98%) are plotted in the box plot they may be classified as representative of anomalous areas that are highly prospective. Samples with high Mg contents (MgO>K_2O, AI>64% and CCPI>93%) may be considered representative of areas that may be classified as of moderate priority in an exploration programme.

The findings of the mineral chemical and geochemical investigations of the footwall alteration at the Kantienpan, Areachap and Prieska Cu-Zn ore bodies are used to

define various statistical factors. The applicability of these factors in lithogeochemical exploration is demonstrated by calculating the respective factor scores for a regional lithogeochemical data set. It is demonstrated how these factors could be used to identify samples collected from localities that are highly prospective for the discovery of concealed VHMS style mineralization.

Based on the statistical analyses of the regional data set, the altered rocks may be distinguished from the metapelitic rocks by their high scores for the alteration factor and low scores for the peraluminous factor. The peraluminous rocks may be separated from the hornblende-gneisses by their high scores for the peraluminous factor, and from the amphibolites by their very low ortho-amphibolite factor scores and high peraluminous factor scores.

The variation, of trace elements in the surface calcrete layer that conceals the mineralization in the studied areas, displays the geochemical signature of mineralization, but the concentrations of Cu, Zn and Pb are much lower at and near surface and increase down depth within the profiles. The absolute concentrations and peak to background ratios of the elements of interest at the surface therefore depend on the thickness of the underlying calcrete layer in the area.

Two methods, a total analysis (x-ray fluorescence, XRF) and partial extraction (NH_4EDTA solution), were applied in to evaluate results, which would be successful and commercially viable in a general exploration programme, using regolith samples. The results of the two methods above were then compared to another patented partial extraction method (mobile metal ion, MMI) on a data set previously reported on by Rossouw (2003). At Kantienpan, where the sand cover is very shallow to absent, dispersion appears to be more related to the secondary redistributions of gossaniferous clasts, than to dispersion of mobile metal ions on the surface of sand particles. The XRF method shows a wider dispersion halo here than methods based on partial extraction. Whereas, at Areachap, where a relatively thick sand (approximately one metre) covers the calcrete layer, partial extraction (based on a NH_4EDTA solution extraction) results in a larger, recognizable, dispersion halo than that detected by XRF. The MMI results show a larger span for Zn, followed by NH_4EDTA and finally

XRF. For Cu, the NH_4EDTA method exhibits the largest span followed by XRF and then MMI.

The anomalous Cu, Zn and Pb contents extracted by partial extraction methods from the wind blown sand deposits indicate that these elements were derived from the ore minerals related to the massive sulphide deposits. However, Mn and Fe contents analysed by XRF also show high values that could not be only related to derivation from massive sulphide ores. Some of the high concentrations of these elements in the sand cover is ascribed to the weathering of other iron-rich rock forming minerals.

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