South Africa's Newest Mineral Oasis: Geology of the Salt River Volcanogenic Massive Sulfide (VMS) Deposit

Craig R. McClung
Salt River Resources Ltd.
craig.mcclung@srr.co.za

Introduction:

The polymetallic Salt River deposit comprises a tabular stratiform/stratabound sulfide body located on the farm Adjoining Geelvloer No 197 ca. 80 km to the southeast of the town of Pofadder in the Northern Cape Province of South Africa. To date, ongoing exploration has yielded a total mineral resources of 28 Mt of ore, at 1.72 wt.% Zn; 0.63 wt.% Cu; 0.44 wt.% Pb; 23.5 g/t Ag and 1.0g/t Au with a high-grade shoot along the eastern edge of the deposit. However, it should be noted that the deposit remains open at depth and to the west where a further four prospects have been identified.

Regional Geology:

The Salt River deposit occurs at the southeastern outcrop limit of the Bushmanland Subprovince of the metallogentically significant Namaqua Metamorphic Province (NMP). The NMP represents a crescent-shaped belt of Paleo- to Mesoproterozoic volcano-sedimentary rocks affected by poly-phase upper amphibolite to lower granulite facies metamorphism and deformation during the Namaquan Orogeny (1000-1200 Ma). Despite the complex and polyphase deformation at a regional scale, the geological structure is rather simple in the vicinity of the deposit, with a uniform strike of 300˚ and dip at 25˚ to the northeast, while the high-grade portion of the orebody plunges at roughly 22˚ in a northeasterly direction.

Stratigraphy:

The orebody is hosted by the supracrustal rocks of the informally termed Geelvloer Sequence of the Kendhart Subgroup (Paizes, 1975; Joubert, 1986b), which forms part of the Mesoproterozoic Bushmanland Group (McClung, 2006.) The host rock sequence to the Salt River deposit comprises a suite of paragneisses, with minor calc-silicate gneiss, amphibolite and granitic gneiss.

The Geelvloer Sequence is nonconformably underlain by pinkish-brown augen gneiss with numerous similarities to the intrusive granites of the Namaquan Orogeny. The localized presence of grey-green, banded and foliated para- to orthoamphibolite marks the base of the Geelvloer Sequence and is sharply overlain by the heterolithic lower biotite gneiss unit. The poorly exposed lower biotite gneiss unit consists of grey biotite gneiss, para- to orthoamphibolites, calc-silicate rocks, chert, as well as lenses of biotite/phlogopite-quartz ± amphibole rock and semi-massive sulfide. The lower biotite gneiss unit is the economically most significant unit as it hosts all of the sulfide mineralization and is gradationally overlain by the calc-silicate gneisses of the laterally equivalent Driekop Fm. (McClung, 2006). On the adjoining properties to the southeast of the Salt River deposit, a variably thick (less than 50 m) package of felsic-intermediate metavolcanic rocks of the Driekop Fm. sharply, but conformably overlies the Geelvloer Sequence. However, in the vicinity of the deposit these

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metavolcanic rocks are observed to rapidly grade into a thick package of calc-silicate gneiss. Although only exposed in drill core, the Driekop Fm. and laterally equivalent calc-silicate gneiss are conformably overlain by a thick sequence (approximately 450 m thick) of paragneiss and amphibolites similar to the Geelvloer Sequence.

Mineralization:

Styles of mineralization:

Four distinct styles of sulfide mineralization have been distinguished, including (i) semi-massive sulfide ore, (ii) chalcopyrite-rich streaky sulfide ore, (iii) disseminated sulfide ore, and (iv) mineralized calc-silicate rocks. The semi-massive sulfide ore forms a thin, but laterally continuous stratiform lens that can reach up to several meters in thickness. It is composed predominantly of very fine- to fine-grained pyrite, with significant amounts of sphalerite and chalcopyrite; well-developed durchbewegung textures occur throughout the semi-massive sulfide lens. Much of the chalcopyrite occurs as typical 'chalcopyrite disease', i.e., as minute solid inclusions within the sphalerite. Galena is minor in abundance and shows an intimate association with accessory molybdenite. Minor amounts of magnetite, barite and sulfosalts have also been observed. Streaky sulfide ore is typically coarse-grained and enriched in chalcopyrite, compared to the semi-massive sulfide ore. Streaky sulfide ore is restricted to 5-30 cm thick units of a coarse-grained biotite/phlogopite-quartz ± amphibole rock occurring predominantly below, but in few instances also above the semi-massive sulfide lens. Locally, this lithology is found to crosscut the sedimentary bedding of the paragneiss host rock. The coarse-grained biotite/phlogopite-quartz ± amphibole rock is intimately associated with and surrounded by fine- to medium-grained cordierite-biotite/phlogopite gneiss containing disseminated sulfides. This cordierite-biotite/phlogopite gneiss grades into a paragneiss host rock typically composed of quartz, plagioclase and biotite. Whilst the cordierite-biotite/phlogopite gneiss is interpreted as the metamorphosed equivalent of pervasively, hydrothermally altered paragneiss; the biotite/phlogopite-quartz ± amphibole rock is thought to represent the metamorphosed equivalent of an irregular stockwork of hydrothermal veins. Locally restricted to a few intersections, mineralized calc-silicate rocks consist of silicified and/or brecciated calc-silicate rocks of the lower para-amphibolite unit cross-cut by veins of pyrite, chalcopyrite and sphalerite.

Metal Distribution:

Geologic modeling of the Salt River deposit reveals an asymmetrical distribution with respect to the average thickness of the sulfide body and distribution of the base metal sulfides. For example, the southeastern extent of the deposit displays a thicker (10-18 m thick) package of sulfides compared to the northwestern extent (less than 2 m thick). Likewise, the distribution of the base metal sulfides displays a gradational change from a Cu-rich zone in the southeast to a Zn-Pb-rich zone in the northwestern portion of the deposit.

Discussion:

Ongoing local and regional-scale geologic and stratigraphic evaluations of the Salt River deposit suggest that the Geelvloer Sequence was deposited in a tectonically active east-northeast trending trough or half-graben. The rapid facies change in the Driekop Fm., as well as the presence of thick laterally extensive calc-silicate rocks to the west-northwest and mixed shallow subaqueous volcanic rocks and calc-silicate

rocks to the east-southeast is interpreted as evidence for deposition in an actively subsiding depositional environment. The ubiquitous presence of bimodal volcanic, volcaniclastic and volcanogenic rocks throughout the Geelvloer Sequence, close spatial association with the granodiorite-tonalite intrusions of the T'Oubep Suite to the northeast and similar U-Pb zircon ages (i.e. ~1200 Ma) for the Driekop Formation (McClung, 2006) and T'Oubep Suite (Joubert, 1986a) indicate that volcanism and sedimentation occurred contemporaneously.

The close spatial association between sulfides, volcanic rocks and Mg-rich footwall alteration, widespread occurrence of chalcopyrite disease in sphalerite, and distribution of the base metals, suggest that the Salt River deposit was formed in association with submarine volcanic activity. However, the obvious dominance of Zn and Cu over Pb, combined with the predominance of metasedimentary rocks in the host rock sequence may be used to place the Salt River deposit into the group of siliciclastic-mafic VMS deposits of Franklin et al. (2005), or into the volcanic-sediment-hosted massive sulfide deposit (VSHMS) class of Goodfellow and McCutheon (2003).

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