The Metallogenesis of the Skorpion Non-Sulphide Zinc Deposit, Namibia

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List of Mineral Names

atacamite \( \text{Cu}_2\text{Cl(OH)}_3 \)
barite \( \text{BaSO}_4 \)
brunckite \( \text{ZnS} \)
chalcopyrite \( \text{CuFeS}_2 \)
chalcocite \( \text{Cu}_2\text{S} \)
chalcopyhanite \( (\text{Zn, Fe, Mn})\text{Mn}_3\text{O}_7\cdot3\text{H}_2\text{O} \)
chrysocolla \( \text{CuSiO}_3\cdot\text{nH}_2\text{O} \)
galena \( \text{PbS} \)
goethite \( \text{FeOOH} \)
gorceixite \( \text{BaAl}_3(\text{PO}_4)_2(\text{PO}_3\text{OH})(\text{OH})_6 \)
greenockite \( \text{CdS} \)
hematite \( \text{Fe}_2\text{O}_3 \)
hemimorphite \( \text{Zn}_4\text{Si}_2\text{O}_7(\text{OH})_2\cdot\text{H}_2\text{O} \)
hydrozincite \( \text{Zn}_6(\text{OH})_6(\text{CO}_3)_2 \)
hydrohetearolite \( \text{Zn}_2\text{Mn}_4\text{O}_8\cdot\text{H}_2\text{O} \)
magnetite \( \text{Fe}_3\text{O}_4 \)
malachite \( \text{Cu}_2(\text{CO}_3)(\text{OH})_2 \)
manganomelane synonym of wad (generic name for Mn oxides/hydroxides)
psilomelane barium manganese oxide hydroxide (no fixed formula)
pyrite \( \text{FeS}_2 \)
pyrrhotite \( \text{Fe}_{1+x}\text{S} \quad (x = 0 \text{ to } x = 0.2) \)
sauconite \( \text{ZnAl}[\text{(OH)}_2 /\text{AlSi}_3\text{O}_{10}] \quad (0.5 \text{ Ca, Na})_{0.5}(\text{H}_2\text{O})_4 \)
scholzite \( \text{CaZn}[\text{PO}_4]_2\cdot2\text{H}_2\text{O} \)
skorpionite \( \text{Ca}_2\text{Zn}_2(\text{PO}_4)_2\text{CO}_3(\text{OH})_2\cdot\text{H}_2\text{O} \)
sphalerite \( \text{ZnS} \)
smithsonite \( \text{ZnCO}_3 \)
tarbuttite \( \text{Zn}_2[\text{OH}/\text{PO}_4] \)
zincolebithenite \( \text{CuZn}(\text{PO}_4)\text{OH} \)
Summary

The supergene Skorpion non-sulphide zinc deposit is located approximately 40 km north of the Orange River in the southernmost Namib Desert, Namibia. It comprises a significant non-sulphide ore body (24.6 Mt @ 10.6 % Zn) and subordinate amounts of primary hypogene base metal sulphide mineralisation, which underlies the non-sulphide ores at depth. The mining commenced in October 2001 with the stripping of the overburden and exposure of the ore body.

The present metallogenic study is based mainly on drill core data from Anglo American's exploration drilling programme in 1999, since the study and the sampling for it was initiated prior to the opening of the mine. Investigations carried out on drill core samples include: i) light microscopy, XRD, and SEM-EDX in order to determine the mineralogy, ii) XRF, ICP-MS, electron microprobe technique and stable isotope analyses in order to determine the geochemistry of the ore body and its host rocks. Additionally, geochemical results from the exploration and infill drilling programme of the Skorpion Mine in 2004 were used in order to describe the supergene metal zonation pattern.

The Neoproterozoic host rocks of the Skorpion deposit are part of a volcano-sedimentary rock sequence within the Gariep Belt. The Neoproterozoic sequence has been affected by upper greenschist-/lowermost amphibolite metamorphism as well as complex deformation, which has resulted in folding and intensive thrusting during the Pan-African Orogeny at approximately 550 – 545 Ma. This event was followed by low-temperature retrograde metamorphism, uplift, fracturing, near-surface and surface weathering. The latter resulted in the formation of the supergene zinc deposit at Skorpion.

The hypogene Late Proterozoic hybrid VH(M)S/SH(M)S Zn-(Cu) protore of the Skorpion non-sulphide zinc ore body has formed in an initial continental rift system between the Kalahari cratonic province and the Rio de la Plata cratonic province. Bi-modal volcanism, anomalously high heat flow and hydrothermal activity have been significant controls for the hypogene ore formation. The Late Proterozoic rift sequence also contains siliciclastic and carbonate sediments, which were deposited in both shallow and deeper water environments.

The supergene non-sulphide ores have formed by oxidation of the base metal sulphide protore by wall rock replacement and in-situ oxidation. The non-sulphide ore minerals comprise predominantly sauconite (Zn-smectite), substantial amounts of hemimorphite and smithsonite, and subordinate amounts of hydrozincite, tarbuttite and chalcophanite. The supergene ore minerals form mainly euhedral and subhedral crystals and occur as open space fillings in inter- and intragranular voids, fractures and breccias.

The supergene non-sulphide ore body is hosted mainly by metasiliciclastic rocks, which are composed of meta-arkoses and –subarkoses, and subordinately by felsic metavolcanic rocks and their volcaniclastic equivalents. The ore body is irregularly shaped, transgressive to sedimentary layering and major tectonic features. It displays a relatively flattop, which is covered by a blanket of unmineralised overburden consisting of alluvial sediments, calcrete and Recent sand dunes.

The supergene ore body is laterally zoned displaying a pronounced supergene lateral metal zonation pattern, which has developed as a result of differences in metal solubilities. Iron and copper zones represent the leached part of the supergene ore body that corresponds to the location of the sulphide protore. The more mobile zinc has precipitated away from the iron and copper zones forming a markedly supergene zinc enrichment zone.

Even if the non-sulphide ore body and its lateral metal zonation are transgressive to a major Mesozoic fault system, the supergene deposit is partly controlled by it. The fault system
opened abundant dilatational joints and fractures, which increased the permeability of the host rocks. Thus, meteoric fluids were channeled and were able to percolate along the fault system and to oxidise the hypogene sulphide ores to several hundreds of meters depth. Palaeo-morphological features and palaeo-climatic conditions indicate that the supergene ore body must have formed during Early Tertiary. Subsequently, the uppermost part of the Skorpion ore body has been eroded and alluvial sediments have been deposited on top of the erosional palaeo-surface in Late Tertiary.