Genesis of the Rosebery massive sulphide deposit, western Tasmania, Australia.

by

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Neil K. Martin

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Abstract

The Rosebery massive sulphide deposit, with historical production and current resources of ~32.7Mt @ at 14.5% Zn, 4.4% Pb, 0.58% Cu, 145ppm Ag and 2.2ppm Au, is located in western Tasmania. It is hosted within a Middle Cambrian post-collisional succession of predominantly submarine, calc-alkaline volcanic and non-volcanic sedimentary rocks. The ore occurs as single or stacked, sulphide and barite-rich lenses with podiform to sheet-like morphologies, distributed over 3km of strike and >1.5km depth below the current surface.

The basal stratigraphic unit of the east-dipping mine sequence (the footwall volcanics) comprises a syn-eruptive succession of thick rhyolitic pumiceous mass flow units that were rapidly emplaced on the seafloor, and succeeded by rhyolitic to dacitic turbiditic mass flow and suspension settled volcaniclastic sediments of the transitional stratified volcaniclastics (TSV). The quartz and lithic content of the TSV increased with time as sediment provenance became more distal. The base of the Hangingwall Volcaniclastics was marked by a reduced volcaniclastic influx and deposition of a carbonaceous mudstone, followed by further volcaniclastic mass flow units with a distal clastic provenance. Intrusion of rhyolitic to dacitic peperite sills occurred prior and subsequent to the onset of mineralisation. The current study has shown that syn-depositional displacement of the sediments occurred as the result of basement faulting and sill emplacement, with cessation of significant fault movement prior to deposition of the Hangingwall Volcaniclastics. The mine sequence is truncated at the upper and lower margins by major Devonian reverse faults. Mineralisation is hosted within sediments at the top of the footwall volcanics and within the TSV.

Regional low-temperature diagenesis commenced upon deposition of the volcaniclastic sediments. Hydrothermal circulation through unconsolidated volcaniclastic sediments commenced prior to sediment compaction and lithification, locally preserving uncompacted vitriclastic textures. Hydrothermal alteration proximal to ore comprises a halo of quartz ± sericite ± Mn/Fe-carbonate assemblages, with a thin discontinuous chlorite assemblage located immediately beneath sulphide ore. The current study has identified a transgressive zone of intense quartz-rich alteration beneath P lens that now delineates what was a zone of fluid upflow along a syn-depositional fault. A broad halo of sericite-rich alteration envelops the ore and proximal alteration assemblages, but does not extend into the Hangingwall Volcaniclastics, as the hydrothermal system had waned prior to their emplacement.

Isotopic data indicates a hydrothermal fluid derived through the modification of seawater as it circulated through the Cambrian volcanic succession and underlying Precambrian basement, from which sulphur and metals were leached. At the mine scale, diffuse hydrothermal upflow was loosely focussed along syn-sedimentary faults defined during this study, resulting in the localisation of ore lenses along the margins of a fault-bounded basin. Significant lateral fluid flow within ~200m of the seafloor was promoted by sediment stratification, thick packages of

fine-grained sediment, peperitic sills and the development of stratiform alteration zones. Lateral movement of hydrothermal fluids was focussed along coarser, more permeable horizons within the sediments. This resulted in stratiform zones of alteration and mineralisation, and in the intense alteration of the lower margins of a peperitic quartz-feldspar-phyric sill and a thick siltstone package now overlying the northern ore lenses.

The current study has identified features within the northern part of the mine that indicate a sub-seafloor mode of ore formation, including: massive barite and sulphide lodes that are hosted within rapidly emplaced mass flow and turbidite units; ore lenses that locally transgress bedding; massive sulphide ore with the same immobile element signature as enclosing mass flow sediments; and a laterally extensive halo of alteration and disseminated mineralisation that extends for hundreds of metres laterally away from massive ore, for tens of metres into the footwall, and for several metres into the hanging wall. The siting of ore lenses stratigraphically below a peperitic quartz-feldspar phyric sill that was emplaced prior to the onset of significant hydrothermal circulation further supports a sub-seafloor mode of ore formation. The ore and the host succession do not display any textures to indicate that mineralisation occurred on the Cambrian seafloor.

Initial primary sphalerite-galena-rich mineralisation formed under relatively low-temperature (~200-250°C) and near neutral conditions, as a hot hydrothermal fluid mixed with cooler seawater and reacted with host sediments through which it passed. This mineralisation was characterised by primitive sulphide textures, including spongiform, atoll, colloform and skeletal morphologies. Utilising the laser ablation-ICP-MS analytical technique, this phase of mineralisation was found to be characterised by a low temperature trace element signature within the sulphide minerals that includes: elevated levels of Mn-Ni-As-Ag-Sb-Au-Tl-Pb and low levels of Co-Bi in pyrite; low Co:Ni and Bi:Pb ratio values in pyrite; low levels of Cu-Fe and elevated levels of Zn-Ag-Sb-Pb in sphalerite; and low levels of Sb-Ag in galena. The low temperature sulphide and barite mineralisation locally preserved an albitised volcaniclastic plagioclase component. The low temperature sphalerite-galena mineralisation was locally overprinted by and interspersed with mineralisation formed at higher temperatures, as hot hydrothermal fluids passed through permeable horizons within the ore and adjacent sediments. This phase of mineralisation produced more coarsely crystalline pyrite textures, including anhedral to euhedral grains, aggregates, and overgrowths on earlier sulphide phases. This phase of mineralisation was also characterised by a high temperature trace element signature within sulphide minerals that included: elevated levels of Bi-Sn, moderate levels of Ni-Ag-Sb-Tl-Pb-Co, and low levels of Mn-As-Au in pyrite; elevated Bi:Pb ratio values and moderate Co:Ni ratio values in pyrite; an increased Fe content in sphalerite; and galena with elevated levels of Sb-Ag. The lateral flow of high temperature (~300°C) hydrothermal fluid within the immediate footwall to sphalerite-galena ore produced discontinuous disseminated to massive pyrite-chalcopyrite mineralisation and chlorite alteration. The footwall mineralisation

was characterised by euhedral pyrite morphologies, and a high temperature sulphide mineral trace element signature comprising: elevated Co-Bi in pyrite; elevated Co:Ni and Bi:Pb ratio values in pyrite; and high levels of Fe-Mn-Cu-Sb-Bi in sphalerite.

Sphalerite-galena ore lenses are vertically and laterally zoned, with Fe-Cu enrichment at the base and proximal to interpreted zones of hydrothermal upflow, and Au-Ag-Pb-barite enrichment at the upper and lateral margins. The zonation was the due to the influence of physicochemical gradients present at the time of initial ore mineral precipitation, in combination with subsequent zone refinement processes. The vertical zonation is locally inverted.

In comparison with the northern ore lenses, a cluster of sulphide ore lenses at the southern end of the mine exhibits evidence for higher temperatures of ore formation that includes: significantly elevated average Fe and Cu contents; low average Au and Ag contents; low average $h^{34}S$ values (<12‰); and elevated Co, Ni and Co:Ni ratio values within footwall pyrites. This suggests that the southern ore lenses were located proximal to a major site of hydrothermal upflow at Rosebery, at the intersection of two northeast and northwest trending Cambrian faults. The peripheral ore lenses, including those at the northern end of the mine, formed at lower temperatures after mixing with a greater volume of locally circulating seawater.

Devonian deformation and metamorphism produced a pervasive cleavage, brittle-ductile faulting and folding, and syn-tectonic quartz-carbonate veining containing locally remobilised sulphides variably enriched in Au±Ag. Sulphide ore exhibits deformation fabrics at the meso- and micro-scale. Late syn- to post-deformation Devonian granite intrusion produced minor faulting and veining, and metasomatic fluids that resulted in replacement of sphalerite-galena ore with massive pyrite-pyrrhotite and magnetite-biotite ± chalcopyrite assemblages. Sulphide annealing occurred syn- to post-metasomatism. The host sequence was later subjected to brittle-ductile faulting and minor dolerite intrusion.

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vii Frequently Used Abbreviations etc.

Mineral Abbreviations

ab - albite
apy - arsenopyrite
ba- barite
sp - sphalerite
ga - galena
cpy - chalcopyrite
py - pyrite
po - pyrrhotite
tet - tennantite-tetrahedrite
el - electrum
fp - feldspar
qz - quartz
se - sericite
cl - chlorite
ru - rutile
to - tourmaline

Thin Section Abbreviations

rl - reflected light
tl - transmitted light
xp - crossed polar light
fov - field of view

Mine Grid Datum

0mE, 0mN, 0mRL = 378870.55mE, 5374181.69mN, -3049.49mRL (AMG)
0mE, 0mN, 0mRL = 0'E, 0'N, 0'RL (old grid) = 0'E, 0'N, 10,000'RL (old grid)
Rosebery N = -11°18'10" TN