GEOLOGY AND GEOCHEMISTRY OF THE WARREGO Au–Cu–Bi MINE, TENNANT CREEK, NORTHERN TERRITORY, AUSTRALIA

by

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Submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy at the University of Tasmania.

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This thesis contains no material which has been accepted for the award of any other higher degree or graduate diploma in any tertiary institution and that, to the best of the author's knowledge and belief, the thesis contains no material previously published or written by another person, except when due reference is made in the text of the thesis.

M.R. Wedekind
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I — Controls on High-Grade Gold Mineralization at Tennant Creek, Northern
  Territory, Australia by M. Richard Wedekind, Ross R. Large and Brian T. Williams.
ABSTRACT

The recently closed Warrego Au–Cu–Bi mine located 51 km west of the town of Tennant Creek in the Northern Territory, has produced in excess of 1.2 million ounces of gold, 80,000 tonnes of copper and 10,000 tonnes of bismuth to make it the largest producer of these three commodities in the Tennant Creek goldfield. As with all economic mineralisation in the goldfield, ore is hosted by magnetite-rich, ellipsoidal pipes (ironstone lodes) which also comprise variable proportions of quartz and chlorite. Economic mineralisation (chalcopyrite, bismuthinite and native gold) is located in fractures within the ironstone lode, and is clearly related to an event that post-dates ironstone formation.

The ironstone lodes are hosted by Lower Proterozoic turbidites of the Warramunga Group which comprise poorly sorted, immature sediments that retain the distinctive trace element compositions of two felsic source regions. The similarity in composition and age (~1870 Ma) of the sediments, a quartz porphyry which forms the immediate hangingwall to the ironstone lodes, and the Tennant Creek Granite, suggests that they are all consanguineous. The porphyry has been interpreted as a sill that was intruded prior to lithification and folding of the Warramunga Group (McPhie, 1990), and as such, preceded ironstone lode formation and mineralisation. The Warrego Granite outcrops less than 1 km from the Warrego mine, and the effect of contact metamorphism is strongly evident as the overprinting of cleavage and hydrothermal alteration associated with mineralisation by cordierite, biotite and andalusite porphyroblasts. Conditions of contact metamorphism are calculated to have been between 500° and 550°C and < 2.5 kbar. Extensive recrystallisation of quartz and sulphide minerals within the ironstone lodes has masked paragenetic relationships and destroyed fluid inclusion evidence of the conditions of mineralisation.

Compared to the typically uniform attitudes observed elsewhere in the goldfield, the Warrego ironstone lodes have an unusual plunging attitude, and the sediment and cleavage orientations in the Warrego area are highly anomalous. A simple 90° anticlockwise rotation about a horizontal axis of the block hosting the Warrego mine restores structural elements to typical goldfield attitudes, and the ironstone lode to a horizontal,
east-west alignment where alteration is now concentrated below the lode. Rotation of the block during intrusion of the Warrego Granite is suggested.

Ironstone lode formation is localised at the lower contact of the quartz porphyry which is believed to have acted as an impermeable barrier to the flow of hydrothermal fluids. Fluids appear to have been channelled to the site of deposition by a cleavage-parallel fault generated during folding of the relatively rigid porphyry, and then migrated laterally below the contact, progressively replacing the sediments with chlorite, magnetite and quartz. Textural and trace element data are consistent with a replacement model of lode formation, although some open space filling is likely. Reaction of hydrothermal fluids with cooler more oxidised waters appears to be the most likely method of promoting magnetite deposition, which was initially localised as a front against the relatively unaltered sediments. Continuous fracturing and infilling of this zone by quartz and magnetite during lode formation has resulted in the observed zonation from a magnetite core to an outer quartz-magnetite rim.

Evolution of the system through the tapping of deeper, hotter and more reduced fluids is associated with the subsequent introduction of economic mineralisation. This evolution of the system is possibly related to the intrusion of granite at depth and subsequent establishment of a convecting hydrothermal system. A direct magmatic contribution to the fluid in the form of fluids and/or metals cannot be ruled out.

Two styles of mineralisation are evident:

1. The copper orebodies are characterised by a sulphide-rich assemblage comprising chalcopyrite, pyrite, pyrite/marcasite (after pyrrhotite) and cobalt-rich phases localised within the brecciated core of the ironstone lode. An outer zone of relatively barren quartz-magnetite surrounds the mineralised core. This zonation and mineral assemblage is virtually identical to that reported for the Peko mine (Whittle, 1966).

2. Localised within two distinct zones on the footwall side of the ironstone lodes, a sulphide-poor, chloride- and muscovite-rich mineral assemblage is characteristic of that described in the Juno mine (Large, 1974, 1975). Similarly there is a well-developed zonation in metals (Au → Bi → Cu), bismuth sulphosalts (decreasing Se/Pb), and mineralogy (magnetite–chlorite–muscovite → magnetite sulphide → quartz–magnetite).

Both styles of mineralisation fill fractures without evidence of replacement or alteration of the ironstone lode.

The two styles of mineralisation are interpreted to result from the late-stage overprinting of the copper-rich assemblage by the gold pods which is associated with the oxidation of pyrrhotite. Support for this interpretation is derived from the mixed sulphur isotope signature throughout the ironstone lode, and different chlorite chemistry in the two assemblages. Recrystallisation associated with the intrusion of the Warrego Granite has destroyed textural evidence which might support this interpretation.
Oxygen and hydrogen isotope results suggest that the fluid source for both ironstone lode formation and mineralisation was formation waters. A consistent difference in isotopic composition between barren and mineralised systems results from a 100°C temperature difference between the two stages which is in agreement with fluid inclusion evidence. Lead and sulphur isotopes, and trace element modelling indicate that although relatively localised leaching of the Warramunga Group is sufficient to produce the ironstone lodes, leaching of significantly larger volumes of rocks is required to produce the observed metal abundances.

Fluid inclusion evidence in other mineralised ironstone lodes consistently indicates phase separation occurred with economic mineralisation, and a model whereby pressure release associated with fracturing of the ironstone lode has resulted in destabilisation of metal complexes in solution to promote their rapid deposition is preferred.