GEOCHEMICAL AND MINERALOGICAL STUDIES OF THE TRENCH TUNGSTEN DEPOSIT, MOUNT MULGINE, WESTERN AUSTRALIA

by

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To my dear parents who have set a
good example of "holding on".

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This thesis contains no material which has been accepted for the award of any other degree or diploma in any University, nor to the best of my knowledge and belief, does it contain any material previously published or written by another person, except where due reference is made in the text.

SUMMARY

The Trench deposit is one of two granite-associated W-Mo deposits at Mount Mulgine, Western Australia. Although only 1.5 km apart, the two deposits are of different style - the Trench deposit essentially comprises a mineralized system of quartz veins in a sequence of interlayered ultramafic to felsic greenstones, banded iron formations and extensively greisenised sills, while the other deposit, known as the Hill deposit comprises a mineralized quartz-muscovite greisen at the contact of the Mount Mulgine Granite and the surrounding mafic country rocks.

The two deposits have been actively explored, especially in the last eleven years, but there has been little previous research work. This study has been concerned with the Trench deposit.

The presence of hornblende(and its composition)and of calcic plagioclase indicate that the host rocks attained medium grade (amphibolite facies) metamorphism. The rocks have since suffered retrograde metamorphism as evidenced by abundant epidote after plagioclase, chlorite after biotite and actinolite after pyroxene. Mineralogical and fluid inclusion evidence is consistent with a peak metamorphic temperature of about 500^{o}C. The Si^{+4} content of muscovites, the Al content of hornblende and the FeS content of sphalerites, coupled with estimates of the thickness of the volcanic-sedimentary pile and lack of pressure indicator minerals at Mount Mulgine, suggest that the pressure during metamorphism must have been at least 2 kb but less than about 4 kb.

The metamorphic changes and hydrothermal alteration (including K- metasomatism) have modified or destroyed original rock mineralogies and textures, but studies of "immobile" trace elements have shown that the original rocks were tholeiitic basalts. Although these Archaean greenstones resemble present-day island arc tholeiites and mid-oceanic ridge basalts (MORB), they are unlikely to have formed in environments similar to those of their modern equivalents.

Comparing the Mount Mulgine greenstones with similar rocks elsewhere, it is clear that the elements K, Mg, Fe, Si and possibly Mn were added to, while Na, Al, Ca and P were partly subtracted from, the rocks at Mount Mulgine.

The host rocks are chiefly composed of quartz, epidote, actinolite, hornblende, tremolite, biotite, phlogopite, muscovite, plagioclase, K-feldspars, carbonates, sericite, talc, chlorite, diopside and minor apatite, (altered) olivine, spessartine, andradite, and chrysotile. The mineralization (mainly epigenetic minerals) includes scheelite, huebnerite, molybdenite, pyrite, pyrrhotite, magnetite, chromite, tetrahedrite, fluorite, sphalerite, arseno-

pyrite, chalcopyrite, rutile, stibnite, pyrargyrite, native bismuth and antimony and other minor oxides or sulphides of Pb, Bi, U, Fe, Ti, As, Cu, Ni and Sb.

Fluid inclusion studies support the view, derived from quartz-vein relationships and textural evidence, that there were several mineralizing solutions. The spatial relationship between molybdenite and scheelite and the fact that scheelite is Mo-free are believed to be due to deposition of these minerals from different solutions. Different generations of fluids are also believed to be partly responsible for the many types of inclusions observed and the range of the fluid inclusion data obtained.

Some fluid inclusions have abundant daughter minerals. This, plus the very low first and final melting points (e.g., $-76^{o}C$ and $-49^{o}C$ respectively) of some inclusions imply that major amounts of other cations, in addition to Na, are present in the inclusion fluids. This was confirmed by leaching and analysis of the fluids which showed them to be rich in Ca, Na, Mg, K and Fe (in decreasing order of abundance). Although Al and Li were not detected in the fluid inclusion leach analyses, there is evidence that these elements were also present in the mineralizing solutions. The dominant anion is chlorine. Some inclusions are CO_2-rich, but there is no apparent relationship between mineralization and the CO_2-rich fluids. Scheelite was apparently deposited from slightly alkaline, moderately saline (average 26 wt.% $CaCl_2$ equivalent) solutions at temperatures of around $400^{o}C$.

$\delta^{34}S$ values of pyrite and pyrrhotite are close to zero per mil with a mean of 0.4 per mil and a standard deviation of 0.6. This is interpreted to mean that the sulphur had a magmatic source, which is consistent with the mineralization having been derived from the Mount Mulgine Granite. Sulphur isotope fractionation between coexisting pyrite and pyrrhotite indicates that the sulphides formed in the $385^{o}C$-$730^{o}C$ range and this is in fair agreement with the temperature range obtained from fluid inclusion studies viz. 300-$500^{o}C$. The As content of arsenopyrite and the Na and Ti contents of hornblende suggest similar temperatures.

Tungsten mineralization in the Trench deposit is clearly closely associated with quartz veins and no lithological control has been established. The quartz veins mostly formed in fractures which initially acted as channelways for the mineralizing solutions. The fractures themselves are believed to have formed mainly during regional folding and/or during the intrusion of the granites. Scheelite precipitation is considered to have been largely controlled by temperature conditions and appears to have occurred during regional metamorphism.

The Trench deposit is not strata-bound although the meta-volcanic sedimentary host rocks are similar to those of the strata- and time-bound (Early Palaeozoic) Felbertal W deposit in Austria. The fluid inclusion and sulphur isotope data are also very similar to those of many W deposits of various types.

In spite of the absence of carbonate rocks at Mount Mulgine, the mineralogy of the Trench deposit is similar to that of typical W skarn deposits (e.g., the scheelite deposits in the Bindal area, northern Norway, and in San Luis, Argentina). The development of the Trench deposit mineral assemblages appears to have been a function of both hydrothermal processes and metamorphism.

Tungsten deposits in the Archaean are rare and, at present, there are no known deposits of this age which are comparable in size to the Trench deposit.

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