The geology, timing of mineralisation, and genesis of the Menninnie Dam Zn–Pb–Ag deposit, Eyre Peninsula, South Australia

Michael W. Roache MSc (Hons)

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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, to the best of the author's knowledge and belief, contains no material previously published or written by another person, except where due reference is made in the text of the thesis.

Michael W Roache

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Frontispiece: View looking south along the 10000 mE base line of the Menninnie Dam Pb - Zn - Ag prospect. The road to riches, or the road to nowhere?
Abstract

The Menninnie Dam Pb - Zn - Ag deposit is located on the northern Eyre Peninsula of South Australia, approximately 1-2 km south of the main mass of the Gawler Range Volcanics. The deposit has no surface expression and was located by drilling of aeromagnetic anomalies in deeply weathered, flat lying terrain. Mineralisation occurs over ~ 3 km strike and is hosted by upper amphibolite facies (~ 700°C and 7 kbars) marbles and diopside-rich calc-silicate lithologies, correlated with the Katunga Dolomite and lower units of the Cook Gap Schist of the Middleback Subgroup, a subdivision of the Hutchison Group (1964 - 1845 Ma.). The Katunga Dolomite is bound to the west by a shear zone (> 50 m wide) formed during the latter stages of the Kimban Orogeny (1740 - 1710 Ma.). Syn-deformation granite dykes intruded into the shear zone, and, to a lesser extent, into the Katunga Dolomite and Cook Gap Schist. Late tectonic pegmatite dykes intruded into the Katunga Dolomite and lower units of the Cook Gap Schist, where they produced zones of K-feldspar - calc-silicate metasomatism.

Previous researchers have incorrectly suggested that the Menninnie Dam Pb - Zn - Ag deposit is a Broken Hill-type. However, Pb - Zn - Ag mineralisation post-dates metamorphism, deformation and metasomatism and has replaced the host marble, and to a lesser extent, diopside-rich calc-silicate lithologies. On the basis of lithologic relationships, most mineralisation formed within 100 - 600m of the palaeosurface, and resulted in a central zone of stockwork and matrix to marble and calc-silicate breccias, flanked by veins. Sulphide and gangue minerals consist of a simple assemblage of pyrite, quartz, sphalerite, galena and Ca-Mn-Mg-Fe carbonate, with accessory chalcopyrite, chlorite, adularia, sericite, fluorite, rhodonite, talc, phlogopite, dolomite, hematite and matildite. Three paragenetic stages of mineralisation are present with an early pyrite stage, followed by a sphalerite galena, and late pyrite stages. Metal abundances have a bell-shaped distribution along the length of the deposit and the highest values are associated with the zone of stockwork and breccia mineralisation.

Post metamorphic, porphyritic rhyolite intruded the Hutchison Group, and interacted with (heated?) groundwater resulting in explosive fragmentation of the host rocks and formation of polymictic breccia pipes. Some of these erupted onto the palaeosurface and formed layered polymictic breccias. Rhyolite continued to intrude through polymictic breccia pipes, and resulted in formation of peperite at the margins. Some rhyolite intrusions erupted onto the palaeosurface and formed volcanic breccias and rhyolite lavas. Polymictic breccias contain clasts of paragenetically early sulphide and gangue minerals, and have an altered matrix that includes paragenetically late sulphide minerals, indicative of syn-mineralisation emplacement. U-Pb zircon dating of the rhyolite intrusions constrains the timing of mineralisation to 1594 ± 7 Ma. which is indistinguishable from that determined for the Hiltaba Suite granitoids and co-magmatic Gawler Range Volcanics.
Modelling of regional gravity and aeromagnetic data indicates the Menninnie Dam deposit lies near the north-western margin of a 20 km diameter Hiltaba Suite granite that intruded to within 1 - 3 km of the palaeo-surface. Lead was derived from the underlying Hiltaba Suite granite and leached from Cook Gap Schist. Lead isotope ratios have a spatial distribution on a prospect scale, and the least radiogenic ratios correspond with the highest metal values and the central zone of stockwork and breccia style mineralisation, consistent with a single zone of fluid up-flow. Carbonate gangue is interpreted to have precipitated via interaction of the mineralising fluid ($\delta^{18}O = -2.0\%o; \delta^{13}C = -6.9\%o$) in equilibrium with $H_2CO_3(aq)$ ($> 0.01$ molal) and the host marbles ($\delta^{18}O = 15.5$ to $21.09\%o; \delta^{13}C = -1.1$ to $1.6\%o$) between 200° and 125°C. Hydrous phyllosilicates associated with mineralisation have calculated fluid values of $\delta^{18}O = -0.7$ to $-2.0\%o$ and $\deltaD = -43$ to $-48\%o$, indicative of a mixed meteoric - magmatic origin for the mineralising fluids. Sulphide $\delta^{34}S$ values range from -3.0 to 8.2‰, with most between 4 to 6‰. The lack of evidence for sulphur isotope fractionation between different sulphide minerals is consistent with non-equilibrium precipitation of sulphides from a reduced fluid, low temperature kinetic effects and / or a $H_2S : metal$ ratio $\geq 1$. Sulphur was sourced from either the magma, the country rocks, or a combination of both.

Primary fluid inclusions hosted by sphalerite and quartz have a range of trapping temperatures and salinities interpreted to have resulted from mixing of $\approx 140^\circ C$ and $\approx 27$ wt.% $NaCl$ equivalent Na-Ca-K-Cl brine with a $\approx 180^\circ C$ dilute chloride water. Thermodynamic modelling has shown that sufficient concentrations of Pb and Zn ($> 1$ ppm) can be transported together with reduced sulphur ($\Sigma S = 0.002$ molal) in a low temperature ($150^\circ C$) saline brine ($\approx 6$ molal) to form the Menninnie Dam deposit. The physiochemical attributes of the mineralising fluid at $150^\circ C$ are estimated to have been $\log fO_2 = -46$ and $pH = 4.6$. Dilution through mixing with heated groundwater was a possible base metal depositional mechanism but is predicted to have been less effective than the $pH$ increase that resulted from dissolution of the host marbles.

Soon after cessation of the mineralising event, the stratigraphy was mantled by a single cooling unit $> 260$ m thick of lithic-rich ($\approx 45\%$ and up to $20$ m across) welded ignimbrite (MD ignimbrite). The thickness, abundance and size of lithic clasts in the MD ignimbrite, and shallow intrusion of granite are consistent with an intracaldera setting. Following welding and cooling of the MD ignimbrite, the lower part of the MD ignimbrite and the Hutchison Group near the southern end of the Menninnie Dam deposit were partially altered to a texturally destructive quartz - chlorite - carbonate - calc-silicate assemblage by a hot, low salinity water ($190 - 356^\circ C$ and $0 - 3$ wt. $% NaCl$ equiv.). Carbon, hydrogen, and oxygen isotopes are consistent with a meteoric water that had undergone partial isotopic exchange with igneous rocks. Mineral textures, whole rock geochemistry, lead and sulphur isotope data are consistent with the Menninnie Dam Pb - Zn - Ag mineralisation being partially dissolved and reprecipitated by this event, with no addition of metals or sulphur.
My thanks go to my partner, Margaret for her love, patience and support throughout the course of this thesis.

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