CHAPTER 2 South Australian exploration analogues and key exploration targets

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INTRODUCTION

The type deposit for giant Proterozoic iron oxide – Cu–Au mineralised systems is the giant Olympic Dam Cu–U–Au–Ag–REE orebody in South Australia. Similarly, a large segment of the geological terrain that hosts the giant Broken Hill Pb–Zn–Ag orebody lies within South Australia. These are world-class examples of orebodies that should form part of the portfolio of any base metal explorer. The recent discovery of the Prominent Hill prospect by Minotaur Resources, after 27-years exploration by many companies in the Olympic Dam and Mount Woods regions, indicates that success may be slow, but persistence pays off. The Prominent Hill discovery confirms that economic Olympic Dam style mineralisation is not confined to Olympic Dam itself.

South Australia has great exploration potential, but thin sedimentary cover has delayed success. Exploration activity has been traditionally model driven because of poor outcrop. A greater understanding of local mineralised geological terranes, as well as carefully selected examples from elsewhere in Australia and internationally, will encourage focused successful exploration and reduce the risk inherent in early stage exploration (Fig. 2.1).

OLYMPIC DAM (Cu–U–Au–Ag–REE)

600 Mt at 1.8% Cu, 0.5 kg/t U_3O_8, 0.5 g/t Au and 3.6 g/t Ag within a resource of >2300 Mt containing ~30 Mt Cu, 930 000 t U_3O_8, 1200 t Au, 6700 t Ag and ~10 Mt REE (principally La and Eu), with an average total iron content of 26% (Reynolds, 2000).

Iron-rich mineralised hydrothermal fluids, associated with widespread, comagmatic, Gawler Range Volcanics and Hiltaba Suite magmatism, have extensively altered the eastern margin of the Gawler Craton from the Peake and Denison Ranges in the north to the Moonta–Wallaroo region on Yorke Peninsula in the south. Altered rocks include deformed Palaeoproterozoic sediments and granites as well as Mesoproterozoic Hiltaba Suite, Gawler Range Volcanics and interbedded sediments.

The Olympic Dam orebody is wholly contained within the Olympic Dam Breccia Complex, a zoned breccia system derived from, and hosted by, Roxby Downs Granite (Reeve et al., 1990). The breccia body is broadly funnel shaped and elongated in a northwesterly direction. The central core of barren haematite–quartz breccia is intruded by diatremes and dykes and surrounded by mineralised haematite-rich breccias. The outer zone consists of variably brecciated, variably altered Roxby Downs Granite. The central core and mineralised breccias are ~3x3.5 km (in plan) with a northwesterly arm 3 km long and 300–500 m wide. Individual breccia bodies in the northern and northwestern parts of the breccia complex (where more information is available) also trend northwesterly and dip steeply, reflecting larger scale contemporaneous strike slip faulting (Sugden and Cross, 1991).

Breccia types range from wholly granite-rich to haematite rich and are very complex due to polycyclic brecciation and alteration by hot iron-rich fluid. Ore is richest in heterolithic haematite breccias, which contain a wide variety of haematite clasts with different textures and grain sizes, indicative of many phases of brecciation and alteration. Copper grades are typically 1–5% and gold 0.3–1 g/t, although zones of gold enrichment occur locally. Uranium (pitchblende) is usually associated with copper mineralisation. Throughout the deposit, ore is broadly zoned in an irregular funnel-shaped distribution, which dips more steeply towards the central barren core. A relatively sharp interface exists between the bornite±chalcocite and chalcopyrite±pyrite mineralisation. This interface is believed to reflect contact between upwelling hot, reduced iron-rich fluid and colder oxygenated water (Reeve et al., 1990; Haynes et al., 1995). Flame-like irregularities in this surface extend vertically up to 100 m above the underlying chalcopyrite±pyrite mineralisation, possibly representing high-pressure jets.

The Olympic Dam deposit is interpreted to have formed in an active hydrothermal system with contemporaneous magmatism and seismic activity (Reeve et al., 1990). The alteration envelope is extensive and dominated by sericite and iron oxide. Persistent phreatomagmatic venting accompanied by brecciation produced a composite nested crater in which phreatic and volcanic debris was deposited. The floor periodically collapsed, presumably during phreatic and/or phreatomagmatic activity, so that discrete blocks of finely laminated crater sediments and ash were incorporated in breccias (Reeve et al., 1990).

Metal precipitation is believed to be a direct result from the mixing of hot reduced iron-rich fluids and cooler oxygenated surface waters (Reeve et al., 1990; Cross et al., 1993; Haynes et al., 1995). Sulphide zoning within the deposit, with pyrite at depth followed by chalcopyrite, bornite and chalcocite nearer to surface, indicates that the increase in oxidation state towards the upper part of the deposit is consistent with the presence of surficial oxidising water.

Haynes et al. (1995) inferred from thermodynamic modelling that metals may have been leached from overlying Gawler Range Volcanics basalts and precipitated on contact with hot, reduced, iron-bearing magmatic fluids. This scenario appears unnecessarily complex requiring basalts as a source metals for mineralised iron oxide deposits elsewhere in the Gawler Craton. Haynes et al. (1995), however, did concede that very hot reduced magmatically derived iron-rich fluids could have transported U, Cu and Au. Ore would then have been precipitated on contact with cooler sulphate-bearing surficial water. Both models are considered and discussed in detail by Johnson (1993). WMC sulphur isotope data (Eldridge and Danti, 1994) and unpublished fluid inclusion data (K. Ehrig, WMC, pers. comm., 2002) support a magmatic source for the hydrothermal fluids and metals.

Fluid inclusion and stable isotope data (Roberts and Hudson, 1983; Conan-Davies, 1987; Oreskes and Einaudi, 1990, 1992) and sheet silicate geothermometry (WMC unpublished data) indicate that ore was deposited over a range of temperatures of 150–350 °C. Neodymium isotopic signatures of ore indicate a significant mantle source inferring that mantle-derived rocks or magmas strongly influenced fluid compositions. These data also indicate that the host Roxby Downs Granite or related plutons were not the dominant source for mineralising fluids (Johnson and Cross, 1991; Johnson and McCulloch, 1995). Interestingly the source of the Olympic Dam magnetic anomaly has not been intersected.

U–Pb geochronology of the Roxby Downs Granite, felsic dykes that intrude mineralised haematite breccia and tuffaceous material from a crosscutting diatreme all have ages within error of the host granite ~1590 Ma (Johnson, 1993) and the comagmatic Gawler Range Volcanics (Fanning et al., 1988).

The Olympic Dam deposit was later eroded and covered by >300 m of flat-lying Neoproterozoic and Cambrian sediments, these too being locally significantly mineralised.

POSSIBLE TECTONIC MODELS

The tectonic setting that influenced the site of the Olympic Dam orebody remains open for debate. Many researchers have inferred that Olympic Dam is directly associated with heating of the continental crust and introduction of metal by a mantle plume (Giles, 1988; Reeve et al., 1990; Flint in Blissett et al., 1993). More recent work by Fanning et. al. (1996) indicated that the Gawler Craton was co-joined with the East Antarctic Craton at 1750–1700 Ma. The resultant large crustal plate (Mawson Continent) likely slowed mantle cooling, so that a mantle plume gradually stoped upwards as the overlying crust was weakened by heating. The mantle plume was in place sufficiently long enough to induce widespread crustal melting. Large volumes of predominantly acid to intermediate magma were emplaced in the central and eastern Gawler Craton. Intense iron oxide alteration, possibly coincident with peak mantle stoping, has affected the eastern margin of the Gawler Craton and possibly coincidently the Curnamona Province. Some support for this proposed origin may come from recent work of Romanowicz and Gung (2002) who have reported the possible existence of mantle superplumes under the lithosphere from the study of seismic waves. By mapping seismic wave energy, which is decreased as temperature of the host medium rises, they have been able to infer a hot spot underlying the central Pacific. The central hottest zone 'mapped' is as big as the Australian continent.

An alternative tectonic setting, proposed by Ferris et al. (2002), is a plate margin model. The arcuate nature of the Hiltaba Suite plutons, arc-related chemistry for granitoid belts preceding the Hiltaba event, and intense iron oxide alteration focused on the eastern Gawler Craton may indicate a fundamental tectonic margin that could be interpreted as a plate boundary. This interpretation proposes an alternative model to the largely anorogenic setting for emplacement of the Hiltaba Suite, an intracontinental, extensional back-arc, located behind a northeast-dipping subduction zone, south of the Nuyts Domain, which produced the arc-related magmatism of the St Peters Suite (Ferris et al., 2002).

EXPLORATION ANALOGUE

Exploration potential within the Gawler Craton is high due to the increasing evidence of mineral endowment and the relative low drilling density for a terrain of this calibre. Analogues are likely to be sited on major active faults adjacent to ancient shallow seas or lakes that contained cooler oxygenated water necessary to precipitate ore. The highly iron-oxide-altered host will be brecciated by multiphase fluids and contain evidence of persistent Gawler Range volcanism or Hiltaba Suite magmatism (mafic or felsic) intruding possibly a wider variety of rock types than currently known. Faults that precede or were active during Hiltaba magmatism should provide exploration focus. The injection of pulses of magma and associated hot, reduced, ore-bearing fluid accompanied by intense brecciation is considered essential to development of mineralisation because it allows the system to stope to the surface and make contact with oxygenated water. The haematite-rich orebody will have a distinct gravity anomaly and possibly a magnetic anomaly reflecting magnetite and/or mafic–ultramafics at depth.

The recent discovery of the Prominent Hill Cu–U–Au prospect, on the southern margin of the Mount Woods Inlier, appears to fit this model (Carter, 2001 2002). Intense iron oxide and sericite alteration, accompanied by brecciation, of contemporaneous volcanics and sediments has occurred with associated emplacement of copper, uranium, gold, silver and rare earth mineralisation. The deposit is dense, with an adjacent magnetic anomaly. Interestingly, the most intensely altered haematite-rich zone is EM responsive (D. Carter, Minotaur, pers. comm., 2002).

A detailed discussion on the geological framework, distribution and controls of FeO–Cu–Au mineralisation in the Gawler Craton is documented in Skirrow et al. (2002).