POONA AND WHEAL HUGHES Cu DEPOSITS, MOONTA, SOUTH AUSTRALIA

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LOCATION

The Poona and Wheal Hughes deposits are approximately 3 km NE of Moonta township at 34º02´24˝S, 137º36´59˝E (Poona) and 34º03´21˝S, 137º36´51˝E (Wheal Hughes); Maitland 1:250 000 map sheet (SI53-12).

DISCOVERY HISTORY

The Moonta-Wallaroo district of northern Yorke Peninsula was an important source of Cu between 1860 and 1923 producing over 350000 t Cu and 2 t Au. The narrow, shear-hosted Cu sulphide lodes are covered by 5-15 m of sedimentary overburden and initial discovery came from recognition of secondary Cu carbonate or chloride in the spoil of wombat burrows. Recent mining operations at Poona and Wheal Hughes (1988-1992) followed a 30-year exploration history in the district by Western Mining Ltd, North Broken Hill Ltd and Broken Hill South Ltd. The lodes were located in 1985 using large-loop (1 km) ground TEM survey with follow up 100 m coincident-loop SIROTEM surveys, and close-spaced drilling of conduction anomalies (Williams and Fraser, 1992; Dentith and Cowan, 2003).

PHYSICAL FEATURES AND ENVIRONMENT

The climate in the Moonta area is semi-arid with rainfall of <400 mm per year. Mean minimum and maximum temperatures range from 6-15ºC (July) to 16-30ºC (January). The landscape is a gently undulating depositional plain with relict seif dunes and loamy calcareous soil with widespread shallow calcrete. Prior to the 1860s, the land was covered by open scrub and *Eucalyptus* mallee woodland, now mostly cleared and planted with cereal crops. The Poona and Wheal Hughes mines are in an inter-drainage setting at about 40 m elevation and 4.5 km from the coast (Figure 1).

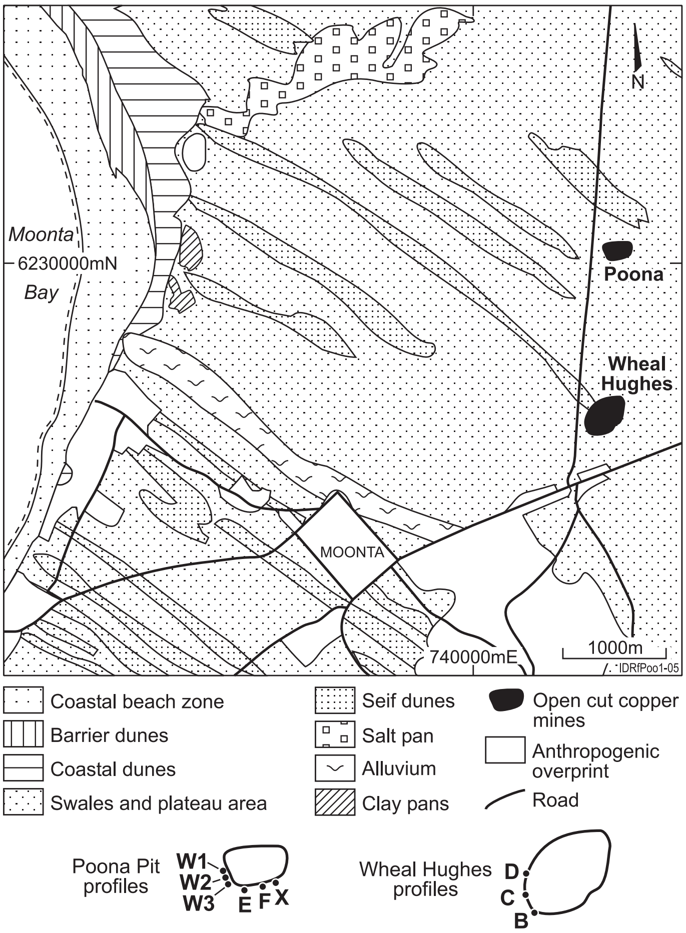

Figure 1. Regolith map of the Moonta district showing principal depositional units and location of the Poona and Wheal Hughes mines (after Hartley, 2000).

GEOLOGICAL SETTING

The Moonta mines, including Poona and Wheal Hughes, are all within Moonta Porphyry, a Palaeoproterozoic, foliated rhyolite to rhyodacite complex. Relict primary textures in the porphyry indicate a sequence of comagmatic ash-flow tuff and tuff breccia with intrusive microgranite (Lemar, 1975). The volcanics intercalate with Wallaroo Group metasediments, including Doora Member schist and calcsilicate which host the Wallaroo Cu deposits, 15 km NE of Moonta. The Palaeoproterozoic rocks were intruded at 1580 Ma by Mesoproterozoic Hiltaba Suite granite, now regarded as the source of heat and fluid that mobilized metal ions to sites of deposition in fractures in Moonta Porphyry to form the Moonta Cu lodes (Conor, 2002).

The older Proterozoic basement is overlain by gently folded to flat-lying sediments that include platform marine deposits of Neoproterozoic Burra and Umberatana Groups, Cambrian Winulta Sandstone and Kulpara Limestone and Tertiary Melton Limestone. Only remnants of these sediments are preserved on the NW Yorke Peninsula beneath Early Pleistocene terrestrial clay, younger carbonate dunes and loamy soil.

REGOLITH

Basement outcrop near Moonta is restricted to the coast at Moonta Bay, where weathered and mottled Hiltaba Suite granite is exposed on the beach platform in unconformable contact with silicified Cambrian sandstone. Here, sections through Pleistocene clay and younger carbonate dunes are also visible in coastal cliffs. The coastal zone north of Moonta Bay includes modern beach and associated dune deposits with saline swamps and clayey alluvium in low-lying areas adjacent to the coast (Figure 1). Inland, the undulating landscape of swale and plateau is covered by loamy calcareous soil that blankets NW-SE trending calcareous dunes and a variable thickness of Pleistocene clay (Hartley, 2000).

In the Poona pit, 0.6 m of calcareous clay loam is developed on 1-2 m thick, calcareous, aeolian sand and silt with platy, nodular and pebbly calcrete. The calcrete overlies 2-4 m of terrestrial red-brown clay showing blocky ped structures and weak mottling. The clay is dominantly mixed illite, smectite and kaolinite, with a variable silt and fine sand content, and is equated with terrestrial lacustrine and overbank deposits of Early Pleistocene Hindmarsh Clay (Zang, 2003). Thin, 20-30 mm wide, alunite seams occur in the clay, some 0.4 m below the contact with overlying carbonates. The clay unconformably overlies Moonta Porphyry that is variably weathered to 15 m, with 4-6 m highly weathered mottled zone (dominantly kaolinite, quartz and Fe oxide-oxyhydroxide megamottles) over variably weathered saprolite and saprock. Palaeomagnetic dating of Fe-rich mottles gives an age of crystallization of the magnetic Fe phase as 8±4 Ma in Late Miocene to Early Pliocene times (Pillans, pers comm., 2004). The weathering front is at approximately the same depth (20 m) as the present water-table (groundwater salinity ~ 42 000 mg/L), but deepens in the ore zone footwall. Here, kaolinitic alteration of the porphyry extends for a further 20 m due to highly acidic conditions from pyrite oxidation (Keeling *et al*., 2003). In fresh porphyry, the joint and fracture surfaces are commonly coated with halloysite to form an envelope around the ore zone extending to 80 m depth (Figure 2) (Mauger *et al*., 1997). The halloysite has precipitated from acidic waters migrating down the shear during periodic lowering of the water-table in response to sea level fluctuations over the past 1 Ma (Keeling *et al*., 2003).

In the Wheal Hughes pit, 1.7 km S of Poona (Figure 1), weathered porphyry is overlain by 1 to 4 m of coarse-grained, arkosic sandstone of the Cambrian Winulta Formation; this, in turn, is overlain by 2-4 m of Hindmarsh Clay and calcrete-cemented aeolian deposits.

MINERALIZATION

At Moonta, mineralized veins and lodes, up to 12 m wide and several hundred metres long, were mined to 650 m depth in Moonta Porphyry. The lodes are mainly tabular veins within fractures and shears that make a series of concentric arcs trending from NNE to ENE. Mineralization includes chalcopyrite, bornite, chalcocite, pyrite, molybdenite, hematite and magnetite, with traces of Au, Ag, Bi, fluorite, fluorapatite and uraninite. The veins have sharply defined contacts with the porphyry wall rock and are pegmatitic with coarse sulphide masses and patches of tourmaline.

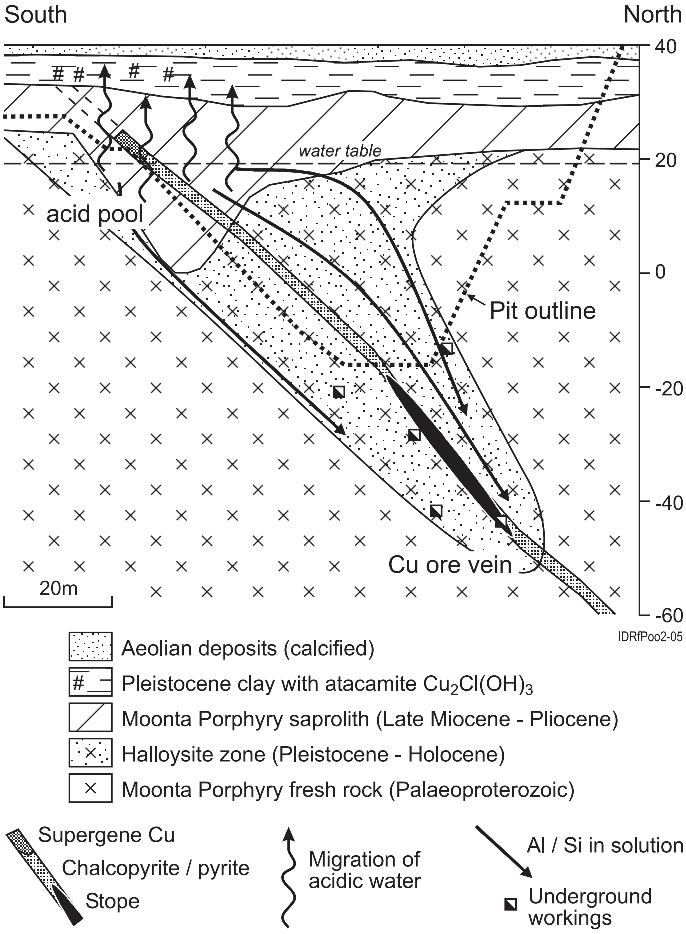

Figure 2. Section through the Poona mine with regolith cover and extent of weathering reconstructed from pre-mining drillhole data and current pit profiles.

The Poona orebody is a thin fissure vein, striking 070°, dipping 50° NW and plunging 22° W. The vein incorporates brecciated and replaced host porphyry and has a strike of some 160 m, terminated by steeply dipping faults. The lode is up to 6 m wide, but averages 3-4 m (Janz, 1990). Primary ore is chalcopyrite and pyrite, with minor bornite and gold. The saprolite is mostly leached of sulphides to 15 m depth, where a 4-5 m thick zone of supergene chalcocite and covellite, with minor digenite, djurleite and native Cu was encountered. The Wheal Hughes orebody includes several ore lenses hosted by a 25 m wide NE-trending shear. The NE part of the deposit, known as Leighton's lode, consists of a single vein separated from the main lode by a cross-cutting fault. Main mineralization is in two parallel veins, 2–5 m wide, trending 045° and 25 m apart, called the 'hanging wall' and 'footwall' lodes. A 'Middle lode' trending at 030° joins the two parallel lodes. Ore was enhanced at the intersection of the 'Middle lode' with the 045° trending lodes. Primary ore is the same as at Poona. Combined production was 18 000 t Cu from 450 000 tonnes of ore grading between 4.6-5.3% Cu and 0.7-1.5 g/t Au (Conor 2002; Both *et al*., 1993).

REGOLITH EXPRESSION

Atacamite ($Cu_2Cl(OH)_3$) in transported clay directly above weathered sulphide ore was recognized in the late 1800s to early 1900s and used to prospect for lodes in the Moonta-Wallaroo district (Jack, 1917). Atacamite was sufficiently concentrated at some sites to warrant treating the clay to extract Cu. Subsequently, Sokoloff (1948) and Mazzucchelli *et al*. (1980) confirmed that Cu in cover sediments is an effective geochemical tool for locating mineralization in the district. The preferred sampling medium is transported clay directly beneath the

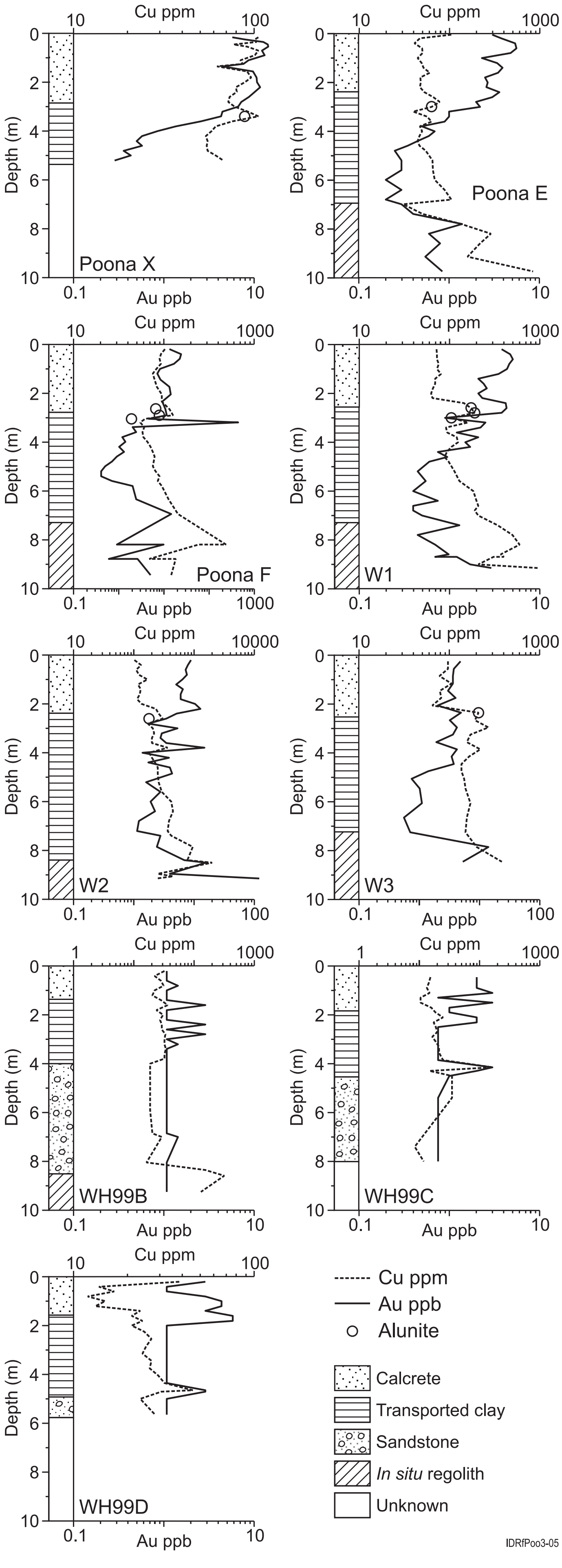

Figure 3. Copper and Au concentrations in sampled profiles at the Poona and Wheal Hughes (WH) mines. Y axis is depth (m), Cu values top (ppm) and Au bottom (ppb) (log scale) (after Hartley, 2000).

calcrete. Adelaide Resources Ltd (Fairclough and Schwarz, 2003) show good areal correlation of calcrete geochemistry with known historic copper lodes. Thresholds in calcrete were determined as Cu =30 ppm and/or Au =3 ppb. Lateral dispersion of Cu and Au in transported cover is of the order of 100 m and makes a useful exploration target for buried copper lodes, provided dispersion has not been impeded.

Detailed (0.2 m) sampling of transported overburden down pit face profiles at Poona and Wheal Hughes (Hartley, 2000, Lintern, 2004) showed, at Poona, elevated Au in calcrete (5-12 ppb). This commonly is at a maximum in the upper platy and nodular carbonate at about 0.5 m, with some decrease in the underlying pebbly to loose pisolitic carbonate. Gold is also anomalous in the upper 0.5–2 m of Hindmarsh Clay directly beneath the calcrete, but decreases to around 1 ppb or less, in the lower clay (Figure 3). Gold increases again at the contact with weathered porphyry. In accord with earlier studies, Cu is greatest at Poona (>80 ppm) in transported clay directly below or within 1 m of the base of the calcrete zone. This section of clay also includes thin alunite layers that are Cu rich. Uranium (to 36 ppm) and rare earth elements (Ce, La, Sm, Nd) are also enriched in this level of the clay (Hartley, 2000). Throughout the carbonate zone and transported clay at Poona, Cu consistently is anomalous (above 30 ppm). In contrast, the carbonate and transported clay at the Wheal Hughes mine have much lower Au (<3 ppb) and Cu (<25 ppm) contents. In two profiles (WH99C and D), elevated Cu (max 165 ppm) occurs in a narrow interval at the base of the clay directly above the contact with Cambrian sandstone (Figure 3). Copper and Au remain low throughout the sandstone with Cu increasing at the contact with weathered porphyry (few data recorded) (Hartley, 2000). The occurrence of a thickness of 1-4 m of Cambrian sandstone at Wheal Hughes appears to be an effective barrier to upward dispersion of metal ions from the sulphide ore. The sandstone is more likely to impede hydromorphic dispersion by capillarity or diffusion rather than a rise in groundwater level (Keeling, 2004).

In areas of thin transported cover at Moonta, pedogenic carbonate or clay, directly beneath the carbonate zone, provide useful geochemical sample media for locating Cu sulphide mineralization at depth, provided the orebody extends into the zone of weathering and there are no barriers to dispersion.

DISPERSION MODEL

B*Ca [3]

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SAMPLE MEDIA SUMMARY TABLE

Sample medium	Indicator Elements	Analytical methods	Detection limit (ppm)	Background (ppm)	Maximum anomaly (ppm)	Dispersion distance (m)
Residual Regolith						
Weathered	Cu	ICP-MS[1]	0.5	<50	3500	20-50
bedrock	Au	ICP-MS[2]	0.0005	<0.001	0.070	N/A
Transported Regolith						
Pleistocene	Cu	ICP-MS[1]	0.5	10-20	260	100
clay	Au	ICP-MS[2]	0.0005	<0.0005	0.0086	50-100
	U	ICP-MS[1]	0.02	5	36	n\a
Alunite	Cu	ICP-MS[1]	0.5	<15	270	Distribution uncertain
seam	Au	ICP-MS[2]	0.0005	<0.001	0.005	
	U	ICP-MS[1]	0.02	10	36	
Calcrete	Cu	ICP-MS[1]	0.5	<20	210	100
	Au	ICP-MS[2]	0.0005	<0.002	0.012	50-100

[1] ICP-MS analysis of 0.25g samples after HF/HCl/HNO_3 digest

[2] ICP-MS analysis of 25g samples after 24 h cyanide digest

Note: Data adapted from Hartley (2000) with background and dispersion estimates taking into account data in Mazzucchelli et al., (1980) and unpublished calcrete data by Adelaide Resources Ltd.