PERNATTY LAGOON - MOUNT GUNSON Cu DEPOSITS, SOUTH AUSTRALIA

R.A. Creelman

Gateway Mining Ltd., P.O. Box A278, South Sydney, NSW 1235

LOCATION

Pernatty Lagoon is a large playa on the Stuart Shelf, some 100 km NNE of Port Augusta at its S end, and 25 km from Woomera at its N end. It is 65 km long, and 4-12 km wide (Figure 1). The Cattle Grid orebody occurs on its western edge at 137º08'E, 3º30'S; Torrens (SH 53-16) 1:250 000 map sheet.

DISCOVERY HISTORY

The oxidized Cu mineralization at the Main Open Cut and nearby West Lagoon deposits (Figure 2) was discovered in 1873 with mining commencing in 1875. There has been intermittent mining in the area since.

During the period 1898-1943, approximately 1700 t of Cu and 450 kg of Ag were produced, mainly from oxidized Cu ores at the Main Open Cut, although attempts were made to treat transitional Cu ore from the West Lagoon deposit.

Exploration since 1970 has located two blind orebodies, East Lagoon and Cattle Grid. East Lagoon was found in 1969, concealed beneath 3-5 m of lagoon mud and a sandstone unit along a disconformable contact between the Whyalla Sandstone and the Pandurra Formation (Figure 3). The Cattle Grid orebody has the same geological setting as East Lagoon, but is concealed by dune sand. It was discovered in 1971 by stratigraphic drilling that investigated the Pandurra Disconformity as a major ore control. Although it was detected by IP surveys in 1964 and 1971, the responses were insufficient to warrant follow-up.

From 1970 to 1989, the majority of the production was from sulphide ores. The bulk of production was from 1974 to 1986 when the CSR Company mined the Cattle Grid orebody, producing 127 000 t Cu and 62 t Ag. The Cattle Grid orebody was the most significant (5.1 Mt at 2.44% Cu). Supplementary ore from the Main Open Cut provided approximately 270 000 t at grades similar to those from Cattle Grid. This was mixed transitional and sulphide ore (Tonkin and Creelman, 1990). The Adelaide Chemical Company leached the remaining oxide ore at Main Open Cut from 1986 until 1989. At the close of their operations, in 1989, total production was 149 275 t Cu and 65 t Ag. Leaching of the chalcopyrite ore left in the Cattle Grid Pit started in 2000 and is continuing, but production is not known.

PHYSICAL FEATURES AND ENVIRONMENT

The Pernatty Lagoon environs are semi-desert, with blankets of red dune sand covering most flat areas. The Adelaidean rocks are exposed along the western edge of the playa, where they are marginally higher than the surrounds. North and W of Pernatty Lagoon, there are prominent mesas of younger Adelaidean rocks that rise around 100 m above the plain. The E side of the playa is covered with thick, white- to beige-coloured dunes that contain some crystalline gypsum deflated from the playa.

Close to the mine, the dunes are stabilized by stands of *Acacia* and other desert species. Relief is low, the highest ground is rock outcrop along the western side of Pernatty Lagoon. Inter-dunal clay pans are common nearer the lake shore. Silcrete and some calcrete also occur.

Lake sediments are fine, wet muds whose fluids have ionic strengths ten times that of seawater and are supersaturated with respect to gypsum and halite. Regionally, groundwaters have ionic strengths about one-tenth of the brines (*i.e.*, close to seawater). Some perched water-tables contain fresh water suitable for stock; these are small stores that can be over-pumped in dry times and quickly yield water at gypsum saturation levels.

The semi-arid desert climate has an average annual rainfall of 190 mm. Average temperature ranges are 19-34ºC in January and 6-17ºC in July. Generally, there are only 10 days per year above 40ºC. Rainfall occurs throughout the year, but heavier falls are in late autumn, with some late summer heavy thunderstorms.

GEOLOGICAL SETTING

The Mount Gunson deposits are on the Late Proterozoic Stuart Shelf, an undeformed block of sediments between the Gawler Craton to the W and the folded Adelaide Geosyncline rocks to the E. The Adelaide Geosyncline and the Stuart Shelf are separated by the Torrens Hinge Zone (Figure 1). This includes the Torrens Fault, which runs the length of Lake Torrens, and then S through Port Augusta and into the Spencer Gulf. It is a major geosuture and increases in vertical displacement from N to S (Thomson, 1976).

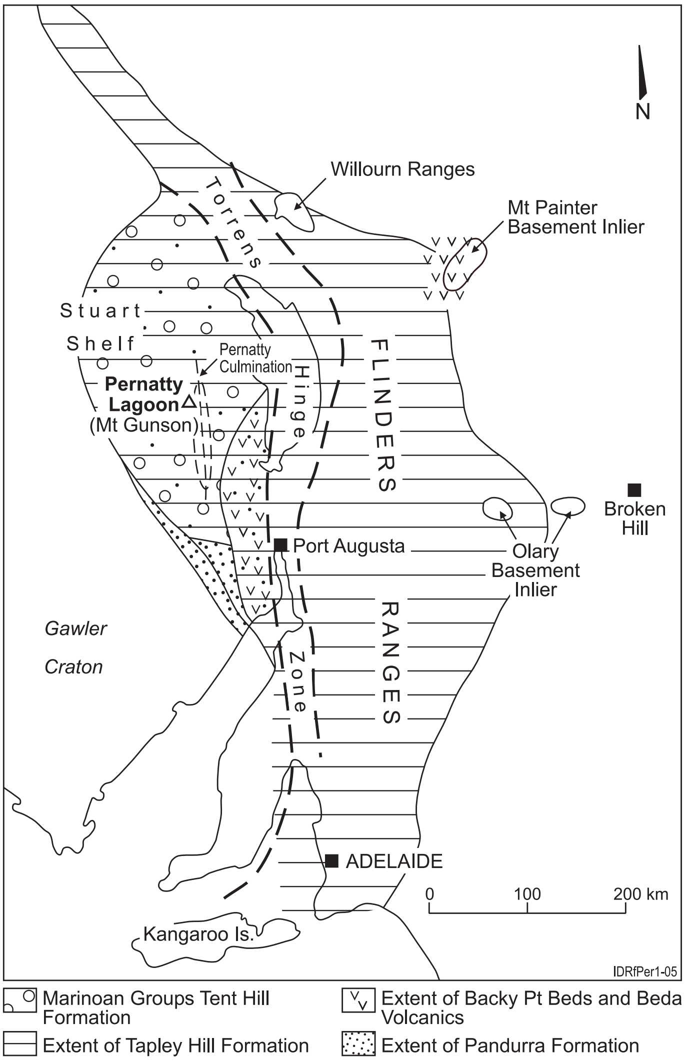

Figure 1. Regional extent of major stratigraphic units of the Stuart Shelf (after Preiss, 1979).

A feature of the Pernatty Lagoon area is the Pernatty Culmination, a complex horst that controlled all sedimentation after the Pandurra Formation. This palaeo-high was on-lapped by Late Proterozoic sediments both from the W and E. There is strong evidence that some later units, particularly volcanics, have been eroded from the Pernatty Culmination.

The Middle Proterozoic Pandurra Formation outcrops along the Pernatty Culmination as an inlier surrounded by Late Proterozoic units (Figure 2). During the hiatus between the deposition of the Pandurra and Tapley Hill formations there was prolonged exposure and weathering when volcanics were erupted and eroded; feeder dykes remain as evidence for this. During the hiatus, there were significant glacial and periglacial events that disrupted the upper Pandurra surface, creating fractures and openings that provided spaces for later mineralization (Williams and Tonkin, 1984). These openings still remain and control all mineralization (Figure 3).

The Late Proterozoic units that on-lap the Pernatty Culmination are the Brighton Limestone (previously called the Woolcalla Dolomite, part of the Tapley Hill Formation), the Whyalla Sandstone, and finally the Woomera (previously called Tregolana) Shale. The carbonate unit occurs E of the mine where is passes under the lake sediments, but is more extensive S of Pernatty Lagoon.

The disconformities are important to mineralization. The major discomformity is between the Whyalla Sandstone and the Pandurra Formation, but also significant are the upper and lower surfaces of the Brighton Limestone (Figure 3).

REGOLITH

The Stuart Shelf generally, and the Mt Gunson area specifically, have little outcrop, restricted drainage, sand cover and high salinity, particularly in and near the playas. All rocks are leached and lack geochemical expression above the water table.

Dune sand covers areas W of the Adelaidean outcrop. The playas cover the rock with fine very saline mud. The top of the mud is leached, but the lower part, immediately above the bedrock, can contain geochemical anomalies.

MINERALIZATION

All ore bodies occur along permeable stratigraphic horizons. Most of these are the disconformities, the most important being the Pandurra-Whyalla disconformity, but there are also sulphide accumulations on the Whyalla-Woolcalla (Brighton Limestone) and Woolcalla-Pandurra disconformities. If the surface of the lower unit has been disrupted, opening the surface by fracturing and brecciation, the open spaces can fill with epigenetic mineralization. In both the East Lagoon and West Lagoon ore bodies and, to a lesser extent, in the Cattle Grid orebody, the Whyalla Sandstone is highly permeable and there is significant mineralization in the Whyalla sandstone matrix (Creelman, 1976; Creelman, 1983; Rattigan, 1990).

The Mount Gunson Copper Deposits are considered to be supergene deposits of metals accumulated by long-term regolith processes

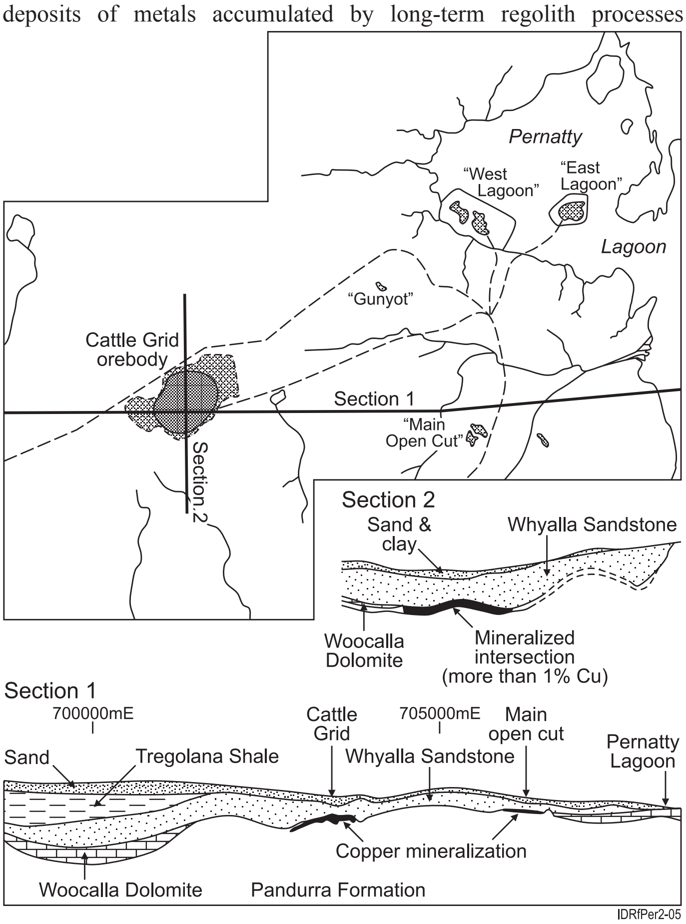

Figure 2. Location of mineralization around Pernatty Lagoon (after Creelman, 1983).

(Creelman, 1983; Tonkin and Creelman, 1990). Knutson *et al.*, (1983) postulated a deep-seated hydrothermal origin, but a reinterpretation of their S and Pb isotope data (Creelman, 1983) did not support this early hypothesis. The metals, derived from volcanic units that have been weathered from the land surface, accumulated in the groundwaters. Anomalous Co and Ni in the ores could imply a mafic rock origin. Sulphur in the ores is the result of recent biogenetic reduction of sulphate from the groundwater in both open and closed depositional systems. For the above reasons, the disposition of the sulphide sheets conform to modern land-surfaces and palaeo-geomorphic features.

All ore bodies are zoned from Cu sulphides to Cu-Fe sulphides. Other minerals in the ore are carrollite (Co, Ni sulphosalt), native Bi, wittichenite (Bi sulphide), sphalerite, and galena. There are appreciable amounts of As in some pyrite, and Ni in the carrollite. Each zone at Cattle Grid can be related to a systematic rise in oxidation conditions passing upwards and outwards from the core (Creelman, 1983). There is strong evidence for repeated dissolution and redeposition that obliterates many earlier assemblages and textures (Creelman, 1976; 1983).

REGOLITH EXPRESSION

The major challenge for the application of surface geochemical sampling at Pernatty Lagoon is the widespread transported cover and the difficulty of differentiating the aeolian cover from soil derived from saprolitic regolith, as the two are intimately mixed. In addition, the outcropping rocks are very strongly leached, and there is little geochemical response in any metal above the permanent water-table. Accordingly, stream sediment and surface rock sampling in the Pernatty Lagoon area was of limited use (see Rattigan *et al.*, 1977). Sampling lake mud revealed geochemical anomalies, but drilling beneath did not find mineralization.

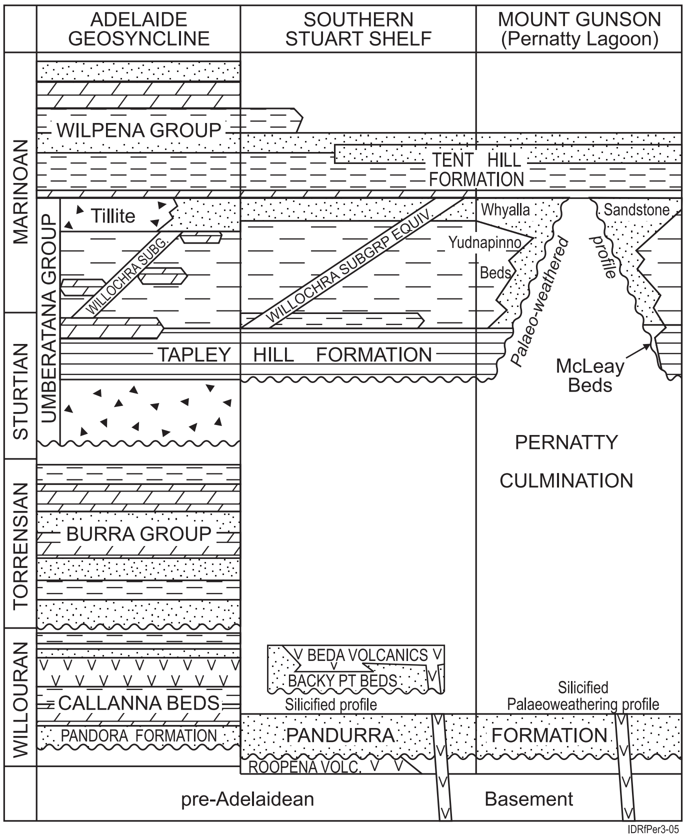

Figure 3. The stratigraphy of the Stuart Shelf and correlations with the Adelaide Geosyncline (after Knutson et al., 1983).

Meaningful dispersion of anomalous Cu in groundwaters around the Cattle Grid orebody was not demonstrated. The most effective geochemical technique for metal dispersion is profile analysis of drill samples. Anomalies occur on the disconformities (Brighton Limestone - Whyalla; Whyalla-Pandurra, and Brighton Limestone - Pandurra; Figure 3). Rocks at the disconformities, particularly the Whyalla-Pandurra disconformity, contained >10 000 ppm Cu and Zn, providing strong indications of mineralization. The earlier exploration suggested that sedimentary sheets, especially mudstones and shales, were effective barriers to upward migration of metals (Rattigan *et al*., 1977), so sampling had to be confined to the permeable sandstone units and disconformities.

Copper and Zn analyses of ashed mulga (*Acacia* spp.) twigs proved to be useful in defining the sandstone-hosted Cattle Grid orebody (Rattigan et al., 1977; Figure 4A). However, over mineralization overlain by shale (Figure 4B), Cu and Zn did not respond; the sampling density was insufficient for the Mo response to be significant.

Erratic high metal concentrations in the shales and mudstones mean anomalous biogeochemical measurements could occur in areas known to lack significant mineralization. Biogeochemistry needs further testing to separate the response of the erratic anomalies from the expression from substantive mineralization.

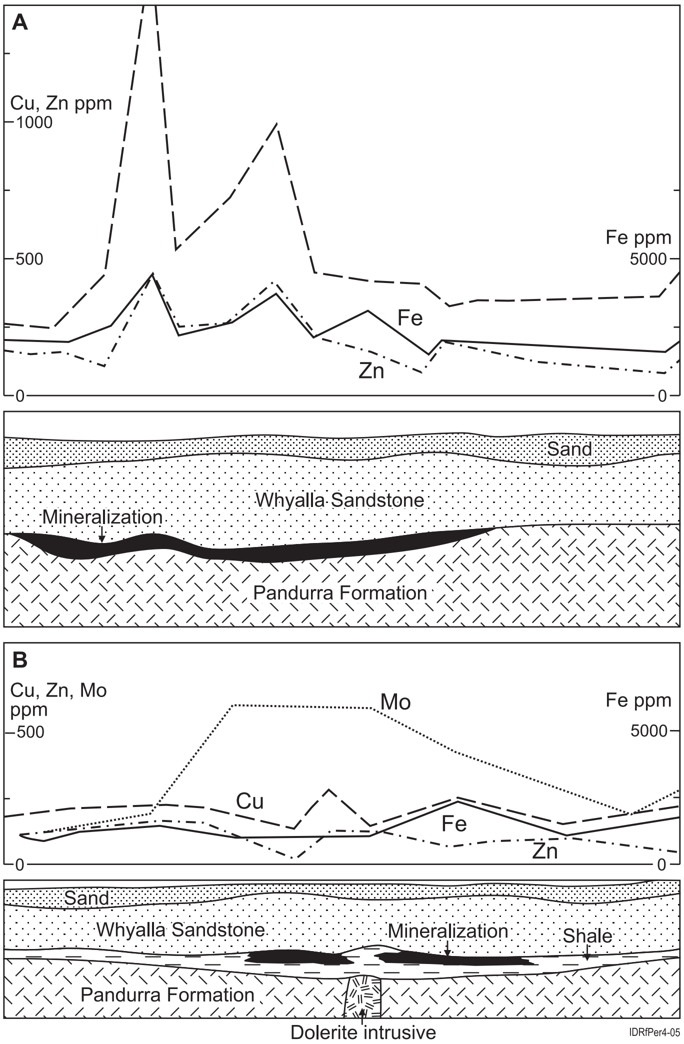

Figure 4. A. Cu, Fe and Zn in mulga twig ash over the sandstone-hosted Cattle Grid orebody. B. Copper, Zn and Fe in mulga twig ash and Mo in myall ash over shale-hosted mineralization near Mt Gunson (after Rattigan et al., 1977).

REFERENCES

Creelman, R.A., 1976. The mineralogy of the Pernatty Lagoon Copper Deposits, South Australia. Proceedings of the Australasian Institute of Mining and Metallurgy, No 257: 259-272.

Creelman, R.A., 1983. A Petrological, Mineralogical and Lead Isotope Study of Copper in Sandstones and related Sediments. Ph.D. Thesis, Macquarie University (unpublished).

Knutson, J., Donnelly, T.H., and Tonkin, D.G., 1983. Geochemical constraints on the genesis of copper mineralization in the Mount Gunson Area, South Australia. Economic Geology, 78: 250-274.

Preiss, W.V., 1979. Adelaidian sedimentation: Adelaide Geosyncline and Stuart Shelf. SADME Report 79/24.

Rattigan, J.H., 1990. The Cattlegrid copper discovery. In: K.R. Glasson and J.H. Rattigan (Editors), Geological Aspects of the discovery of some important mineral deposits in Australia. The Australasian Institute of Mining and Metallurgy, Melbourne. pp 121-124.

Rattigan, J.H., Gersteling, R.W. and Tonkin, D.G., 1977. Exploration geochemistry of the Stuart Shelf, South Australia. In: C.R.M. Butt and I.G.P. Wilding (Editors), Geochemical Exploration 1976. Journal of Geochemical Exploration, 8: 203-217.

Thomson, B.P., 1976. Precambrian geology and tectonics of the Stuart Shelf and Torrens Hinge Zone. In: B.P. Thomson, B. Daily, R.P. Coates and B.G. Forbes (Editors), Late Precambrian and Cambrian Geology of the Adelaide Geosyncline and Stuart Shelf, South Australia. 25th International Geological Congress, Sydney 1976. Excursion Guide 33A. pp.1-11.

Tonkin, D.G., and Creelman, R.A., 1990. Mount Gunson copper deposits. In: F.E. Hughes (Editor), Geology of the Mineral Deposits of Australia and Papua New Guinea. The Australasian Institute of Mining and Metallurgy, Melbourne. pp.1037-1043.

Williams, G.E., and Tonkin, D.G., 1985. Periglacial structures and palaeoclimatic significance of late Precambrian block field in the Cattle Grid copper mine, Mount Gunson, South Australia. Australian Journal of Earth Sciences, 32: 287-300.

SAMPLE MEDIA - SUMMARY TABLE

Sample medium	Indicator elements	Mean (ppm)	Minimum (ppm)	Maximum (ppm)	Dispersion characteristics
Stream Sediments	Cu Pb Zn	N/d N/d N/d	10 20 15	40 30 60	Erratic and of limited value
Rock: Unmineralized	Cu Pb Zn	15 28 33	10 20 5	30 30	Dependent on rock type
Rock: Proximal to mineralization	Cu Pb Zn	N/d N/d N/d	300	$>10^4$	
Lake mud over arenites	Cu Pb Zn	92 16 90			No relationship to mineralization, but to rock type
Lake mud over mudstones and carbonates	Cu Pb Zn	92			No relationship to mineralization
Lake mud over Pandurra Formation	Cu Pb Zn	100 170 260			No relationship to mineralization
Hydro-geochemistry	Cu Pb Zn U3O8	0.092 0.026 0.086 0.006	<0.002 <0.002 <0.002 0.005	0.580 1.600 0.250 0.075	Related to ionic strength of the groundwaters; brines are rich
Bio-geochemistry Cattle Grid	Cu Zn Mo	N/d N/d N/d	200 100 <100	>2000 >400 600	From Mulga twig ash
Bio-geochemistry over mudstone mineralization	Cu Zn Mo	N/d	200 100 100	300 150 600	From Mulga twig ash

From 1970-1990, the commercially available analytical techniques based on AAS and ICP analyses were used – e.g., stream sediments, rock chips and plants by AAS following one hour leach in hot concentrated perchloric acid (Rattigan et al 1977). Since 1990, ICP-MS was used, following mixed acid digestion. Thus, conclusions based on older data may be modified by use of newer techniques. N/d = not determined.