

THE DISTRIBUTION OF PATHFINDER ELEMENTS AT THE NORTH PORTIA PROSPECT, LAKE FROME EMBAYMENT, SOUTH AUSTRALIA

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INTRODUCTION

The North Portia Cu-Au prospect is situated in the Lake Frome embayment in South Australia (Figure 1). The mineralisation is hosted in a buried basement structure called the Benagerie Ridge Magnetic Complex (BRMC), situated in the Curnamona province (Leyh & Conon, 2000).

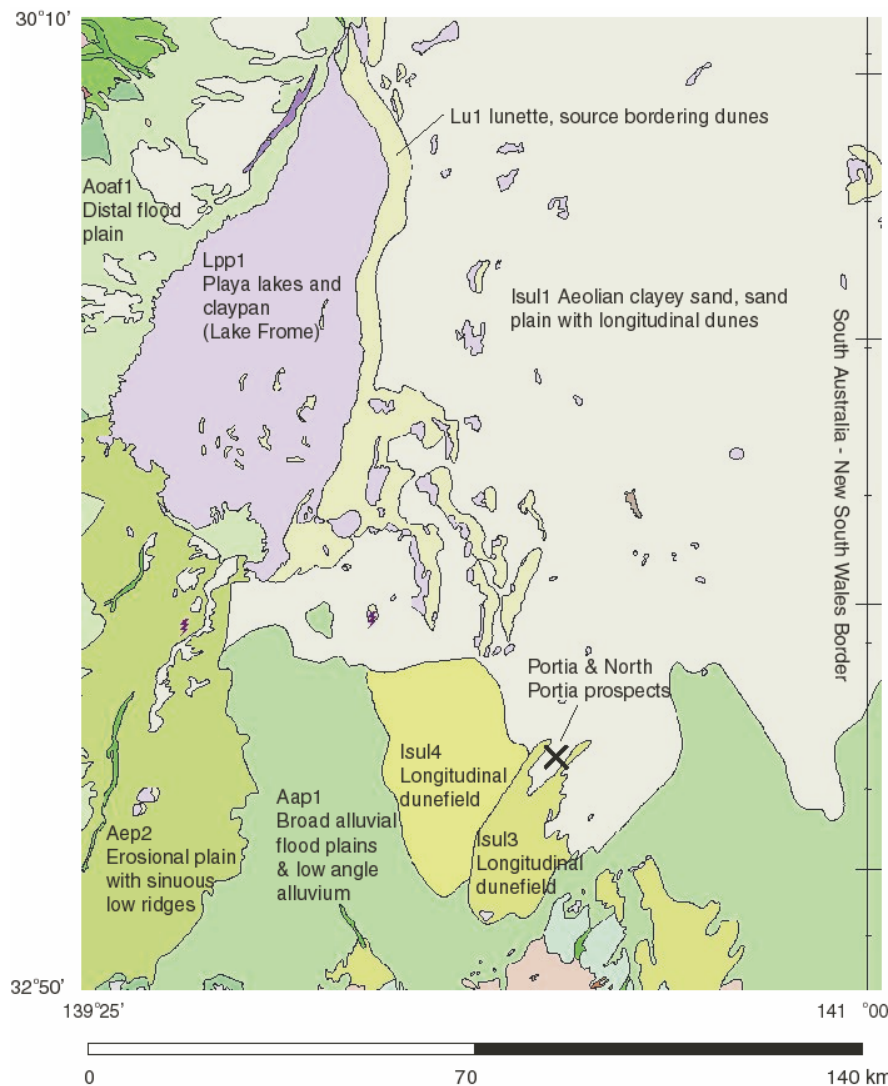


Figure 1: Location of the North Portia prospect on a Curnamona regolith landform map, after Gibson (1999).

The BRMC dips towards the north, and at the prospect, the Proterozoic bedrock and saprolite are overlain by 40 to 70 m of Cainozoic sediments. The saprolite is locally overlain by a palaeo-valley filled with light grey clay and sand, informally named as the Portia Unit (Tan 2001). Olive grey clay and dark grey clay of the lacustrine Namba Formation (Callen 1990) overlies the Portia Unit, and where the latter is absent, directly overlies the saprolite. Quaternary degraded dune and alluvium (Gibson 1999, Gibson & Wilford 1999) overlie the Namba Formation (Figure 2).

This project aims to establish the useful pathfinder elements and their distribution in the Proterozoic saprolite and Cainozoic sediments. Pathfinder elements include all elements associated with mineralisation, or elements unique to certain marker lithology or alteration

assemblage, which can give vector to mineralisation. Useful pathfinder elements in the weathering environment are those that remain in the saprolite and sediments in relatively high abundance (i.e. above detection limits of most chemical analysis techniques such as XRF). These elements rely on adsorption or incorporation into mineral hosts that are in equilibrium with the chemical environment.

GEOLOGY OF THE BASEMENT ROCK AND MINERALISATION

The Proterozoic protolith comprises evaporite, saline mud and organic-rich sediments. During paragenesis

and metasomatism, sodic alteration obliterated the rock matrix to form quartz-albitite and variably altered carbonaceous phyllite (Teale, 1999).

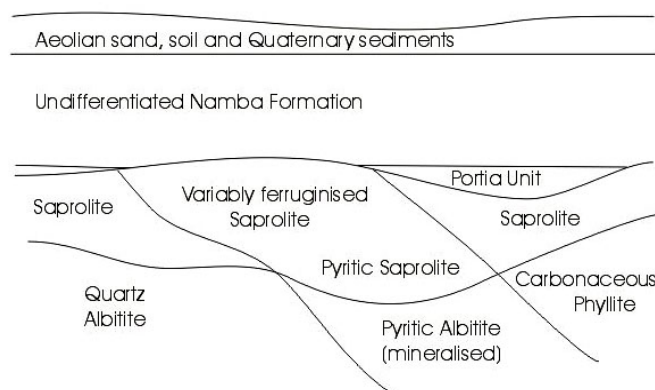


Figure 2: regolith-geology relationships at the North Portia prospect showing the Cainozoic sediments, saprolites and bedrock units.

At North Portia prospect, the geology has been classified into 9 units by Teale (1999) and mainly consists of massive to banded albitite, pyritic albitite, calc-silicate unit and carbonaceous phyllite. The mineralising events are complex, and include early molybdenite and chalcopyrite replacement and infill, crosscutting chalcopyrite-pyrite-fluorite-gold, to late stage molybdenite-chalcopyrite and emplacement of Ba-Pb-Zn-Mo-F in fault structures (Teale, 1999). The refraction of veins and faults through beds of different competency also causes brecciation and allowed the formation of Cu-Au mineralisation. In a broad sense, the Cu-Au mineralisation is associated with the pyritic quartz-albitite.

A range of minerals is present in the Proterozoic bedrock, which includes silicates, carbonates, phosphates, sulphides, sulphates, oxides and native elements. The silicates include quartz, albite, K-feldspars, biotite-phlogopite, chlorite, tremolite, scapolite and tourmaline. The carbonates include calcite, ankerite, dolomite and siderite. The phosphates comprise apatite, monazite, xenotime and other minor REE-phases. The sulphides and sulphate include chalcopyrite, enargite, galena, sphalerite, molybdenite, arsenopyrite, pyrite and barite. The oxides include rutile, anatase, haematite and magnetite, and the native element include argentiferous gold. Fluorite is also locally present. Factor analysis has been used to establish the 9 geochemical groups in the Proterozoic bedrock (Table 1), and elements in the first and third groups are potential useful pathfinder elements.

Table 1: Element groups and their respective host minerals in the Proterozoic bedrock.

Group No.	Associated element groups	Host minerals	Spatial location
1	Cu, Au, Bi, Ag, (Mo) (Pb, As), Co	Argentiferous gold, chalcopyrite, enargite, molybdenite, galena, arsenopyrite, pyrite	Cu-Au-Bi mineralisation with varying amounts of Mo and Ag. Pb and As may represent another mineralisation style associated with carbonaceous phyllite.
2	Ca, Mn, Fe, Mg, (Ce, P)	Calcite, Mn-calcite, ankerite, Mn-ankerite, dolomite, siderite, phlogopite-biotite, chlorite, tourmaline, tremolite, apatite, REE phosphates.	Host rock sequence, footwall and hanging wall.
3	Zn, Cd	Sphalerite	Mineralisation in carbonaceous phyllite.
4	Ba, Sb	Barite, ?pyrite	Sulphide mineralisation.
5	Ba, K, (As)	K-feldspar, micas, ?arsenopyrite	Non-mineralised zones.
6	Na	Albite, scapolite	Throughout the host rock, but predominantly in footwall.
7	Ti, V K, Ti	Rutile, anatase K-feldspar	Throughout the host rock units, more abundant when proximal to K-feldspar?
8	Fe, P, Co	Pyrite, ?REE-phosphate	Sulphide zones throughout the host rock units.
9	Ce	REE phosphates and carbonates	Throughout the host rock sequence, in beds, nodules, ellipsoids, veins and as mineral inclusions.

Note: Elements in parentheses have weaker associations with other elements within the group.

EFFECT OF WEATHERING ON THE DISTRIBUTION OF PATHFINDER ELEMENTS

Preferential weathering of calc-silicate unit and pyritic quartz-albitite, and erosion has resulted in a saprolite with varying thickness (< 10 to > 40 m). Non-pyritic quartz-albitite and carbonaceous phyllite appear to be

less weathered. Prolonged weathering, including post-Cainozoic sedimentation, has removed most primary minerals except quartz, and secondary minerals, mainly phyllosilicates and Fe-oxides, formed. Hence, quartz and kaolinite with various haematite and goethite forming red and brown mottles (Figure 3) dominate the saprolite. Disseminated Fe-oxide box-works (Figure 4), rather than massive gossan, were found in the saprolite, reflecting the disseminated nature of the Cu-Au mineralisation. Proximal to mineralisation and in the lower part of the saprolite under reducing condition (ie. in the saturated zone), pyrite, primary and secondary sulphides are present (Figures 5 and 6).

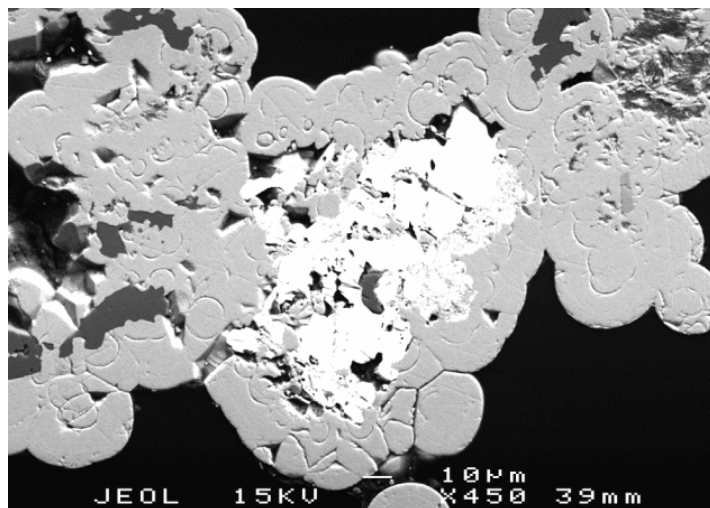


Figure 3 (left): SEM image showing colloform Fe-oxide precipitating around primary REE-phosphate (monazite).

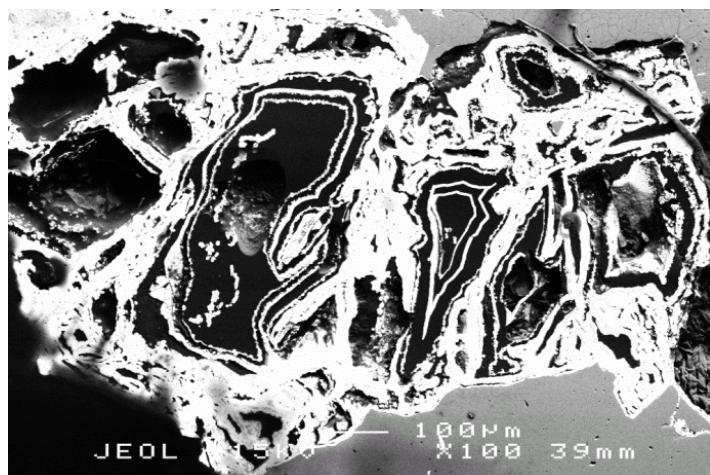


Figure 4 (right): Scanning electron image (SEM) using secondary beam showing disseminated box-work gossan in the ferruginous saprolite.

High concentrations of Cu, Au, Pb, Zn, Mo, As, Ni and Co occur in the mineralised, pyritic, lower saprolite. These elements are hosted in both primary and secondary minerals, eg. chalcopyrite, chalcocite, covellite, native copper, argentiferous gold, molybdenite, arsenopyrite, pyrite (Ni, Co) and sphalerite. In the highly weathered upper saprolite, the concentrations of these elements decrease sharply. Moderate concentrations of Cu, Au, Mo and As are associated with Fe-oxides and retained in the ferruginous saprolite. Pb and Zn are not associated with the Cu-Au mineralisation and the distribution do not appear to be highly associated with ferruginous saprolite. Other elements such as Ag, Bi, Cd and Sb have low concentrations in the bedrock, and the distribution in the saprolite is sporadic. This is partly exacerbated by the high detection limits of the analytical technique (1 ppm for Ag and 5 ppm for Bi, Cd and Sb). These elements may be considered as useful pathfinders if analytical methods with lower detection limits were used.

Amongst the sediments, the Portia Unit contains the highest abundance of trace elements with up to 250 ppm Cu (Figure 7), 0.3 ppm Au, 200 ppm As and 66 ppm Mo. Throughout the remainder of the sedimentary units, these elements are generally below threshold concentrations. Both Ni and Co concentrations remain low (averaging 20 ppm), whereas up to 100 ppm Zn occurs in the smectite-bearing Namba Formation but is interpreted as not deriving from the underlying mineralisation. Towards the base of the Namba Formation, within 10 m of the sediment-saprolite unconformity where the Portia Unit is absent, up to 180 ppm Cu, 0.1 ppm Au, 70 ppm Mo and 110 ppm As occur.

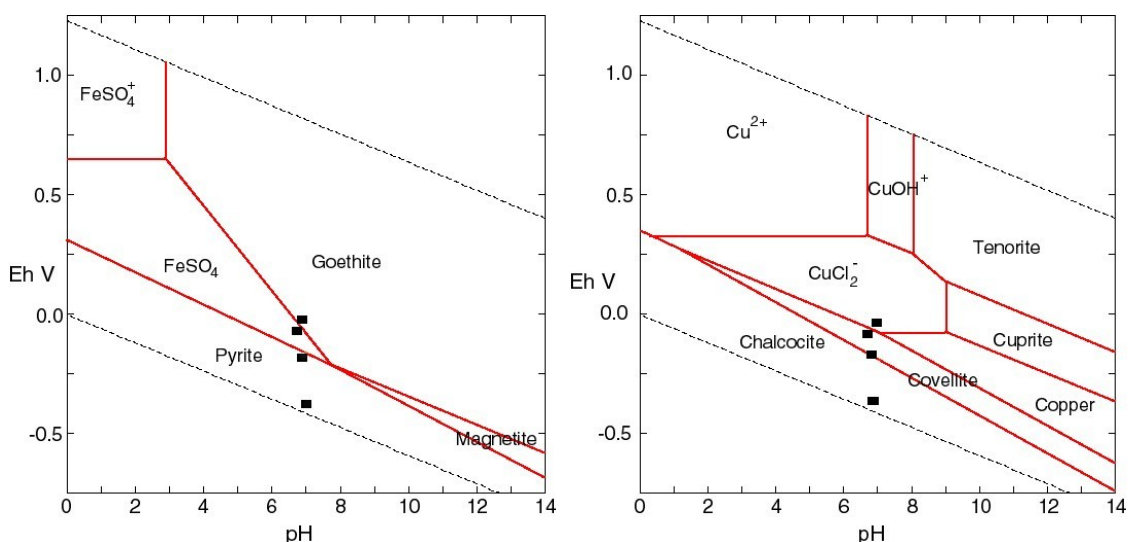


Figure 5 (left): Eh-pH diagram showing the stability field of Fe-bearing minerals (Fe-Cl-S-C-O-H system, $a[\text{Fe}^{2+}] = 10^{-6}$). The 4 rectangles represent groundwater data collected from 4 bores in the Benagerie Ridge region, showing the slight to moderate reducing conditions of the groundwater. The screens of the water bores are located in the saprolite.

Figure 6 (right): Eh-pH diagram showing the stability field of Cu-bearing minerals (Cu-Cl-S-C-O-H system, $a[\text{Cu}^{2+}] = 10^{-7}$). The 4 rectangles represent groundwater data collected from 4 bores in the Benagerie Ridge region, showing the slight to moderate reducing conditions of the groundwater. The screens of the water bores are located in the saprolite.

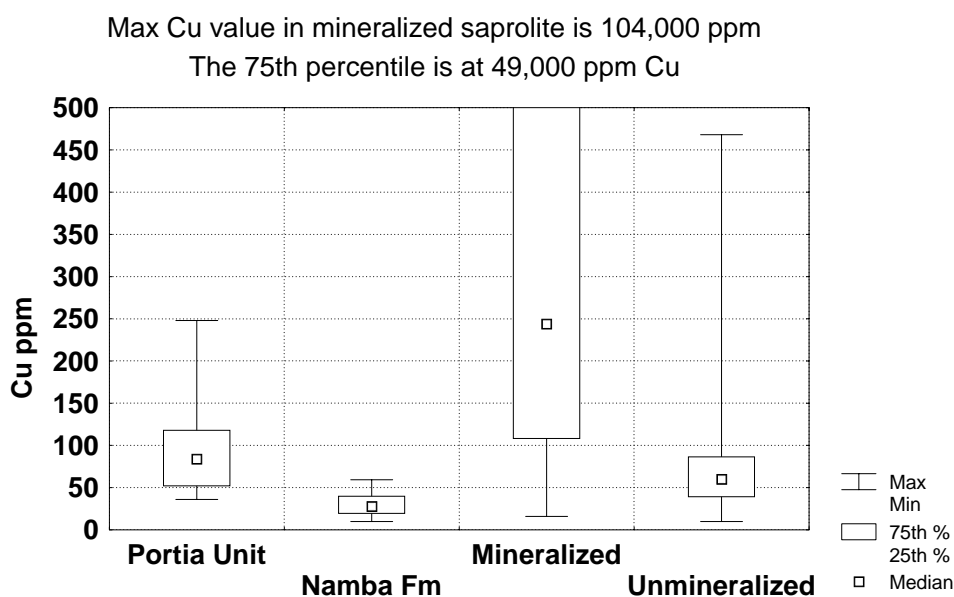


Figure 7: Box and whiskers plot showing the Cu concentrations in the various units, mineralised (pyritic) and unmineralised saprolite, Portia Unit and Namba formation.

IMPLICATION FOR MINERAL EXPLORATION

Amongst the Cainozoic sediments, the Portia Unit offers good sampling medium as the sediment was derived from the saprolite. The lower part of the Namba Formation, when overlies directly on the Proterozoic saprolite, also provides good indication for bedrock mineralisation. Since many of the pathfinder elements are associated with ferruginous saprolite and pyritic saprolite, these saprolites offer good vector to underlying mineralisation. Nevertheless, Au, which is not strictly associated with Fe-oxide, may occur in non-ferruginous saprolite as individual grain or flake. Hence, sample needs to be carefully split and homogenised to minimise the “nugget effect”.

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