

VEGETATION AND SOIL EXPRESSION OF THE JAGUAR BASE METAL DEPOSIT, YILGARN CRATON

R.R. Anand & M. Cornelius

CRC LEME, CSIRO Exploration and Mining, PO Box 1130, Bentley, WA 6102

INTRODUCTION

Most sulphide-rich base metal deposits in the tropics and sub-tropics have been found through the discovery of outcropping gossans or through recognition of the geochemical signature of gossan fragments in soil, lag and stream sediments. Many discoveries were made in the semi-arid and arid terrains of Australia, mostly in erosional terrains where gossans, or gossan remnants, are exposed at surface. With the exception of Ni sulphides, there have been few discoveries in areas of extensive, thick and complex regolith and low relief, such as in the Yilgarn Craton. We need to develop exploration techniques for finding base metal deposits in these difficult environments.

There is a common perception that a linear relationship exists between the chemistry of plants and their soil substrate. However, most plants prevent the absorption of certain elements at their root tips, and each plant species has a different requirement for, and tolerance to, trace elements (Dunn *et al.* 1996). Plants may also absorb elements dissolved in groundwater that may not readily precipitate on soil particles, and extensive root systems, typical of many plants, integrate the chemistry of a large volume of soil. In Australian arid environments, roots may penetrate to depths of tens of metres, permitting extraction of metals from both mineralisation and the regolith. Plants do not only extract elements from near surface, but from the entire regolith profile, groundwater and even bedrock. Therefore, in many environments, biogeochemical and soil surveys provide different information on the chemistry of the substrate (Dunn *et al.* 1996).

In the near-surface, bacteria colonise mineral surfaces, growing as biofilms (Southam *et al.* 1995, Reith 2003) or as complex-particle association of cells (Ferris *et al.* 1987), and encounter surface water and groundwater as it flows past (a sessile growth phase). When combined with the ubiquitous nature of bacteria and the enrichment of specific bacterial populations due to mineral and aqueous substrates, bacteria are likely to have a profound effect on the formation of metal anomalies surrounding mineral deposits.

Biogeochemistry has not been widely used as an exploration technique for Au and base metals in Western Australia because sampling of soils and other surface materials has been reasonably effective in finding new mineral deposits in deeply weathered areas with or without shallow transported overburden. Future discoveries of base metal and Au resources in deeply weathered terrains are likely to occur under several to many metres of transported overburden where soil and lag sampling is ineffective. As the focus of exploration shifts to these more difficult terrains, biogeochemistry needs to be reinvestigated. Mulga (*Acacia spp.*) is one of the most common trees within the northern Yilgarn and its potential as a sampling medium has been tested at the Jaguar Cu-Zn-Ag deposit. This paper presents the geochemical expression of vegetation and soil over the deposit and discusses the dispersion mechanisms.

SETTINGS AND METHODS

The Jaguar Cu-Zn-Ag deposit is located approximately 4 km south of the Teutonic Bore open pit in the Eastern Goldfields Province of the Yilgarn Craton and contains a resource of 1.72 Mt at 3.6% Cu, 11.9% Zn and 127 g/t Ag (Pilbara Mines 2004). The main ore body is approximately 250 m below surface, dipping steeply to the west. A possibly stratiform, primary dispersion halo around the deposit extends to surface and has been intersected in shallow percussion drilling. The deposit is located beneath a present day drainage that extends south from Teutonic Bore Mine. The regolith sequence comprises a partly truncated residual weathering profile covered by 10-20 m of alluvium and colluvium. The colluvium and alluvium consist of shallow soil (20-30 cm), hardpanised colluvium (1-2 m), ferruginous gravels and mottled clays. The soils are sandy clays and show no horizon development.

Twenty five shallow pits (0.3-0.5 m depth) overlying and distal to the mineralisation were dug to collect soil and root samples. Soil samples were taken 5-10 cm below surface at each site to compare the chemistry of the plant and surrounding soil. Total, partial and selective digests of soil samples and hardpanised colluvium were also used to investigate any potential chemical signature of the bedrock mineralization at surface. Soils from the rhizosphere were also collected for bacterial investigations by Dr Steve Rogers, CRC LEME-CSIRO Land and Water, Adelaide. Soils were air dried, sieved to < 250 µm and extracted with: (i) aqua

regia; (ii) 0.1 M hydroxylamine hydrochloride (Mn oxides); (iii) 0.25M hydroxylamine hydrochloride (amorphous Fe oxides); (iv) sodium dithionite (crystalline Fe oxides); and, (v) Enzyme Leach (amorphous Mn oxides). Litter, roots (fine and coarse), bark, branch wood and phyllodes were sampled from all 25 sites and analysed to ascertain metal distribution throughout the plant. The samples were washed prior to drying at 70°C. The preparation, including ashing (ash yield 1.7-12.3%) and quality control, was done by Dr Colin Dunn, Consulting Geochemist, Canada. The materials were analysed for 51 elements by ICP-MS at ACME Laboratories in Canada. Vegetation and regolith control samples were included with each analytical batch.

RESULTS

The < 250 µm soil fraction largely consists of quartz and kaolinite with small amounts of goethite, hematite and mica. The soils have high concentrations of Si (63-69 wt. % SiO₂) and Al (13-18 wt. % Al₂O₃) with lesser amounts of Fe (7-8 wt. % Fe₂O₃) and K (1.08-1.21 wt. % K₂O%). The soils show a single point anomaly of Cu (59 ppm), Pb (18 ppm), Zn (151 ppm) and Cd (0.25 ppm) across the interpreted up-dip surface projection of the Jaguar deposit. Selective extractions (hydroxylamine hydrochloride (0.1M and 0.25M) and sodium dithionite) also show single point anomalies in Cu and Zn but not in Cd. A Pb anomaly only appears in 0.25M hydroxylamine hydrochloride which extracted 'amorphous' Fe oxides. Enzyme Leach produced a marginally displaced (west of the mineralisation) strong, single point anomaly in Cu, Pb, Ni, As, Ga, Br, Rb, Y and Zr. In all extractions, Zn concentrations were much greater than those of Cu and Pb, which is consistent with the < 250 µm soil data. There does not appear to be a direct correlation between the abundances of Mn and Fe and Cu, Zn and Pb. There were no significant base metal anomalies over the mineralisation in the hardpanised colluvium below the soil.

The biogeochemical survey shows a significant increase in concentrations of Zn, Cu, Pb, Cd, Ag, In, Sb and Sn in ashed vegetation samples over the mineralisation compared to the soil samples. Zinc, in particular, is broadly anomalous in phyllodes, bark, branch wood, roots and litter. Litter has a broad and strong multi-element (Zn, Cu, Pb, Cd, Ag, In, Sb, Sn) response compared to other parts of the plant. The concentrations of Zn, Cu, Pb, Cd, In and Sb reach levels of up to 4,660 ppm, 1,400 ppm, 40 ppm, 15 ppm, 350 ppb, 0.6 ppm, 0.6 ppm and 1.8 ppm respectively and are 5 to 25 times higher than those of phyllodes, bark, roots and branch wood. The reasons for hyper-accumulation of elements in litter are not clear but it may be due to residual concentration by the loss of carbon during the decomposition process, accumulation of metals by microbes and organic-metal complexes. Microbes have a high surface area-to-volume ratio because of their small size and therefore provide a large contact area that can interact with metals in the surrounding environment (Ledin 2000).

CONCLUSIONS

Preliminary results suggest that Mulga is a suitable sample medium for biogeochemical surveys in the central Yilgarn Craton. Chemical analysis of bark, phyllodes, roots, branch wood and litter can assist in outlining concealed mineralisation. The biogeochemical survey appears to be more conclusive than conventional soil and selective extraction of soil. Differences in chemistry of various parts of the plant will be discussed at the meeting.

Acknowledgments: Ian Robertson and David Gray reviewed a draft of this abstract which is acknowledged with appreciation. Jabiru Metals Limited kindly gave permission to access the Jaguar site and drill materials, and Peter Ellis provided information and data. Sample preparation and QC for the vegetation samples was by Colin Dunn/Vancouver. Balbir Singh and Cajetan Phang (CSIRO/CRC LEME) provided support with the sampling. Professor Pauline Grierson, UWA, assisted in identifying plant species. Amanda Cornelius (CRC LEME/CSIRO) provided support with GIS.

REFERENCES

- DUNN C.E., BROOKS R.R., EDMONDSON J. & REEVES R.D. 1996. Biogeochemical studies of metal-tolerant plants from Southern Morocco. *Journal of Geochemical Exploration* **56**, 13-22.
- FERRIS F.G., FYFE W.S. & BEVERIDGE T.J. 1987. Bacteria as nucleation sites for authigenic minerals in metal-contaminated lake sediments. *Chemical Geology* **63**, 225-232.
- MADIN M. 2000. Accumulation of metals by micro-organisms - processes and importance for soil systems. *Earth Science Reviews* **51**, 1-31.
- REITH F. 2003. Evidence for a microbially mediated biogeochemical cycle of gold - a literature review. *In*: ROACH I.C. ed. *Advances in Regolith*. CRC LEME, pp. 336-341.
- SOUTHAM G., FERRIS F.G. & BEVERIDGE T.J. 1995. Mineralised bacterial biofilms in sulphide tailings and in acid mine drainage systems. *In*: LAPPIN-SCOTT H.M. & COSTERON J.W. eds. *Microbial Biofilms*. Cambridge University Press, Cambridge, Great Britain, pp. 148-170.