MINERAL HOSTS FOR GOLD AND TRACE METALS IN REGOLITH: A LA-ICP-MS STUDY

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INTRODUCTION

Geochemical dispersion of Au, base elements and their pathfinders is partly controlled by the availability of mineral hosts in the regolith. The element-mineral associations have been investigated in *in situ* regolith developed on mineralised rocks at the Boddington Cu-Au deposit, Mt Percy Au deposit and Scuddles massive Cu-Zn sulphide deposit in the Archaean Yilgarn Block, Western Australia. The residence of Au and trace elements has been determined by *in situ* Laser Ablation-Inductively Coupled Plasma-Mass Spectrometry (LA-ICP-MS) and electron microprobe analyses. A method to interpret the LA-ICP-MS data obtained from mainly heterogeneous microcrystalline material has been developed during this study (Le Gleuher 2003a & 2003b). Once the location of trace elements has been established, directions for exploration sampling and geochemical prospecting can be suggested.

GEOLOGICAL SETTINGS AND MINERALISATION

The Boddington Au deposit is located in the Saddleback Greenstone Belt, a sequence of greenschist to lower amphibolite facies metamorphosed sedimentary, felsic and mafic volcanic and pyroclastic rocks. The porphyry-style Au-Cu-Mo-W-(Bi) mineralisation is hosted in felsic to intermediate volcanics (Symons *et al.* 1988). The climate is Mediterranean-type, with hot dry summers and mild wet winters with an average annual rainfall of about 800 mm. The Saddleback area is an eroded plateau 300-350 m above sea-level, covered by bauxitic laterite.

The Mount Percy Au deposit is situated in the Kalgoorlie gold fields in the Norseman-Wiluna Greenstone Belt. The Mt Percy gold deposits consist of two main mineralised zones: the Sir John-Union Club-Lucknow lodes in the Devon Consols Basalt; and, the Mystery orebody to the west in the Hannan's Lake Serpentinite. In the Mystery orebody, gold mineralisation is preferentially hosted within porphyries and contact alteration zones. The climate is semi-arid, and has irregular average annual rainfall of 250 mm. Mt Percy is situated in a relatively high part of the landscape, in a region that has a total relief of only a few tens of metres.

The Scuddles Cu-Zn deposit is in the Golden Grove district, Murchison province. The mineralised horizon occurs in a sequence dominated by felsic and intermediate volcaniclastic sediments and lavas and comprises an upper layer of massive Zn-Fe sulphides grading downwards to a pyritic zone. A zone of stockwork, stringer and disseminated Cu-Fe sulphides underlies the massive sulphide ore. The climate in the Scuddles area is semi-arid, with an average annual rainfall of 260 mm. The area is a low relief peneplain with prominent ridges of resistant material.

MINERALOGY AND BULK GEOCHEMISTRY OF THE REGOLITH

Boddington gold deposit

At Boddington (Figure 1), the regolith consists of saprock, saprolite, ferruginous saprolite, a bauxite zone, ferruginous duricrust (fragmental and pisolithic) and loose nodules and pisoliths (Anand 1994). In the saprolite, mica is intensively weathered to kaolinite, and goethite and hematite replace Fe-sulphides. Saprock and saprolite contain interstratifed chlorite-vermiculite, biotite-vermiculite clay minerals and vermiculite. The pisoliths are composed of fine-grained Fe oxides (goethite, hematite and possibly maghemite) and gibbsite.

Gold is concentrated in the lower part of the bauxite zone, the middle of the clay saprolite and the lower saprolite. Copper, Mn, Zn, Co and Ni are concentrated at the base of the saprolite. Arsenic, Mo, W, Bi and Pb tend to be concentrated up through the profile.

In: Roach I.C. ed. 2005. *Regolith 2005 – Ten Years of CRC LEME*. CRC LEME, pp. 183-186.

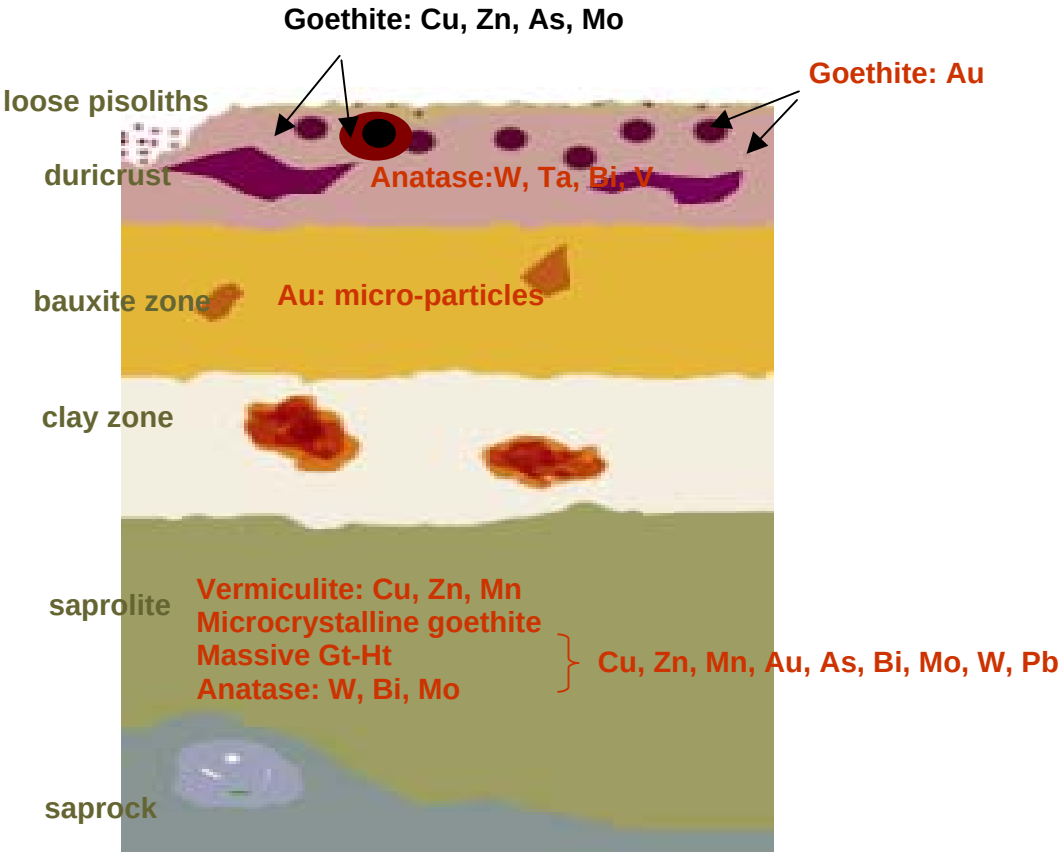

Figure 1: Boddington Au deposit: cartoon describing the mineral hosts for base metals and pathfinders in the regolith.

Mt Percy gold deposit
At Mt Percy, the saprolite comprises a greenish saprolitic horizon, a clay saprolite with an alunite-rich zone, a mottled and plasmic clay zone, a lateritic duricrust with local silification and a soil with pedogenic carbonates. The saprolite contains abundant sulphide relicts replaced by goethite and hematite. Cutans consisting of microcrystalline kaolinite, goethite and hematite are abundant in the strongly ferruginised mottled and plasmic clay zone.

Gold is most abundant in the lateritic duricrust and pedogenic calcrete. The mottled and plasmic zone is relatively Au depleted (< 100 ppb), with patchy enrichments due to unweathered quartz veins. The upper saprolite displays local Au concentrations in an alunite-rich zone. Butt (1991) noted that the elements generally considered associated with the Au mineralisation such as S, Sb, Ag, Te and W are not directly correlated with Au in the alteration zone and display distinctive dispersion patterns.

Scuddles Cu-Zn sulphide deposit
At Scuddles, the hanging wall lavas are deeply weathered to a depth exceeding 100 m in places whereas the saprolite over the mineralisation is very thin. The saprolite merges into a 1-2 m thick mottled zone and is locally capped by a silicified layer.

In the hanging wall, high and low charge corrensites (up to 7%), resulting from the weathering of chlorite, and Mn-oxides nodules (coronadite and lithiophorite) are abundant. In the upper saprolite, corrensite is much less abundant and Fe-rich smectites are present. The saprolite above mineralisation contains abundant Fe-rich chlorite, little corrensite and Mn-oxides (coronadite-hollandite and lithiophorite) and hematite-goethite pseudomorphs after sulphides. The upper saprolite locally displays Fe-rich concretions, which are commonly banded. Copper, Zn, and Pb are concentrated in the hanging wall. Bismuth, Mo, Sb and In are concentrated in the top horizons over mineralisation (Figure 2).

TRACE ELEMENT RESIDENCE IN REGOLITH MATERIAL

Boddington gold deposit

In the saprolite, Au (up to 270 ppb), Cu, Bi, W, Mo and As are preferentially trapped in microcrystalline goethite formed from the weathering of vermiculite and in massive goethite-hematite pseudomorphs. Vermiculite layers also incorporate high levels of Cu. In the pisolithic duricrust, Au (up to 1 ppm) occurs as individual particles in the goethitic material of the internodular matrix, cortex and core. Copper, As, P and Mo are concentrated in the cortex goethite. Kaolinite and gibbsite do not scavenge trace elements related to the mineralisation. The W and Bi enrichment observed in the duricrust is partly caused by residual accumulation of anatase. The element-mineral associations at Boddington are summarised in Figure 1.

Mt Percy gold deposit

Gold (up to 400 ppb) is concentrated in cutans in the mottled and plasmic clays, presumably as cryptocrystalline particles. Goethite-rich cutans strongly scavenge Sb, As, Mo and Cu. The cutan goethite has formed from late solutions that have been circulating through the material and therefore became enriched in these elements. Tungsten and Sb are also residual in rutile, and some Cu is incorporated in alunite in the clay saprolite. The occurence of W and Sb in several mineral phases is responsible for the absence of close correlation between Au, W and Sb at the alteration profile scale

Scuddles Cu-Zn sulphide deposit

In the hanging wall lower saprolite, Cu and Zn are preferentially trapped in vermiculitic layers of high charge corrensite (Figure 2). Lower amounts of Cu and Zn are also captured by low-charge corrensite (chlorite-smectite). Lead and Mn are concentrated in coronadite and lithiophorite. In the upper saprolite, smectites resulting form the weathering of corrensite have inherited Cu and Zn.

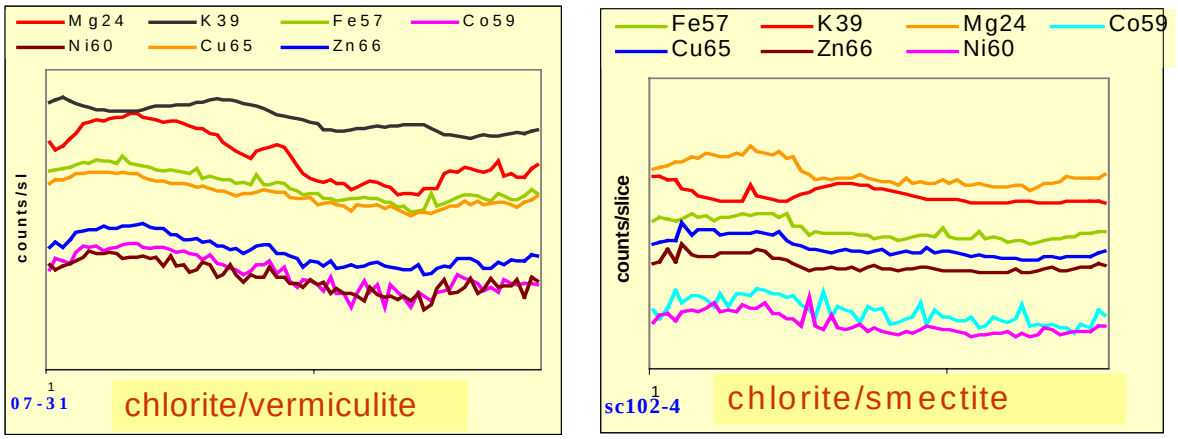

Figure 2: LA-ICP-MS time resolved spectra of selected isotopes in Scuddles corrensite: **Left**: High-charge corrensite; **Right**: Low-charge corrensite.

Over mineralisation, high levels of Cu, Zn, Pb and As are present in hematite-goethite assemblages in the lower saprolite. Antimony (up to 440 ppm) and Mo (up to 220 ppm) are concentrated in goethite in the reddish mottles of the upper saprolite whereas Bi is enriched in the bleached kaolinitic material where it occurs as Pb-Bi micrograins. Antimony, Mo and Bi are also present in rutile uniformly distributed in the horizon. Base metals have not been detected in kaolinite.

Above the mineralisation, potential captors such as corrensite and smectites are not abundant and as a result, Cu, Zn and Pb mobilised by the dissolution of sulphides are not retained. They have been captured further west by abundant receptors such as Mg-clays and Mn oxides resulting in anomalous Cu and Zn levels in the hanging walls.

CONCLUSION

The trace element dispersion is strongly controlled by the occurrence of one or several suitable receptors in the regolith. The clay fraction (< 2 µm) including vermiculites, smectites and corrensites is crucial for trace element retention. Microcrystalline goethite traps Au, base metals and pathfinders (Sb, W, Bi and Mo). Kaolinite and gibbsite dilute geochemical anomalies, and the relative accumulation of residual rutile and anatase inflates W, Bi, Sb and Mo anomalies in bulk analyses.

The LA-ICP-MS method has been shown to be a valuable tool for the determination of trace elements in clays and ferruginous materials.

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