MINERAL HOSTS FOR GOLD: A STUDY OF TRANSPORTED OVERBURDEN AT THE ENTERPRISE PIT, MOUNT GIBSON GOLD DEPOSIT.

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INTRODUCTION

The Mount Gibson gold deposit is about 300 km NNE of Perth and 28 km SW of Mt. Gibson Homestead. It lies in the Murchison District at 29° 45′ S, 117° 10′ E; Ninghan 1:250,000 map sheet. Significant Au in 'laterites' ('Gibson Anomaly') over a distance of 6 x 0.5 km was discovered in 1983 by Reynolds Metals Australia Ltd and was subsequently mined as ore, the cut off grade being 1 g/t Au. Production commenced in 1986. Since mid-1987, exploration has focused on the search for bedrock-hosted deposits beneath the laterite, revealing supergene oxide- and sulphide-zone ore at Enterprise, Donkey D, Orion One, Orion North, Wombat and Deep South and primary Au-Ag deposits at Hornet and Orion Two. To the end of September 1994, the Mt. Gibson Au project had produced about 17 tonnes of fine Au and in excess of 10 tonnes of Ag. Several studies covering the regolith evolution and geochemical dispersion in regolith have been carried out in the Mt. Gibson district (Anand *et al.* 1989, 1991, Madden 1996, Jones & Lidbury 1998). The mineral hosts project aims to build on these and identify trace element relationships with specific minerals and mineralogically controlled structures (e.g., cutans) associated with weathering processes in the regolith. Ultimately, the aims are to better identify and rank Au anomalies and to understand Au dispersion in the regolith, with a key emphasis on areas of deep cover and transported overburden. The upper sediments at the Enterprise Pit, Mt. Gibson, are especially useful in studies of the latter as they have been subjected to weathering processes that include ferruginisation, calcification and silicification that may form new minerals that in turn may be important mineral hosts for significant trace elements (e.g. Au). Recent studies using in-situ analysis of regolith samples have been successful in this regard (Le Gleuher 2003a, b).

PHYSICAL FEATURES AND ENVIRONMENT

The area has a semi-arid, hot Mediterranean climate with an average annual rainfall of 250 mm. 250 mm. The vegetation is mainly acacia on sand plains. Eucalypt woodlands, largely of salmon gum, York gum and mallee, together with some native pine, occur on fine-textured soils in local erosional tracts and along valleys. The area around the Mt. Gibson Au deposits is one of gently undulating and deeply weathered, subdued relief broken by greenstone hills, granite mounds and low breakaways. Towards the west rises a sand-plain that straddles a granitic ridge, which forms the local drainage divide. Essentially, the landforms of the area are pre-Tertiary, with Tertiary to recent modification.

GEOLOGICAL SETTING AND MINERALISATION

The Mt. Gibson Au deposits are located at the southern tip of the Retaliation Belt, the southern-most portion of the Yalgoo-Singleton Greenstone Belt of the Archaean Yilgarn Craton (Watkins & Hickman 1990). There is very little bedrock exposed at Mt. Gibson; in general, the depth to fresh rock is in excess of 50 m. The Archaean basement to the Mt. Gibson mine area dominantly comprises of metavolcanic and intrusive felsic rocks and their sheared equivalents, which have been metamorphosed to mid-amphibolite facies (Yeates & Groves 1998). The structure of the host sequence to mineralization is dominated by the Mt. Gibson Shear Zone, a broad (up to 1 km wide), north-northeast striking, generally east-dipping, anastomosing ductile shear network, which is developed primarily within the mixed mine sequence and contains all the known primary Au mineralization. A mixed mine sequence is dominated by variably differentiated tholeiitic metabasalts and metadolerites, with lesser magnesian metabasalts and quartz-feldspar porphyries. The surrounding granitoids predate Au mineralization, which is hosted in relatively late, regional-scale shear zones, both locally at Mt. Gibson and regionally throughout the Murchison Province (Watkins & Hickman 1990).

ENTERPRISE PIT

The Enterprise Pit (Figure 1) is located within the colluvial-alluvial plains. Prior to mining, the area had a lag-strewn surface on colluvium-alluvium, sloping gently to the north with the colluvium-alluvium thickening to the north. In the Enterprise Pit, the Au-bearing bedrock comprises quartz veining in sheared metabasalt with mixed sulphides of pyrite, pyrrhotite, chalcopyrite, sphalerite and galena. This is overlain by some 20 m of bleached saprolite composed of white kaolinitic clays and occasional green smectitic clays together with quartz veins (up to 1 m thick) and rare basic dykes, now ferruginised. Goethite staining occurs in isolated areas in the clays, becoming more prevalent towards the top of the profile. *In situ* regolith is overlain by transported overburden principally consisting of two Tertiary and Quaternary sedimentary units. Slabby to pisolitic ferricrete is formed in Tertiary sediments. These were originally sandy-clay to clay-rich sediments that have been modified to form pisoliths by the *in situ* introduction of hematite and goethite. The pisoliths consist of hematite, kaolinite, quartz and goethite. The matrix and nodules of the ferricrete contain fine clay spherites thought to have been derived from granites. The uppermost sandy to sandy-clay unit is 3-4 m thick and has been subjected to calcification and silicification to produce calcrete and hardpans, with the top 1-2 m being hardpanised. Within this uppermost unit, sub-horizontal to horizontal laminations have developed commonly marked by thin coatings of precipitated Mn-oxides.

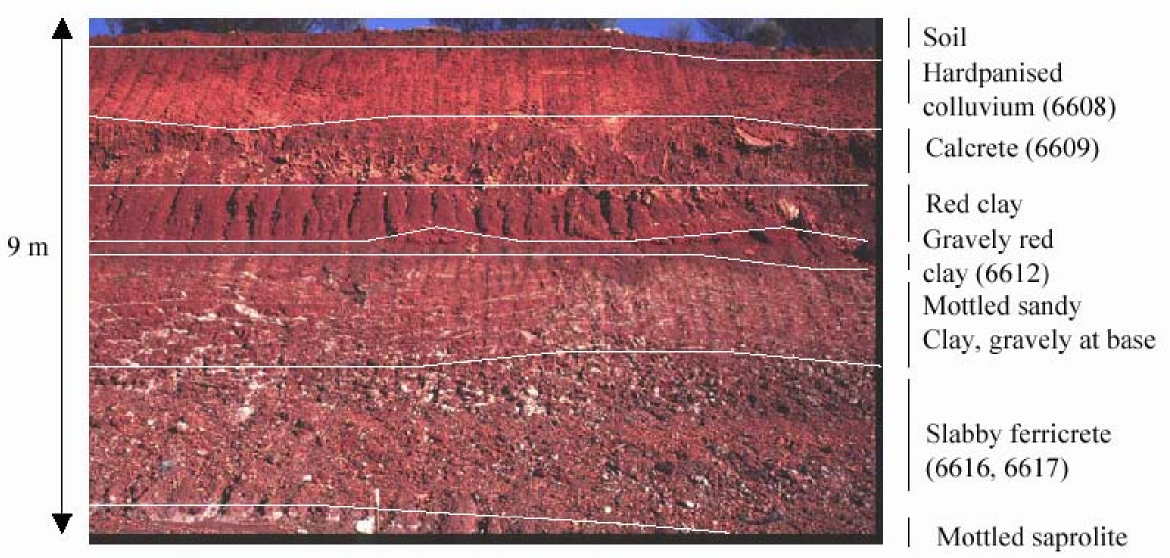

Figure 1: profile of the transported sediments, Enterprise Pit, Mt. Gibson.

Bulk samples from the Enterprise Pit were analysed for major and trace element geochemistry using INAA and XRF. Mineralogy was determined by XRD and SEM-EDS, and *in situ* geochemical analyses were derived by laser ablation ICPMS (LA-ICPMS) on selected polished thin sections by LA-ICPMS. Le Gleuher (2003 a, b) and references therein, provide a full description of thin-sections.

BULK GEOCHEMISTRY AND LA-ICPMS

The bulk sample of sulphide-rich metabasalt bedrock contains high concentrations of Au (>20 ppm), Ag (88 ppm), As (363 ppm), Zn (954 ppm), Cu (375 ppm) and Pb (1120 ppm). These elements are generally depleted in the saprolite, although localised concentrations do occur associated with sub-vertical quartz veining and isolated ferruginised zones. The slabby ferricrete is anomalous with up to 587 ppb Au detected in one sample, and white clay between the slabby layers containing 112 ppb Au. Arsenic accumulations occur in areas of ferruginisation (20-50 ppm), even in the saprolite, and reach 85 ppm in slabby sediments. The hardpanised sediments and calcrete near the top of the profile yield little As but appreciable Au (128-436 ppb). Using this bulk geochemistry, we targeted polished thin-sections of Au- and/or As-rich samples for *in situ* micro-analysis using LA-ICPMS. Prior to analysis, the thin sections were mapped using back-scattered electron imaging in the SEM. As the sections were of a normal thickness (30 µm), a laser spot diameter of 100 µm was used to ensure a sufficient ablation volume of sample for analysis (Figure 2). Results of analyses have been normalised to 100 % oxide at this stage prior to electron microprobe analyses to provide an internal standard for each analysis. Table 1 summarises the key results for selected elements from different minerals with emphasis on components derived from the weathering processes reflected in the transported sediments.

The *in situ* analyses are able to identify areas of Au enrichment in the samples. In most analyses the trend mirrors that of the bulk geochemistry with As, Cu and Zn all having a preference for Fe-rich areas. In the slabby ferricrete (6616) the Au, As, Cu and Zn are contained in the minor hematite-rich clasts rather than the dominant matrix which comprises quartz, goethite, kaolinite and hematite. Interestingly, the white clay (6617) that lies within these slabby zones contains appreciable Au. LA-ICPMS results identified the clay as a local host for Au but with little As, the Fe-stained clay (6617b) shows a slightly higher enrichment in Au together with higher As and Cu.

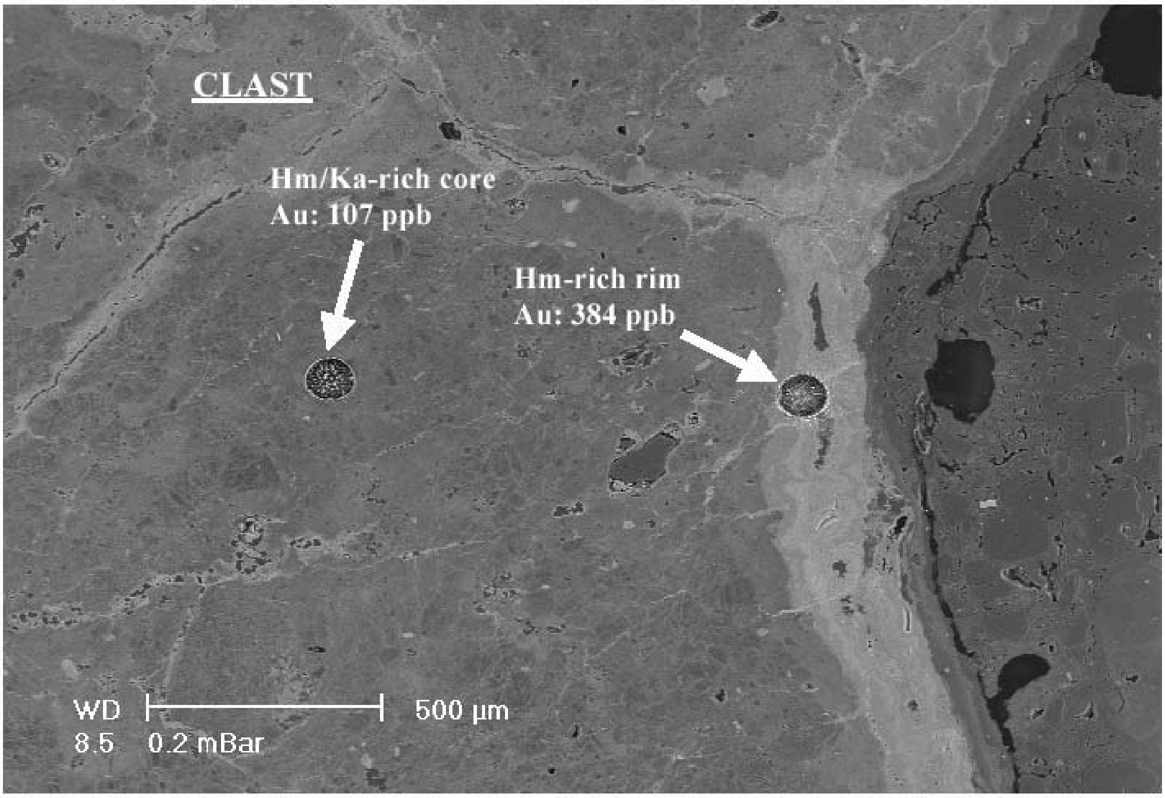

Figure 2: SEM (BE) image showing laser pit positions of LA-ICPMS analyses in the nodular duricust sample (0560). Hm- hematite, Ka- kaolinite.

Table 1: LA-ICPMS data for selected samples and elements.

Sample No.	Regolith unit	Mineral/Structure	SiO_2 wt %	FeO wt %	Al_2O_3 wt %	CaO wt %	Au ppm	As ppm	Cu ppm	Zn ppm
6608a	Hardpanised colluvium	Ca-rich matrix	48.7	8.7	22.5	20.200	**1.870**	17.8	169.0	20.2
6608b	Hardpanised colluvium	Si-rich matrix	60.6	8.1	27.4	1.600	**0.158**	11.6	116.0	31.7
6609a	Calcareous hardpan (calcrete)	Ca-rich matrix	4.6	0.9	1.4	90.300	**0.163**	2.0	18.0	3.8
6609b	Calcareous hardpan (calcrete)	Ca-rich matrix	6.4	0.0	0.1	91.900	**9.058**	1.4	18.2	1.8
6612a	Gravely red-clay	Core of a clay spherite in a clast	55.7	2.6	40.4	0.126	**0.042**	7.9	34.24	2.8
6612b	Gravely red-clay	Fe-rich clay spherite in a clast	27.0	51.8	19.8	0.118	**0.019**	112.6	36.6	4.9
6616a	Slabby ferricrete	Hematitic clast	7.8	86.6	5	0.106	**0.018**	263	26.9	2.3
6616b	Slabby ferricrete	Hematitic clast	8.9	82.2	7.9	0.044	**0.096**	284.8	38.3	12.9
6617a	Clay (in ferricrete)	Kaolinite	55.5	1.7	38.9	0.170	**1.110**	11.4	46.0	1.2
6617b	Clay (in ferricrete)	Fe-stained kaolinite	32.0	41.7	24.9	0.210	**1.580**	359.7	290.0	10.5
0560a	Nodular duricrust	Hematitic rim to clast	7.9	81.7	10.1	0.030	**0.384**	179.4	51.9	1.0
0560b	Nodular duricrust	Hematite/kaolinite core to clast	31.7	42.7	24.4	0.050	**0.107**	94.3	65.5	6.9

Sample 0560, of a nodular duricrust from a separate area at Mt. Gibson, contains high concentrations of Au associated with hematitic areas. The nodular duricrust sample is included here as it displays several phases of ferruginisation. It is the late stage influx of hematite as veins within and rims to clasts that displays the highest Au anomalism. The gravely red clays (6612) at Enterprise Pit that contain clasts comprising small clay (6612a) and hematitic (6612b) spherites (or balls) in a matrix of hematite, kaolinite and quartz, show As closely associated with Fe-rich areas, but the spherites are relatively Au-poor. In the uppermost sequence of hardpanised colluvium (6608) and calcrete (6609), high concentrations of Au are found in the calcareous matrix. Silica-rich areas in the matrix of the hardpan (kaolinite + amorphous silica) are also rich in Au and the hardpan analyses yield more Cu than in calcrete. Some highly anomalous values were obtained using LA-ICPMS on the nodular duricrust sample (0560) and the calcrete (6609). Preliminary observations would suggest this represents grains of Au in the sample, producing a nugget effect in the analyses. It should be noted however, that Au grains were not observed in these samples during SEM observations, indicating that they may be very fine grained.

SUMMARY

The transported sediments at the Enterprise Pit display a complex history of ferruginisation, calcification and silicification, with Au being concentrated in several different mineral hosts including kaolinite, hematite rich clasts, hematite cutans and in a calcite-rich matrix. Although these are transported sediments, there is evidence that late stage hydromorphic dispersion of elements has taken place as their chemical signature reflects the underlying mineralisation i.e. Au, As, Cu and Zn. Sample 0560. However, from a different area of Mt. Gibson, a nodular duricrust occurs that illustrates several phases of ferruginisation, in which *in situ* analyses indicate that growth of hematite in veins and as rims to nodules is the stage that produces Au anomalism. Seemingly, this is before a final stage of goethite replacing hematite. This growth of goethite still retains some Au but concentrations are not as high as in the hematite rich areas.

In most cases *in situ* LA-ICPMS analysis was able to identify the minerals or mineralogical structures that act as hosts for Au, As, Cu and Zn at the thin-section scale. The analyses also have the possibility of identifying the nature of the Au and other metals in the regolith materials, as the profiles can comprise peaks, probably representing grains, or plateaus suggesting a more even distribution, possibly within mineral lattices.

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