MT GIBSON GOLD DEPOSIT, WESTERN AUSTRALIA

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LOCATION

The Mt Gibson gold deposit is in the Murchison goldfield, about 280 km NNE of Perth and 28 km SW of Mt Gibson Homestead, at 29º45′S, 117º10′E; Ninghan 1:250 000 map sheet (SH 50-7).

DISCOVERY HISTORY

Tobias Find (now within one of the pits) was discovered in 1910-1916 but production (1 kg Au) was not significant. The auriferous laterites in the district were not recognized until 1982, when Reynolds Australia Metals Ltd found anomalous Au in surface samples. Exploration in 1983 revealed significant Au in ferruginous duricrust and gravel over an area of 6 x 0.5 km. The Mt Gibson gold mine commenced operations in 1986, based on a shallow lateritic ore reserve of 5.3 Mt at 1.6 g/t Au. Cut-off grades of 1 g/t Au or less were used at various periods. Continued exploration delineated thirteen deposits, including some primary mineralization (Gee, 1990). The lateritic ores came from the strongest parts of a geochemical anomaly of more than 7 x 1 km developed above intermittent shoots of primary Au and disseminated sulphide mineralization. Open pit and underground mining was suspended in 1997. However, production continued from stockpiles and dump leach. Total production to 2000 is approximately 25 t Au and as much Ag (Register of Australian Mining 2000/2001). The deposit was acquired by Legend Mining Ltd in August 2005 from Oroya Mining Ltd.

PHYSICAL FEATURES AND ENVIRONMENT

The Mt Gibson area is a gently undulating lateritic sandplain, with a subdued relief broken by greenstone hills, granite mounds and low breakaways. The land falls only 40 m over the 10 km strike of mineralization towards Lake Karpa. The vegetation is mainly *Acacia* woodlands on sand plain. *Eucalyptus* woodlands, largely of salmon gum (*E. salmonophloia*), York gum (*E. loxophleba*) and mallee, together with some native pine (*Callitris* spp.) occur on fine-textured soils in local erosional tracts and along valleys. The climate is semi-arid, with an average annual rainfall of 250 mm, falling mostly during winter (May to August). Mean temperature ranges are 21-37ºC (January) and 5-18ºC (July).

GEOLOGICAL SETTING

The Mt Gibson Au deposit is situated at the southern tip of the Retaliation Belt, in the SW portion of the Yalgoo-Singleton Greenstone Belt in the Murchison Province of the Yilgarn Craton. The Archaean basement to the Mount Gibson mine area is dominantly volcanic and intrusive mafic and felsic rocks and their sheared equivalents, which have been metamorphosed to the mid-amphibolite facies. Rare metasedimentary rocks consist of thin, discontinuous, interflow ferruginous cherts. The basement of the mine area consists of five volcanic sequences (Yeats and Groves, 1998). These comprise, from W to E; i) a thick, wedge-shaped, tholeiitic metabasalt; ii) predominantly magnesian metabasalts, with komatiitic components; iii) a mine host sequence of mixed variably differentiated tholeiitic metabasalts metadolerites and quartz–feldspar porphyries; iv) magnetic quartz–andesites with interflow metasediments and v) quartz-phyric felsic metavolcanic rocks.

REGOLITH

This summary is from detailed studies of regolith evolution and geochemical dispersion in regolith (Anand *et al*., 1989; Anand *et al*, 1991; Smith and Anand, 1992; Smith *et al*., 1992b; Madden, 1996). Regolith-landform relationships for the Mt Gibson area are shown in Figure 1 and are dominated by differential erosion of deep lateritic weathering profiles. Detritus from the weathered mantle in local uplands has buried the weathered profile beneath colluvium-alluvium on adjacent foot-slopes and lowlands, producing local erosional-depositional couples. Some of these sediments show inversion of the sequence of the dismantled weathered profile; gravelly detritus at the base of the colluvium consists of ferruginous nodules and pisoliths (derived from the top of the profile), grading upwards to silty sandy detritus (from erosion of

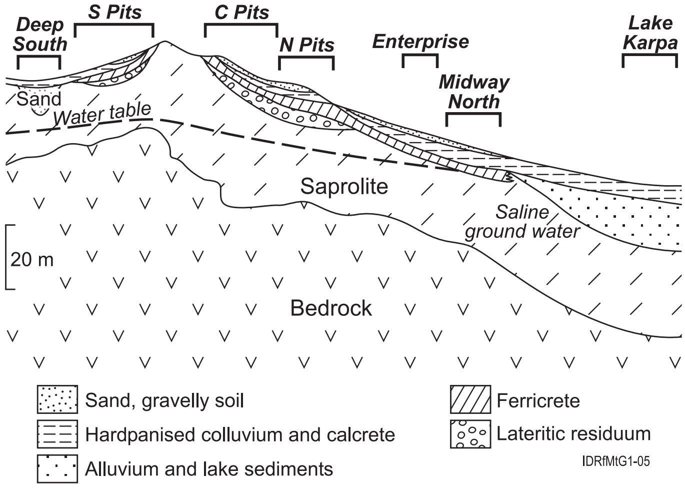

Figure 1. Regolith cross section from the high S and C pits to Lake Karpa (after Smith et al., 1992a).

saprolite). The Au-bearing duricrust and gravel lies on the eastern flank of a low ridge, which has approximately 20 m of relief and a slope of about 1º. In the mine area, the duricrust and gravel are generally 2-3 m thick and cover a regional drainage divide, extending NNE down a secondary drainage. As the duricrust blanket dips gently down the drainage line to the NNE, it becomes progressively buried beneath up to 6 m of transported sand and colluvial sandy pisolitic gravel, much of which is cemented to red-brown hardpan. These products represent degradation and dispersion of the weathered profiles. Sparse bedrock and saprolite protrude through the etched duricrust blanket at higher levels. The higher ground to the W is occupied by poorly exposed mafic and felsic schists.

Saprolite thickness depends on the lithology, the intensity of shearing and the degree of truncation of the weathered profile. At Midway North, the main mineralized shear is weathered to 60 m, whereas mafic volcanics to the east are weathered only to 20 m. Foliated metasedimentary or metavolcanic rocks are strongly mottled, in places, due to recent penetration of tree roots and leaching of Fe.

There are two types of ferruginous duricrusts, nodular lateritic residuum and ferricrete. *Lateritic residuum* is dominated by Si, Al and Fe oxides and consists of hematite, goethite, kaolinite or gibbsite and relict quartz. Minor quantities of exotic materials were introduced by pedological and aeolian processes. *Ferricrete*, mainly pisolitic duricrust, has formed in Tertiary sediments (Jones and Lidbury, 1998). These were sandy clay units that have been modified by later introduction of Fe oxides to form pisoliths or vermiform fabrics. The pisoliths consist of quartz, kaolinite, goethite and hematite. The matrix and nodules of these ferricretes contain very fine clay spherites, thought to have been formed from aeolian sediments. The ferricretes are commonly overprinted by later bleaching. The bleached areas are commonly cylindrical and are cored by tubes that are filled with secondary kaolinite or silica. Widespread preservation of these tubes (fossil root or solution cavity systems) implies high permeability around the unconformity between the sediments and the underlying residual regolith. Secondary calcium carbonate and/or opaline silica cements, related to post-duricrust groundwater regimes, occur in soils and near-surface horizons of colluvium and lateritic residuum in places.

MINERALIZATION

Primary mineralization is associated with quartz veins in shears within tholeiitic metabasalts, metadolerites and quartz-feldspar porphyries of the Mine Sequence. Recent exploration by Oroya Mining Ltd has suggested there is a 9 x 2.5 km shear corridor, probably a major regional fault, with multiple lode potential E of the present main line of open pits. There are two main styles of wallrock alteration and associated sulphide mineralization (Yeats and Groves, 1998). Firstly, pyrrhotite-pyrite-chalcopyrite mineralization, which is associated with a pervasive, syn-peak metamorphic, syn-shearing quartz-biotite-sulphide alteration envelope, typical of lode deposits. Secondly, garnet spessartine-almandine-gahnite and cordierite–muscovite-bearing schists, that reflect pre-metamorphic alteration of tholeiitic basalts. The garnet-bearing schists form a coherent stratiform horizon which overlies the main ore zone at the Orion Two deposit, and are associated with recrystallised, metamorphosed, polymetallic sphalerite-galena-pyrite-pyrrhotite-chalcopyrite-tetrahedrite mineralization. Although free Au is rare, there is a strong empirical relationship between enhanced Au grades and the pyrrhotite-pyrite-chalcopyrite assemblage, suggesting that Au was introduced as part of this event. There is a variable primary association of Au with Ag, Cu, Pb, Zn, As, Sb, Bi, W, Se and Ge.

Gold also occurs at mineable grades in several regolith units, and these provided much of the production to date. Prior to mining, some of the auriferous laterite occurred within 0.15-0.50 m of the surface; elsewhere, it was buried by several metres of partly consolidated sediments of local origin. Saprolite beneath the lateritic residuum is bleached and depleted in Au to about 20-30 m. Beneath this, there is substantial saprolite-hosted mineralization with some supergene enrichment as a broad, in places irregular, sub-horizontal unit overlying the primary mineralization.

REGOLITH EXPRESSION

Initial orientation sampling and geochemical dispersion studies focussed principally on lateritic gravels and underlying lateritic duricrust (Anand *et al*., 1989; Smith *et al*., 1992 a, b; Smith and Anand, 1992). Sample categories were treated separately. Broader coverage was obtained for the gravels but the geochemical patterns are similar for both. The widespread Au anomaly is shown in Figure 2. At a threshold of 30-50 ppb Au, a concentration generally applicable for regional surveys of lateritic terrain in the Yilgarn Craton, the anomaly is 1 km wide and extends beyond the area depicted for 7 km along strike. The strongest parts of the anomaly are centred on a line of quartz-hematite veins. Because a number of chalcophile and associated elements (Ag, Pb, As, Sb, Bi and W) show coincident anomalies also centred upon this veining, it is concluded that there is a close genetic link between the lateritic gravel, duricrust and the bedrock sources. There is some lateral dispersion of Au, possibly by combined mechanical and hydromorphic mechanisms, with additional sources possibly 200-400 m up-slope from the main axis of the anomaly.

The distribution of As (Figure 2) is probably related to the quartz-hematite veining, but appears to be displaced asymmetrically down-slope by about 200 m. The As abundance is anomalous, but is low relative to many deposits elsewhere in the Yilgarn Craton. Although the Au anomaly in lateritic gravel is relatively continuous, the distributions of W (Figure 2) Ag, Pb and Sb (Anand *et al*., 1989) are zoned, with higher relative abundances in the N. Their relationship most probably reflects zoning in the primary mineralization. The multi-element chalcophile association is typical of a Au-bearing base metal or polymetallic sulphide source, as subsequently shown by exploration and mining in bedrock. The most notable feature of the geochemical expression of mineralization at Mt Gibson is the size and regularity of the Au anomaly in the lateritic residuum. This is probably due, in part, to sampling a specific regolith unit, whether near the surface or buried by several metres of sediments. Even a sample spacing of 1 km would detect an anomaly as large as that at Mt Gibson.

Later studies at Mt Gibson have investigated geochemical dispersion in transported cover (Madden, 1996; Jones and Lidbury, 1998), and the minerals hosting ore-related elements (Hough *et al*., 2004). The geochemical patterns within the hardpanized colluvium are closely related to patterns in the lateritic residuum (Smith *et al*., 1992b) because the gravel fraction of the colluvium largely consists of ferruginous clasts. The mean concentrations of Au (Anand *et al*., 1991), Mn, Cr, V, Pb, As, Sb, Bi, Ag and W are much greater in the clasts than in the matrix. The abundances of Zn and Cu do not significantly differ between matrix and clasts. Gold enrichment in the hardpan matrix may reflect the original abundances of Au in the eroded materials from the upper part of the

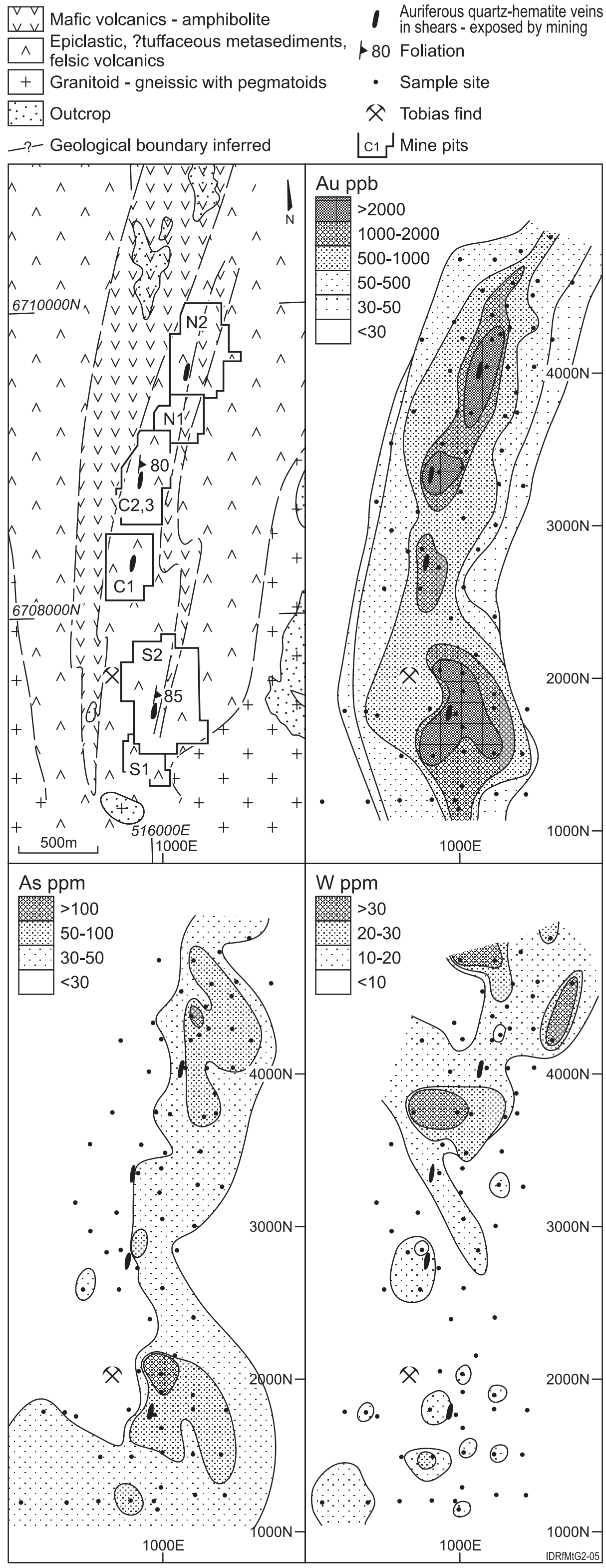

Figure 2. Geochemical dispersion maps showing the distribution of Au, As and W in nodular lateritic gravel and colluvium in the Mt Gibson mining area (Smith and Anand, 1992). The mineralized ore zones are distributed along shears.

mineralized weathering profile, in upland, source areas. Introduction of Au into the hardpan matrix at a much later stage is also possible.

In the pisolitic ferricrete at Midway North, although Au occurs in both the hematite-rich pisoliths and the silicified-kaolinitic matrix, its abundance is much greater in the matrix (mean 0.15 ppm; N=9) than in the pisoliths (mean 0.07 ppm). Magnetic pisoliths are comparatively rich in Fe, Mn, Cr, V, Pb, Zn, As and Ga, whereas non-magnetic pisoliths are enriched in Au, Ag, Cu and Ni. The cores of relatively large pisoliths (20-50 mm) separated by hand from their cutans (Anand *et al*., 1991) showed that their cores are richer in Au (mean about 11 ppm), relative to 2.7 ppm in the cutans, but Ag is more abundant in the cutans. Secondary Au crystals, mostly 5-50 µm, with some exceeding 400 µm, occur in cracks, vughs and cutans of some pisoliths. Authigenic pisoliths in sediments have also been subjected to ferruginization (hematitization followed by goethitization) followed by silicification, calcification and kaolinization, with Au enrichment associated with each facies. Similar features have been reported by Jones and Lidbury (1998). These observations imply there have been several stages of Au mobilization, although the timing is unclear; the association with pedogenic carbonates, however, indicate that Au mobilization is still active.

At Deep South, saprolite is covered with 10-15 m of sediments derived from the erosion of granitic regolith (Madden, 1996). Gold, Cu, Pb and Zn are anomalous in the top 3 m, the silicified horizon of the transported overburden (hardpan). The anomaly is 200 x 50 m with an average concentration of 345 ppb. Manganese oxides and pedogenic carbonates separated from hardpan have as high, if not higher, metal contents as the bulk sample. The Mn oxides are enriched in Au (75 ppb; background <10 ppb), Cu, Ni, Pb and Zn; nodular carbonates contain up to 200 ppb Au. Hough *et al*., 2004 have shown that Au (1-2 ppm) and substantial Cu (290 ppm), Pb (500 ppm), and As (360 ppm) occur in alunite-rich areas in ferricrete at the Enterprise pit, whereas hematite veins and kaolinite-rich clasts are devoid of Au and have much lower abundances of Cu, Pb and As.

As a consequence of landscape lowering during weathering, a variety of relatively resistant materials were incorporated into the lateritic residuum. Gold was rendered soluble as humic complexes, produced by rapid degradation of soil organic matter, and concentrated from these solutions during lateritic weathering. Because lateritic residuum was developed on an undulating landscape, dispersion occurred in sites ranging from upland and slopes to lowlands. Where lateritic residuum accumulates on lower parts of the landscape, at least part of the Fe probably has been transported for some distance. Some trace elements (As, Cu) may have behaved similarly, resulting in large dispersion halos. Mechanical dispersion affects elements held in resistate minerals.

Dispersion haloes in ferricretes and mottled sediments have largely resulted from chemical dispersion by lateral and vertical movements of groundwater. The presence of secondary, fine-grained Au in both matrix and pisoliths suggests that Au mobilization occurred from the mineralized regolith or basement into the ferruginized sediments. In these situations, deep weathering has continued after deposition of the sediments. During this weathering, groundwaters can flow through both the *in situ* weathered rocks and the sedimentary cover, so that geochemical dispersion into the cover is possible.

Hydrogeochemical studies (Gray, 1991) resolved the groundwaters into distinct groups, some of which could be identified as originating from particular lithologies (e.g., granitic, mafic and ultramafic rocks). Groundwaters from the Midway area are anomalous in Au, Fe, Mn, Co, Cu, Cd, Ba and I, have low HCO_3^- concentrations and were concluded to reflect the weathering of sulphides. Soluble Au (>0.05 µg/L) was only detected within the mineralized area. The results suggest that multi-element hydrogeochemical surveys have potential in exploration at both the district and mine scale.

DISPERSION MODEL

TBA

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SAMPLE MEDIA - SUMMARY TABLE

Sample medium	Indicator elements	Analytical method	Detection limit (ppm)	Mean (ppm)	Minimum (ppm)	Maximum (ppm)	Dispersion distance (m)
Saprolite (N=25)	Au	GF-AAS		0.439	0.006	3.52	
	As	XRF	2	15	<2	74	
	Sb	XRF	2	2.5	<2	8	
	Bi	XRF	2	6	<2	70	
	Mo	XRF	1	2	<1	3	
	W	XRF	4	4	<4	14	
Mottled zone (N=13)	Au	GF-AAS		0.8	0.045	2.73	
	As	XRF	2	64	<2	570	
	Sb	XRF	2	2	<2	8	
	Bi	XRF	2	10	<2	61	
	Mo	XRF	1	2	<1	5	
	W	XRF	4	4	<2	11	
Lateritic residuum* (combined lateritic gravel and lateritic duricrust N=167	Au	GF-AAS		1.832	0.005	12.7	
	As	XRF	2	34	3	150	
	Sb	XRF	2	6	<2	15	
	Bi	XRF	2	7	<2	52	
	Mo	XRF	1	4	<1	18	
	W	XRF	4	8	<4	46	
Lateritic colluvium (N=58)	Au	GF-AAS		1.287	0.021	6.6	
	As	XRF	2	28	<2	105	
	Sb	XRF	2	4	<2	12	
	Bi	XRF	2	6	<2	24	
	Mo	XRF	1	4	<1	12	
	W	XRF	4	11	<4	25	
Soil* (N=17)	Au	GF-AAS		0.579	0.08	3.2	
	As	XRF	2	18	<2	53	
	Sb	XRF	2	3	<2	10	
	Bi	XRF	2	3	<2	12	
	Mo	XRF	1	3	<1	7	
	W	XRF	4	7	<4	16	

*From Smith *et al* (1992b).
Au – graphite furnace AAS after aqua regia digestion.
XRF used extended counting times.