

MYSTERY ZONE GOLD DEPOSIT, MT. PERCY, KALGOORLIE, WESTERN AUSTRALIA

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LOCATION

Mt. Percy is two km NE of the centre of Kalgoorlie, Western Australia at 121°28'25"E, 30°43'48"S; Kalgoorlie 1:250 000 map sheet, (SH51-09).

DISCOVERY HISTORY

Gold mineralization was found at the N end of the Kalgoorlie goldfield by prospectors, who mined narrow, low-grade orebodies, mainly from 1893 to 1910. Total production was about 70 000 t at 9.0 g/t (Feldmann, 1916). In 1977, Occidental Minerals Corporation of Australia re-interpreted the geology of the area and re-evaluated Mt. Percy by systematic drilling beneath the old workings. Windsor Resources NL (and later Kalgoorlie Consolidated Gold Mines Pty. Ltd.) commenced open cut mining in 1985; the Mystery Zone was mined from 1987. There is a clear surface geochemical expression in lateritic residuum and calcareous soils.

PHYSICAL ENVIRONMENT

Mt. Percy is situated relatively high in the landscape, in a region that has a total relief of only a few tens of metres. Shallow (<10 m) clay- and pisolith-filled channels at the northern end of the Mystery Zone, close to the present divide between the Lake Yindarlgooda and Wollubar branches of the Roe palaeochannel, indicate some topographic inversion. Massive lateritic duricrusts over the Hannans Lake Serpentinite and Golden Mile Dolerite form the highest points at the S end of the Mystery Pit and at Mt. Percy. The climate is semi-arid, with an erratic annual rainfall of about 270 mm. The mean daily maximum and minimum temperatures are 33.7 and 18.2°C in January, 16.6 and 4.9°C in July. Vegetation consisted of a sparse open woodland of *Eucalyptus* spp. and understorey shrubs including *Acacia* and *Eremophila* spp.

GEOLOGICAL SETTING

Mt. Percy is in the hinge zone and steeply E-dipping limb of the Kalgoorlie anticline, at the northern end of the Archaean Kalgoorlie-Kambalda greenstone sequence, about 8 km N of the Golden Mile. Gold mineralization is associated with quartz veins and felsic porphyries intruding the Hannans Lake Serpentinite (Mystery Zone) and the Devon Consols Basalt (Sir John-Union Club Zone) (Johnson *et al.*, 1990). In the Mystery Zone, komatiites of the Hannan's Lake Serpentinite occur as talc-chlorite-carbonate rocks, intruded by felsic porphyries that contain numerous ultramafic xenoliths of mm to tens of cm in size. The ultramafic rocks, including the xenoliths, have been altered to a green fuchsite-carbonate rock, particularly at the contact with the porphyries. Similar rocks with only minor mineralization occur about 1.5 km along strike to the N and a drill section here was selected as a background site (Figure 1).

REGOLITH

An almost complete, residual lateritic regolith was preserved over the mine area (Butt, 2001). Recent palaeomagnetic data give Jurassic and early Tertiary ages for the regolith at Mt. Percy (B. Pillans, ANU, written communication, 2000). The water-table is below 70 m. The regolith (Figure 3A) consists of:

(i) Saprock: most primary minerals except sulphides and some carbonates are unweathered. The weathering front is at 50-60 m, with minor oxidation extending to 100 m or more along fractures.

(ii) Saprolite: 40-50 m thick. Except where there has been local silicification of saprolite derived from the fuchsitic ultramafic rocks, the transition from plasmic and mottled clays to saprolite is mostly gradual. This is due to progressive destruction of pre-existing primary rock fabrics by settling and development of Fe oxide segregations.

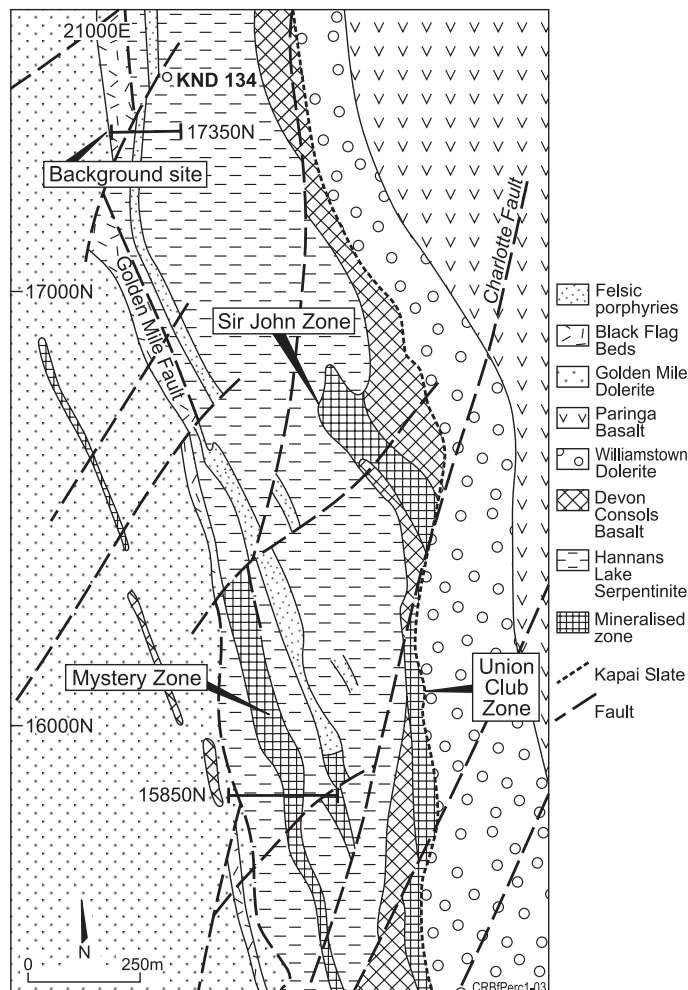


Figure 1. Geological setting of gold mineralization at Mt. Percy, Kalgoorlie, on local mine grid.

The primary fabric is well preserved at greater depth, and the material becomes more competent close to the transition to saprock. The saprolite is dominantly kaolinitic; most primary minerals have been altered, except for muscovite and quartz over felsic and fuchsitic ultramafic rocks and some chlorite over talc-chlorite rocks. Saprolite developed from the felsic porphyries is bleached whereas the green colour of the fuchsite in the ultramafic rocks is commonly emphasized, especially along some ultramafic-porphyry contacts. Secondary alunite has been precipitated in the upper saprolite.

(iii) Mottled and plasmic clays: 10-15 m thick over the talc-chlorite ultramafic rocks, shallower over other lithologies; pale green-grey kaolinitic clay, strongly coloured by secondary Fe oxides. In the plasmic zone, Fe oxides form diffuse impregnations throughout the matrix whereas, in the mottled clay, they form pisoliths and highly irregular nodules and aggregates. Relict muscovite is preserved.

(iv) Lateritic residuum: 1-5 m thick; nodular and pisolitic gravels, with massive duricrusts on the talc chlorite carbonate ultramafic rocks and Golden Mile Dolerite, consisting predominantly of goethite and hematite, with some maghemite close to the surface. It is calcareous in the top metre.

(v) Calcareous soil (<1 m): calcareous loam with calcrete nodules and abundant ferruginous pisoliths and nodules. Lateritic residuum is absent to the E and N, including the background site, and an almost uniform cover of calcareous, nodular red clay soil (1-2 m) overlies non-calcareous red clays, mottled clays and saprolite.

MINERALIZATION

Primary mineralization (cut-off 0.5 g/t Au) in the Sir John-Union Club and Mystery Zones is typically about 30 m wide over strikes of approximately 1800 m and 800 m, respectively, separated by about 300 m of intermittently mineralized rocks. In the Mystery Zone, free-milling Ag-rich Au (to 50% Ag) occurs in quartz-carbonate veinlets, with minor pyrite and traces of chalcopyrite, galena, sphalerite, arsenopyrite and millerite. Mineralization is largely confined to irregular, mostly steeply-dipping lenses in fuchsite-carbonate alteration zones at the contact with porphyries, intruding the Hannans Lake serpentinite. These have mean Au contents of approximately 1000 ppb, with some high-grade zones (2000-13400 ppb) associated with quartz veining. The mineralized zones have high abundances of S, Sb, As, Ag, Te and W.

Mining mainly exploited secondary and weathered residual Au mineralization in saprolite and lateritic residuum. The distribution of Au in the regolith is typically patchy and reflects the inhomogeneous occurrence of primary and secondary Au (Figure 2A).

1. There is little or no lateral Au dispersion in the saprolite. Weak supergene enrichment occurs in the saprolite over 10-15 m, below about 17 m. There is also minor supergene enrichment (55-220 ppb Au) at the background site, between 30 and 40 m depth.

2. A leached and depleted zone (<100 ppb Au), 5-10 m thick below about 2-4 m, is in the clay-rich mottled and plasmic zones and upper saprolite.

3. There is widespread Au enrichment close to the surface, within the lateritic residuum and the overlying soil (Figure 2A). Over much of the deposit, these contain more than 20% pedogenic carbonate, which hosts a significant proportion of the Au. Ferruginous and calcareous fractions of lateritic soils and gravels both have high Au contents; those with the highest Au contents are generally the most calcareous.

The morphology and low (<1%) Ag content of Au grains suggest that most Au in the regolith is secondary (Gedeon and Butt, 1990). Primary Ag-rich grains (>50% Ag) and Au tellurides were recovered from the lower saprolite (below 50 m), in places with Ag-poor secondary grains. The shallowest Ag-rich grain was from 17 m, probably preserved in vein quartz; all Au grains above this level were Ag-poor.

Mass balance calculations based on whole-of-mine grade-control and drilling data (Sergeev and Gray, 2001) indicate a steady loss of Au throughout the regolith, with over 40% less Au in the upper clay saprolite and above. This confirms that the 'enrichments' in the surface and mid-saprolite are only relative.

REGOLITH EXPRESSION

Composite samples of calcareous soil and mostly gravelly lateritic residuum from the top 1 m over the deposit show concentrations of 50->10 000 ppb Au, with lateral dispersion distorting the original, primary distribution evident in the mid-saprolite (Figure 2B). Calcareous red clay soils at the background site contain 30-50 ppb Au, possibly reflecting minor mineralization evident in saprolite.

The distributions of other elements associated with mineralization (S, As, Sb and W) are shown on cross-sections in Figure 3, compared to the geology and Fe and Ca distributions. Data on other elements are given in Butt (1991, 1993, 2001). Regional and local thresholds are given in Table 1.

Iron is strongly enriched towards the top of the regolith over all lithologies, being concentrated in the mottled clays and, particularly, the lateritic duricrust. In the upper saprolite and overlying horizons, secondary Fe oxides occur as diffuse stains and as discrete nodules, pisoliths, veins and void coatings, consisting predominantly of goethite and hematite, with some maghemite. The lower Fe content of the porphyries (means of 2.5-2.9% Fe) compared to that of the ultramafic rocks (5.9-6.6%) is discernible through most of the regolith, but is not evident in the lateritic residuum and red clay soils.

Calcium. The distribution of Ca is characteristic of the region and has particular significance, given the association of carbonate alteration

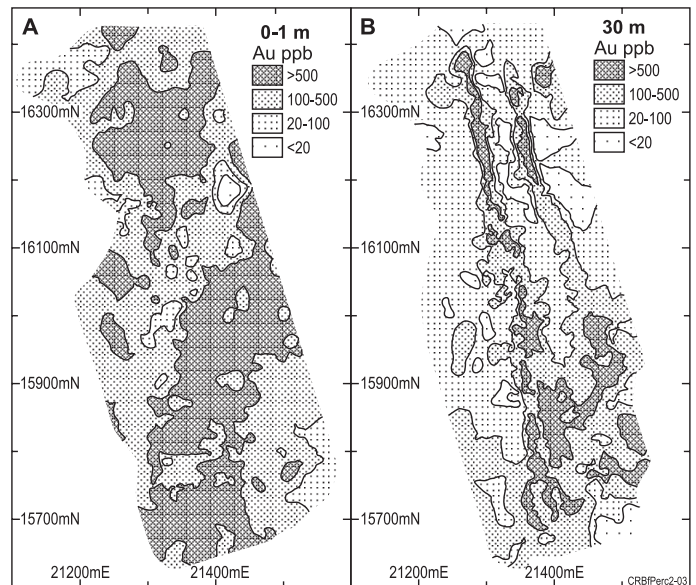


Figure 2. Gold distribution at surface (A) and 30 m depth (B), Mystery Zone, Mt. Percy, derived from mine grade control data.

with mineralization in many Archaean Au deposits, and Au enrichment in pedogenic carbonates. Dolomite is the principal primary host and is one of the first minerals to weather. Calcium is thus strongly depleted (<0.05%) from the base of the saprolite upwards, but re-occurs as pedogenic carbonates in the top 1-3 m.

Sulphur. Sulphide minerals are the most susceptible to weathering, so that S is leached to less than 0.125% throughout the lower to mid-saprolite. However, zones of pronounced S enrichment, to >5.0% S, in the mid-upper saprolite are approximately coincident with zones of supergene Au enrichment at both the Mystery Zone and background site. Some secondary Au grains are embedded in alunite (Gedeon and Butt (1990).

Antimony. Antimony abundances are generally greater in the regolith than in the equivalent unweathered rocks, particularly over the fuchsitic ultramafic rocks. Antimony becomes more widely dispersed and increases in concentration upwards through the profile, with the highest contents (10-30 ppm) in the clay-rich horizons that are leached and depleted in Au. In contrast, the Sb contents of the duricrust and soils are broadly similar to those of the unweathered rocks (<10 ppm) and Sb is concentrated in the ferruginous fraction. Weakly mineralized saprolite at the background site has 7-15 ppm Sb.

Arsenic. Arsenic, like Sb, has restricted dispersion in the lower regolith but becomes more widespread in the upper saprolite. However, this dispersion appears to be less homogeneous than that for Sb and there is much less overall enrichment. Arsenic may be leached from the clay-rich and mottled horizons of the regolith but, unlike Au, some high concentrations are retained, particularly in Fe-rich materials, on the presumed projection of primary mineralization. Lateritic residuum and soils have As contents similar to, or slightly lower than, that of the primary mineralization, with some lateral dispersion, particularly over the talc-chlorite ultramafic rocks. Peak As contents (>300 ppm) in any horizon generally occur in more ferruginous samples or in Fe oxide fractions. Background As contents are <10 ppm over porphyries and fuchsitic ultramafic rocks, but clay saprolite on talc-chlorite rocks has a mean of 30 ppm As, apparently unrelated to the minor mineralization at the site. Arsenic concentrations are partly dependent on those of Fe, hence tend to be higher over ultramafic rocks; ideally, As data should be normalized to Fe content.

Tungsten. Tungsten is consistently enriched, as scheelite, in the primary mineralization. Abundances are 4-10 ppm in fuchsitic ultramafic rocks and 18-28 ppm in porphyries, compared to <2 ppm and <5 ppm in unmineralized or background talc-chlorite ultramafic rocks and porphyries, respectively. Concentrations are slightly greater in the mineralized regolith, particularly over fuchsitic ultramafic rocks, and the distribution is generally more homogeneous, suggesting some dispersion during weathering. An important feature of the W distribution

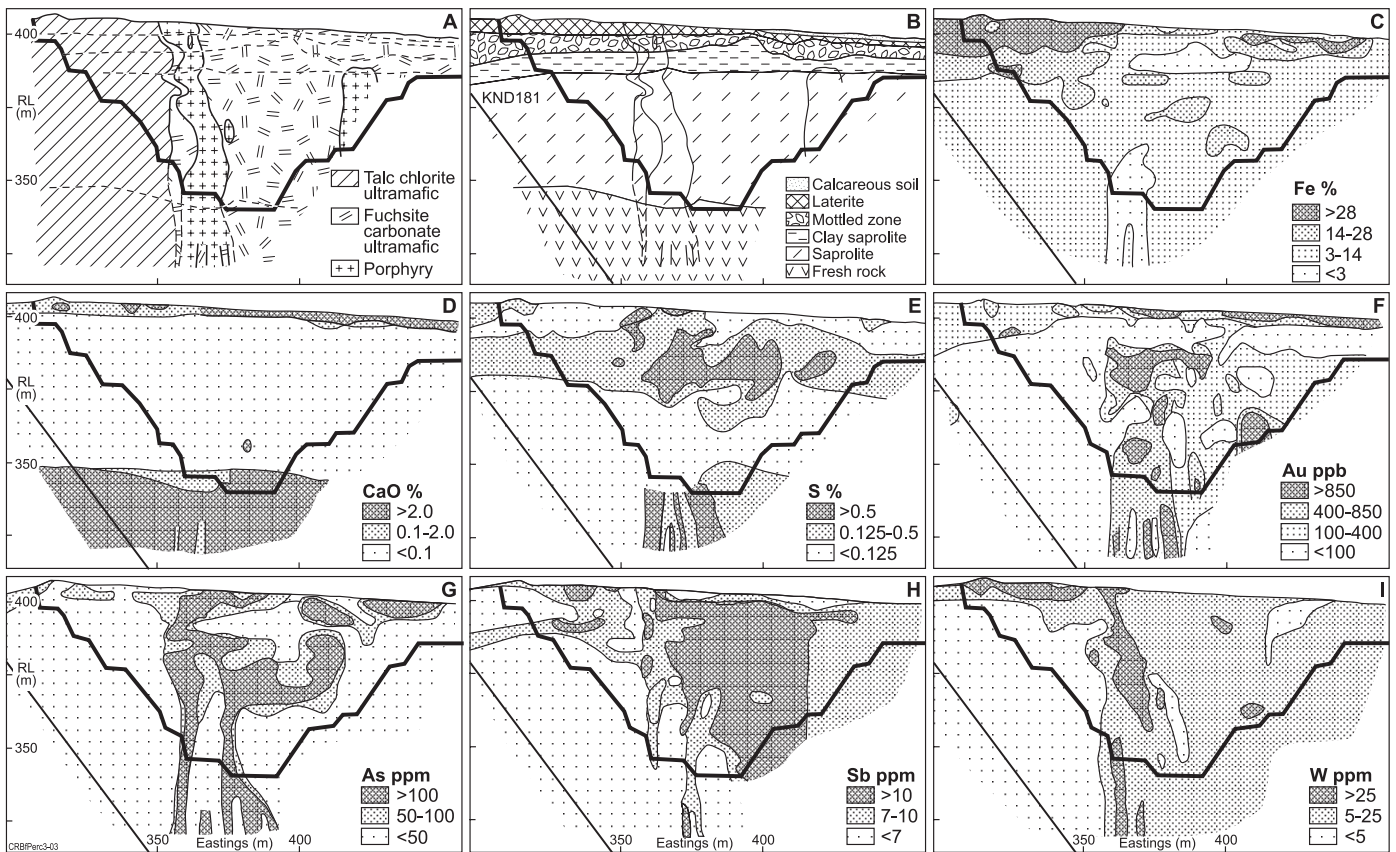


Figure 3. Regolith geology and distributions of Fe, CaO, S, Au, As, Sb and W traverse, 15850 m N, Mystery Zone, Mt. Percy. Fresh rock data from diamond drill hole KND 181 are projected to 330 m RL.

is its retention in the ferruginous fraction of lateritic duricrusts and soils. Thus, it gives a widespread surface anomaly, broadly coincident with that of Au. Duricrusts over the talc-chlorite ultramafic rocks are strongly enriched in W (25-60 ppm), together with Sb and immobile elements including Th and Zr.

Silver and tellurium. Silver and Te contents of primary mineralization are both in the range 0.23-19.0 ppm with Ag/Au and Te/Au ratios mostly between 1 and 5. Complex mixed grains of Au, Ag and/or Te, as elements, chlorides and bromides, were found at 47.5 m (Gedeon and Butt, 1990). Above 45 m, both Ag and Te are leached, and are below detection limit above 25 m (Ag <0.04 ppm, Te <0.1 ppm; 18 samples). These observations regarding Te mobility are at variance with those of Porto (1998) from Posse, Brazil, where Te was found concentrated in lateritic pisoliths.

ACKNOWLEDGEMENTS

Dr. P.C.C. Sauter is thanked for his careful supervision of sample collection and discussion of the data. Dr. D.G. Gray provided Figure 2.

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TABLE 1.
APPROXIMATE THRESHOLDS FOR REGOLITH HORIZONS

Regolith horizon	Au (ppb)	As (ppm)	Sb (ppm)	W (ppm)
<i>Saprolite</i>				
Regional	20	10	4	3
Local	90	35	8	6
<i>Clay horizons</i>				
Regional	10	10	4	3
Local	30	25	10	8
<i>Calcareous soil</i>				
Local: non-lateritic	30	15	4	3
Local: lateritic	50	30	4	3

TABLE 2

SUMMARY TABLE, MT PERCY

Mean concentrations; standard deviation in parenthesis. Number of samples (N) indicated if <5.

	Mystery Zone			Background		
	Talc chlorite ultramafic (unaltered)	Fuchsite ultramafic (altered; mineralized)	Porphyry (altered; mineralized)	Talc chlorite ultramafic (unaltered)	Fuchsite ultramafic	Porphyry (weakly mineralized in saprolite)
Calcareous laterite/soil	Au: 301 (195) Sb: 9 (2) As: 47 (18) W: 36 (10)	1361 (483) 4 (2) 47 (37) 6 (3)	1030 (1070) 8 (2) 77 (40) 28 (6)	30-52 (N=4; not differentiated by lithology) 1-1.5 14-19 1		
Lateritic residuum (N=2, talc ultramafic; others N=3)	Au: 398 (350) Sb: 9 (0.1) As: 70 (4) W: 32 (1)	790 (286) 15 (1) 171 (74) 78 (19)	393 (51) 9 (4) 172 (193) 33 (21)	na	Na	na
Plasmic clay	Au: 9 (10) Sb: 6 (1) As: 19 (18) W: 3 (3)	287 (749) 12 (4) 117 (103) 18 (20)	51 (30) 11 (7) 200 (149) 30 (22)	na	Na	na
Mottled clay	Au: 60 (21) Sb: 7 (1) As: 33 (18) W: 3 (3)	209 (243) 19 (18) 196 (178) 18 (20)	4054 (13315) 10 (3) 176 (105) 23 (5)	7 (6) N=2 3 (0.3) 11 (1.4) 1 (-)	Na	
Clay saprolite	Au: 7 (6) Sb: 8 (3) As: 23 (15) W: 4 (4)	405 (1207) 18 (38) 79 (150) 14 (9)	571 (1208) 8 (2) 73 (95) 24 (10)	2.5 (-) N=4 4 (1.3) 8 (2) 29 (20) 1.5 (1.7)	35 (45) N=2 5 (1) 6 (3) 5 (2)	2.5 (-) N=2 15 (2) 4 (0.2) 7 (4)
Saprolite	Au: 3 (250) Sb: 6 (2) As: 39 (92) W: 4 (8) Ag: Te:	710 (1199) 12 (8) 120 (173) 11 (14) 160-2820 <100-1500	718 (1095) 7 (4) 80 (110) 25 (9) 550-840 130-1500	14 (5) N=27 3 (3) 18 (21) 1.5 (1) - -	9 (16) N=11 5 (1) 6 (3) 4 (3) - -	33 (68) N=13 8 (3) 6 (5) 7 (7) - -
Fresh rock	Au: 5 (9) Sb: 3 (1) As: 53 (116) W: 1 (0.3) Ag: 500-2700 Te: <100	1030 (2560) 6 (3) 184 (218) 6 (3) 230-1880 <100-1800	1040 (1417) 6 (6) 30 (18) 6 (3) 510-17900 200-13200	2.7 (1) N=16 1.3 (0.5) 2 (1) 1 (-) - -	Na	3 (1.7) N=12 3 (1.5) 2 (2) 5 (4) - -

Au, Ag, Te data in ppb; As, Sb, W data in ppm.

INAA Analyses: detection limits 5 ppb Au, 2 ppm As, 0.2 ppm Sb, 3 ppm W.

Acid digest, AAS: 400 ppb Ag; hydride generation AAS: 100 ppb Te