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

C.R.M. Butt
CRC LEME, CSIRO Exploration and Mining, PO Box 1130, Bentley, Western Australia 6102
Charles.Butt@csiro.au

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 open 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 Wollular 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 Hannans Lake Serpentinite and Golden Mile Dolerite form the highest points of the 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.

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 weather-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 pisolithic 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 calcarete 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.
IRON

Table 1. The distributions of other elements associated with mineralization (S, and hematite, with some maghemite. The lower Fe content of the pisoliths, veins and void coatings, consisting predominantly of goethite secondary Fe oxides occur as diffuse stains and as discrete nodules, lithologies, being concentrated in the mottled clays and, particularly, with particular significance, given the association of carbonate alteration refl ector minor mineralization evident in saprolite. Calculeous soil and mostly gravelly lateritic residuum 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 confi rms 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 50–100 000 ppb Au, with lateral dispersion disturbing 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 refl ecting 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 signifi cance, given the association of carbonate alteration with mineralization in many Archaean Au deposits, and Au enrichment in pedogenic carbonates. Dolomite is the principal primary host and is one of the fi rst 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 Sulphides 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 advanced S 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 presumed projection of primary mineralization. Abundances are 4–10 ppm in fuchsitic 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.

REFERENCES


TABLE 1

<table>
<thead>
<tr>
<th>Regolith horizon</th>
<th>Au (ppb)</th>
<th>As (ppm)</th>
<th>Sb (ppm)</th>
<th>W (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saprolite</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>20</td>
<td>10</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Local</td>
<td>90</td>
<td>35</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Clay horizons</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Regional</td>
<td>10</td>
<td>10</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Local</td>
<td>30</td>
<td>25</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>Calcareous soil</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local: non-lateritic</td>
<td>30</td>
<td>15</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Local: lateritic</td>
<td>50</td>
<td>30</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
## TABLE 2
### SUMMARY TABLE, MT PERCY

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

<table>
<thead>
<tr>
<th>Mystery Zone</th>
<th>Talc chlorite (unaltered)</th>
<th>Talc chlorite (mineralized)</th>
<th>Fuchsite (unaltered)</th>
<th>Fuchsite (mineralized)</th>
<th>Porphyry (unaltered)</th>
<th>Porphyry (mineralized)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caledonius metasediments</td>
<td>1030 (1070)</td>
<td>1030 (1070)</td>
<td>1030 (1070)</td>
<td>1030 (1070)</td>
<td>35-52 (N=4; not differentiated by stratigraphy)</td>
<td></td>
</tr>
<tr>
<td>Laterric medium (N=2, talc unaltered)</td>
<td>790 (285)</td>
<td>790 (285)</td>
<td>790 (285)</td>
<td>790 (285)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Plasmic clay</td>
<td>287 (749)</td>
<td>287 (749)</td>
<td>287 (749)</td>
<td>287 (749)</td>
<td>na</td>
<td>na</td>
</tr>
<tr>
<td>Mottled clay</td>
<td>205 (243)</td>
<td>205 (243)</td>
<td>205 (243)</td>
<td>205 (243)</td>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Clay saprolite</td>
<td>405 (1207)</td>
<td>405 (1207)</td>
<td>405 (1207)</td>
<td>405 (1207)</td>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Saprolite</td>
<td>100 (260)</td>
<td>100 (260)</td>
<td>100 (260)</td>
<td>100 (260)</td>
<td>Na</td>
<td>Na</td>
</tr>
<tr>
<td>Fresh rock</td>
<td>1030 (2560)</td>
<td>1030 (2560)</td>
<td>1030 (2560)</td>
<td>1030 (2560)</td>
<td>Na</td>
<td>Na</td>
</tr>
</tbody>
</table>

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.