MT. PERCY GOLD DEPOSIT AREA, WESTERN AUSTRALIA

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LOCATION

The Mt Percy Gold Deposit is located two km northeast of the centre of Kalgoorlie, at 30°43'48"S 121°28'25"E within the KALGOORLIE (SH51-9) 1:250 000 map sheet area.

PHYSICAL SETTING

Geology

Mt Percy lies in the hinge zone and steeply east-dipping limb of the Kalgoorlie anticline, at the northern end of the Archaean Kalgoorlie–Kambalda greenstone sequence, about 8 km north 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), and was mined by open cut methods during 1985–1995 (Johnson *et al*., 1990; Butt, 2001). These mineralized zones (cut-off 0.5 g/t Au) are typically about 30 m wide over strike lengths of approximately 800 m and 1800 m, respectively, and are separated by about 300 m of intermittently mineralized Hannans Lake Serpentinite and porphyry. Primary mineralization consists of free-milling Ag-rich gold (up to 50% Ag) associated with quartz-carbonate veinlets and disseminated pyrite in bleached alteration zones. Mining, however, dominantly exploited weathered mineralization in the regolith.

Geomorphology

Mt Percy is situated relatively high in the landscape, in a region that has a total relief of only a few tens of metres (Figure 1). 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, indicates some topographic inversion. Massive lateritic duricrust over the Hannans Lake Serpentinite and Golden Mile Dolerite forms the highest points at the south end of the Mystery Pit and at Mt Percy.

Vegetation and climate

The climate is semi-arid, with an erratic rainfall of about 270 mm/yr. The mean daily maximum and minimum temperatures are 33.6 and 18.2°C in January, and 16.5 and 4.8°C in July. Vegetation consists of a sparse open woodland of *Eucalyptus* spp. and understorey shrubs including *Acacia* and *Eremophila* spp.

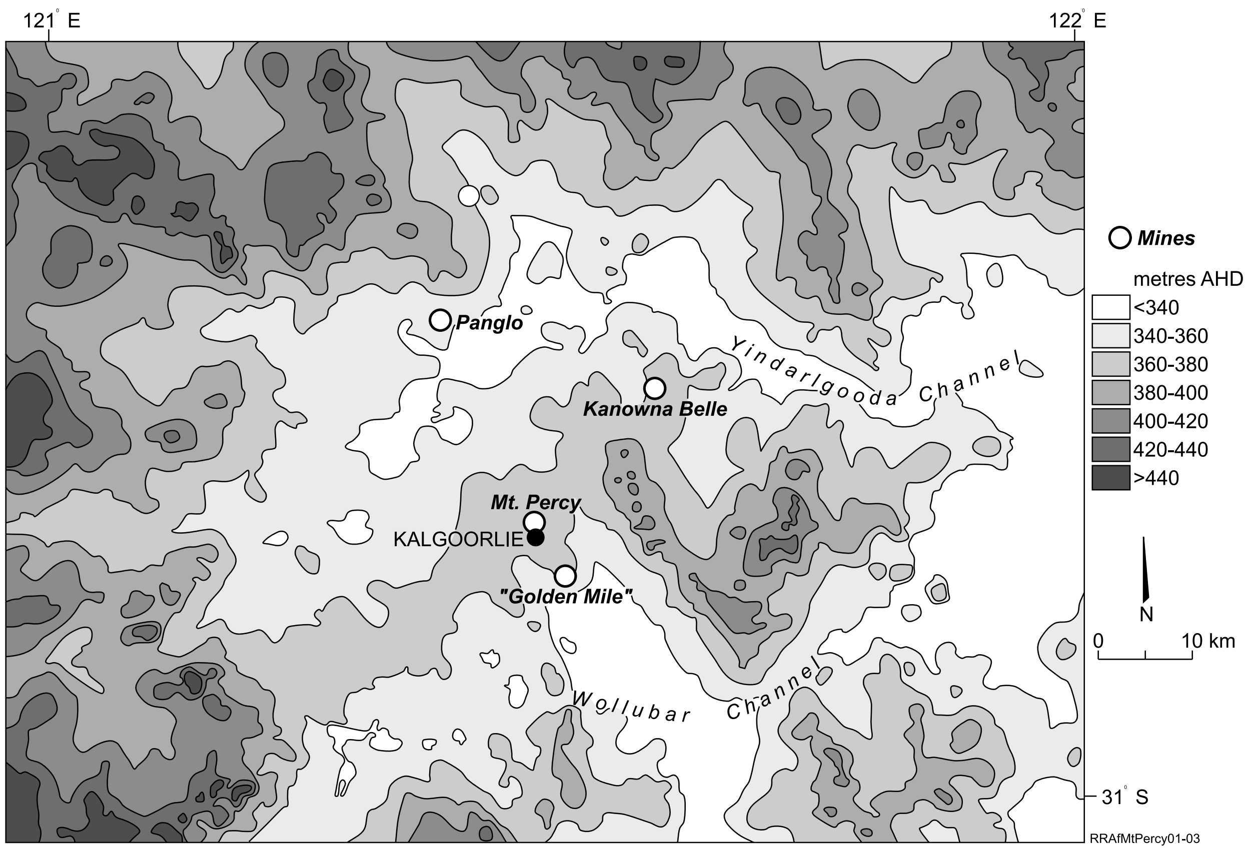

Figure 1. Topographic setting of the Mt Percy gold mine.

REGOLITH CHARACTERIZATION

Regolith profile

An almost complete, residual lateritic regolith was preserved over the mine area. The water-table is below 70 m. In the Mystery Zone, the regolith profile (Figures 2 and 3) consists of:

Calcareous soil: <1 m thick, with abundant ferruginous nodules, powdery calcrete and calcrete rhizomorphs and nodules.

Lateritic residuum: 1–5 m thick; nodular and pisolitic gravels, with massive duricrusts over on the talc–chlorite–carbonate ultramafic rocks and Golden Mile Dolerite, consisting predominantly of goethite and hematite, with some maghemite close to the surface. The lateritic residuum becomes calcareous in the top metre.

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

Saprolite: 40–50 m thick. Except for the local development of silicification in saprolite derived from fuchsitic ultramafic rocks, the transition from plasmic and mottled clays to saprolite is mostly gradual, due to the progressive destruction the pre-existing primary rock fabrics by settling and the development of Fe oxide segregations. With greater depth, the primary fabric is well preserved, 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 in the upper part, especially along some ultramafic/porphyry contacts. Although not visible in hand specimen, secondary alunite has been precipitated in the upper saprolite.

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.

To the north and east of the area, lateritic residuum is absent and an almost uniform cover of calcareous, nodular red clay soil (1–2 m) overlies non-calcareous red clays, mottled clays and saprolite.

A shallow palaeochannel (5–7 m deep), unrecognized prior to mining, has been exposed in the eastern end of the north wall

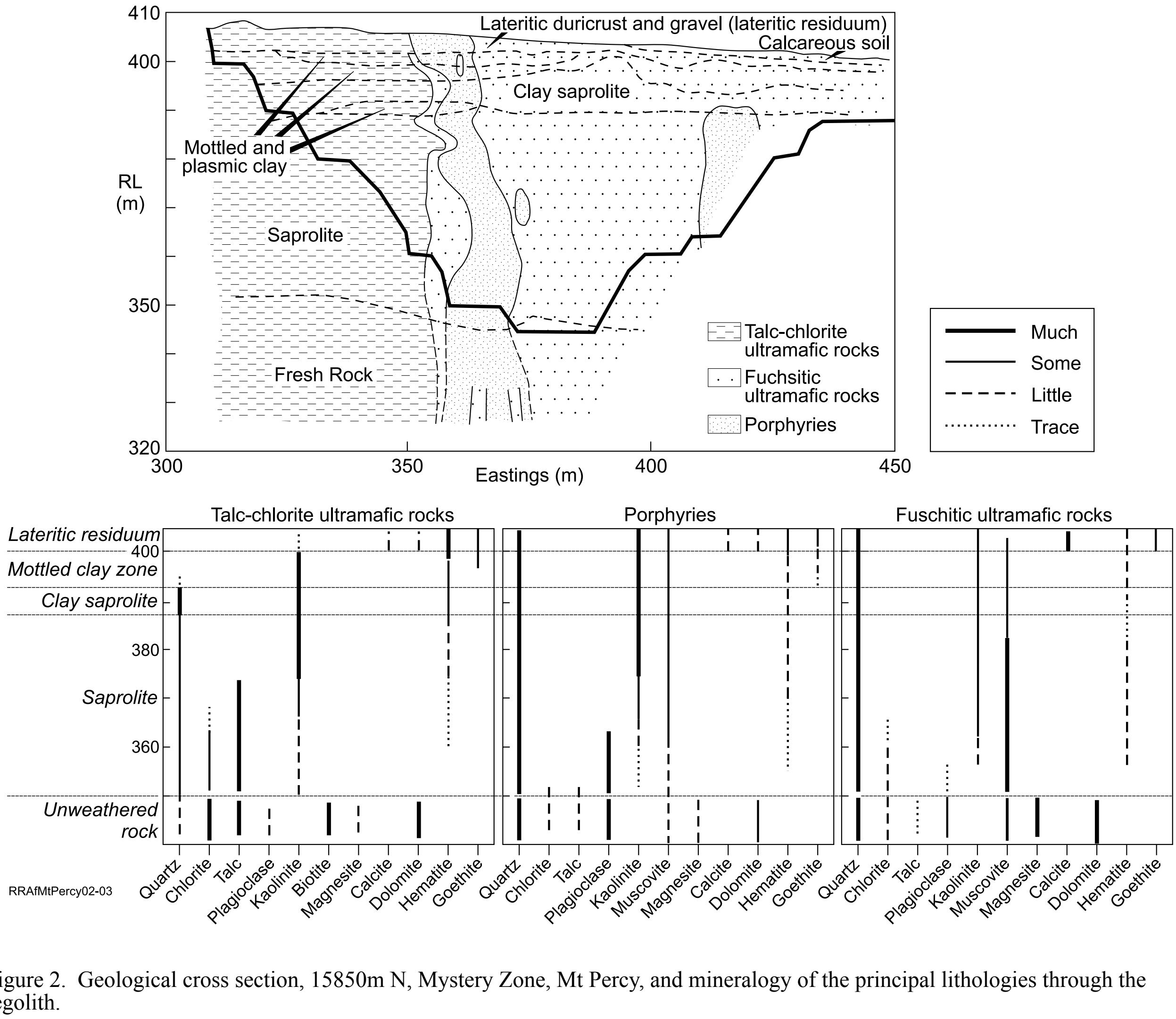

Figure 2. Geological cross section, 15850m N, Mystery Zone, Mt Percy, and mineralogy of the principal lithologies through the regolith.

of the Mystery Zone pit. It contains a massive, grey, kaolinitic clay with abundant, cylindrical megamottles (to ~0.5 m diameter). The upper metre is calcareous, with calcrete rhizomorphs locally extending deeper. There is a clear unconformity at the base of the channel, locally marked by a quartz stone line. A channel or colluvial wash, <5 deep, filled with ferruginous pisoliths and nodules, was also exposed in the north wall.

DATING

Recent palaeomagnetic data give Carboniferous, Jurassic and early Tertiary ages for the regolith at Mt Percy (B. Pillans, ANU, written communication, 2000). It has been conjectured that the preservation of Mesozoic and older regolith may be due to burial and later exhumation, although there is no evidence for a widespread sedimentary cover, nor, indeed, that the regolith could survive this process.

LANDSCAPE AND REGOLITH EVOLUTION

Landscape evolution

Observations at Mt Percy are consistent with many of the general features established for regolith evolution and the formation of supergene Au deposits in semi-arid regions of the southern Yilgarn Craton (Butt, 1989).

Weathering has taken place from the Carboniferous, on a land surface of moderate to low relief that had possibly been glaciated in the Permian. Since the Permian, there have been several major changes of climate, of which two episodes have been of particular importance. These were, firstly, humid, periodically warm to possibly sub-tropical climates of the Cretaceous to mid-Miocene and, secondly, the drier climates since the Miocene. The humid climates, which are interpreted to have supported rainforest during the Eocene (Clarke, 1994) and, probably earlier, caused to extensive, deep lateritic weathering. The change to arid conditions in the Miocene was probably gradual and intermittent, but would

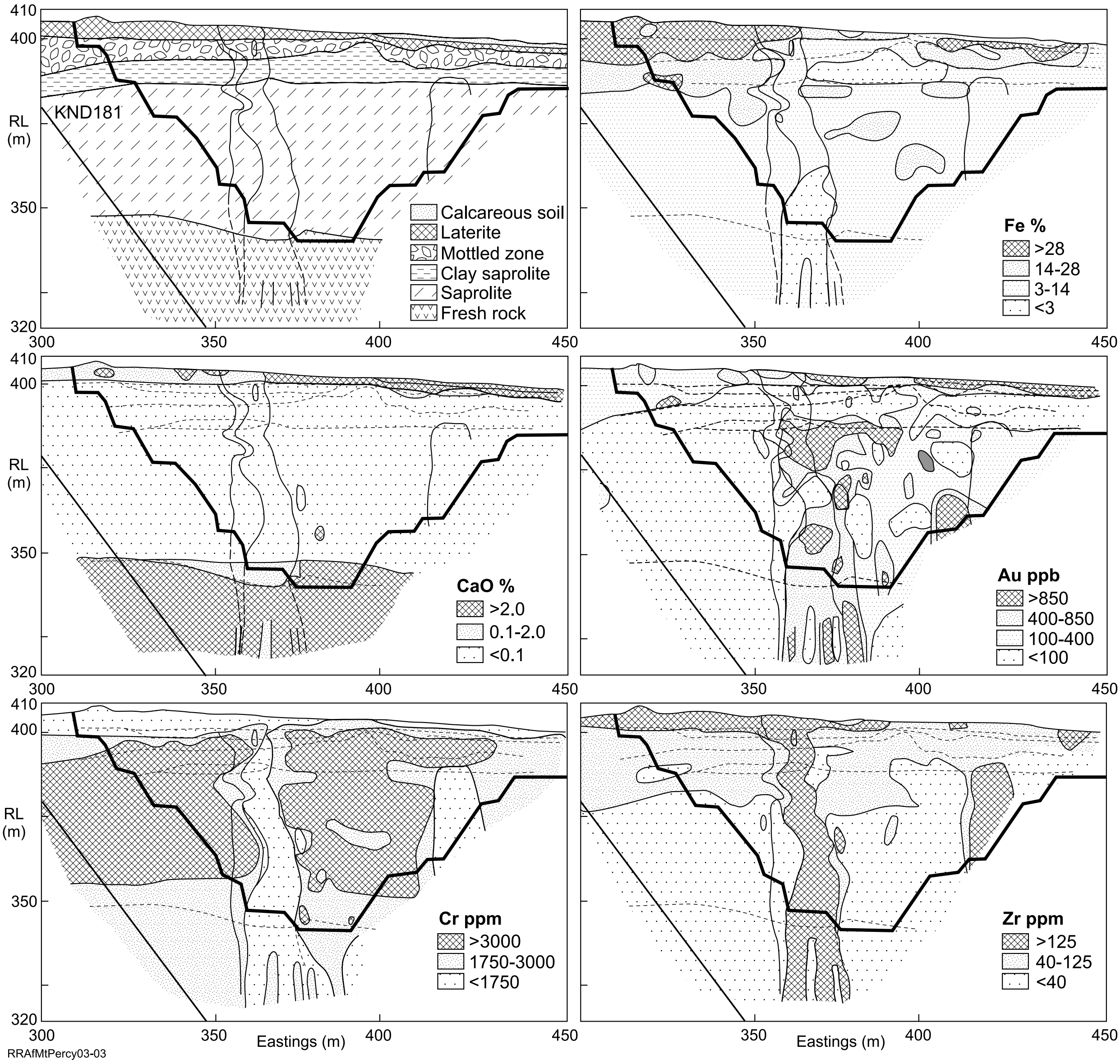

Figure 3. Regolith geology and distributions of Fe, CaO, Au, Cr and Zr traverse, 15850 m N, Mystery Zone, Mt Percy. Fresh rock data from diamond drill hole KND 181 are projected to 330 m RL.

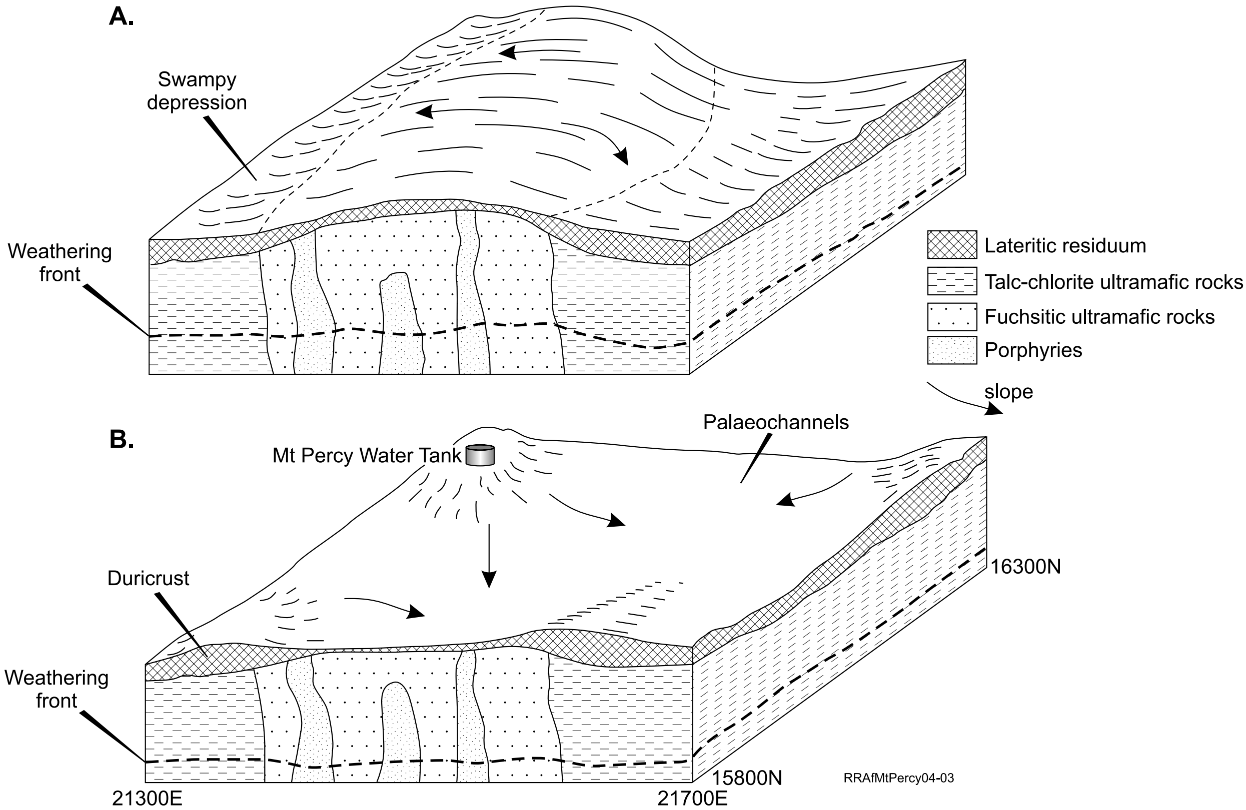

Figure 4. Block models illustrating regolith evolution at the Mystery Zone. **A**: accumulation of Fe oxides in drainage depression formed by preferential weathering of talc–chlorite ultramafic rocks under humid lateritic conditions. **B**: local topographic inversion due to hardening and preservation of Fe-rich duricrust on talc–chlorite ultramafic rocks and partial erosion of upper horizon over fuchsite ultramafic rocks and porphyries. Not shown are possible intermediate steps involving incision of palaeochannels, sediment deposition, weathering and further erosion.

have led to vegetation changes and increased erosion. It also resulted in a general lowering of water tables and changes to, and slowing of, chemical weathering.

Each of the broad climatic episodes had several phases of physical and chemical weathering. For example, the numerous palaeochannels in the Kalgoorlie region, shallow examples of which are present at Mt Percy, were incised into an already weathered landscape during the Eocene. These were subsequently infilled by sediments, generally dated as mid–late Eocene, derived from further erosion of that landscape, that have themselves been intensely weathered.

The general preservation of the regolith at Mt Percy implies that there has been little erosion since the Late Eocene. Nevertheless, the near-surface lateral dispersion of immobile elements such as Zr (see Figure 3), especially into the duricrust over the talc–chlorite ultramafic rocks suggests there may have been local topographic inversion. The host zircons are derived from felsic rocks, but the duricrusts are at higher elevations than the subcrops of porphyries in the vicinity (Figures 2, 3). A possible explanation is that the talc–chlorite ultramafic rocks were more susceptible to weathering than the other lithologies and occupied lower ground during the humid climatic episode. Resistant minerals such as zircon released from the porphyries were transported downslope to accumulate over the talc–chlorite rocks, together with chemically mobilized Fe. Later, preferential erosion of the upper regolith developed on the porphyries and fuchsitic ultramafic rocks has led to topographic inversion (Figure 4).

The hypothesis of topographic inversion is supported by evidence for localized partial truncation of the regolith. In comparison to the talc–chlorite rocks, the lateritic and clay-rich horizons on the porphyries and fuchsitic rocks are thin, with silicified saprolite at or close to the surface in some places. This truncation may have been due, in part, to these horizons being more friable and less indurated, thereby increasing their vulnerability to erosion. Truncation to saprolite at about 400 m RL over these rocks is evident in the south wall and Black Flag Beds and other units to the west of the pit. Conversely, an almost complete profile is present on Mt Percy itself (16200mN), which has massive duricrust developed on Golden Mile Dolerite, and was also present on other talc chlorite units that formed the eastern margin of the Mystery Zone. In contrast, the northern wall exposes the shallow, infilled palaeodrainage channels.

The evidence thus points to a complex sequence of erosional and depositional events occurring during and after lateritic deep weathering that have affected the composition and structure of the near-surface horizons. If this erosion and inversion has occurred, however, it indicates that the apparently residual lateritic gravels present over the porphyries and fuchsitic ultramafic rocks have undergone some surface redistribution.

Regolith evolution

The mineral and element distributions, and compositions of the various horizons of the regolith (Figures 2 and 3) are related to the different weathering processes that prevailed during the principal climatic regimes. Many of the dominant characteristics, including the depth, can be related to the development of the lateritic profile under humid conditions of high water-tables, whereas the arid phases are reflected by modifications such as the introduction and hardening of cements, salinization and gold mobility.

Deep weathering under humid conditions: Mesozoic to the mid-Miocene.

a. At the base of the profile, progressive weathering of sulphides, dolomite, feldspars and ferromagnesian minerals (biotite, some chlorite), with total or partial leaching of their mobile constituents (S, Na, Cs, Ca, Mg, Sr, Mn, Co, Ni, Cu, Zn) and retention of less mobile constituents in secondary minerals, principally kaolinite and Fe oxides (Si, Al, Fe, Ba, Cr, Ti, V, As, Sb, Sc, Ga, Mn, Cu, Ni).

b. In the mid to upper saprolite, dissolution of secondary minerals (e.g., kaolinite, barite) and some resistant primary minerals (e.g., chlorite, talc, muscovite), leading to loss of primary fabrics through slumping and collapse, with some loss of Si, Al, Cr, Ba, K and Rb.

c. Primary Ag-rich gold dissolved, especially from the upper, ferruginous horizons, probably by complexation with organic ligands in neutral to acid conditions, and reprecipitated as fine Ag-poor particles, associated with secondary Fe oxides.

d. Accumulation of immobilized elements in resistant primary minerals in lateritic residuum (e.g., Zr, Hf in zircon; K, Rb in muscovite; Ti in rutile; REE, Ta, Nb, Th, W) and stable secondary minerals (Ti in anatase; V in Fe oxides). Usually Cr is not concentrated; it is hosted by chlorite, not chromite, and released in the saprolite.

2. Weathering under warm, semi-arid conditions: mid-Miocene to present:

a. Dehydration and hardening of lateritic residuum as duricrusts, especially over the talc–chlorite ultramafic rocks.

b. Mobilization of Au and Ag as halide complexes (Gray *et al*., 1992) has probably continued intermittently to the present day, with progressively lower water tables. They are leached from the mottled zone and clay saprolite, and reprecipitated close to the water table, or at redox fronts beneath and related to it, as Ag-poor gold grains and Ag halides.

c. Precipitation of alunite, probably under acid, oxidizing conditions with a relatively high water table, probably associated with Au mobilization.

d. Precipitation of silica, introduced into the profile or derived from dissolving clay minerals, in saprolites of fuchsitic ultramafic rocks, under similar conditions.

e. Aeolian accession of alkaline earth elements, plus ongoing release within the regolith and at the weathering front with transport to the surface under an evaporation gradient and/or by evapotranspiration has led to their accumulation at the surface. Vegetative cycling of these elements and Au has led to their gradual accumulation in the pedogenic carbonates. The Ca distribution (Figure 3) is a consequence of initial leaching and this later precipitation event.

ACKNOWLEDGEMENTS

Dr. P.C.C. Sauter is thanked for his careful supervision of sample collection and discussion of the data. Dr. D.J. Gray assisted with the preparation of Figure 1.

REFERENCES

Butt, C.R.M., 1989. Genesis of supergene gold deposits in the lateritic regolith of the Yilgarn Block, Western Australia. In: R.R. Keays, W.R.H. Ramsay and D.I. Groves (Editors). The geology of gold deposits: the perspective in 1988. Economic Geology Monograph 6. pp. 460-470.

Butt, C.R.M., 2001. Dispersion of gold and associated elements in the lateritic regolith, Mystery Zone, Mt Percy, Kalgoorlie, Western Australia. Geochemistry: Exploration, Environment, Analysis, 1:291-306.

Clarke, J.D.A., 1994. Evolution of the Lefroy and Cowan palaeodrainages, Western Australia. Australian Journal of Earth Sciences, 41: 55-68.

Gray, D.J., Butt, C.R.M. and Lawrance, L.M., 1992. The geochemistry of gold in lateritic terrains. In: C.R.M. Butt and H. Zeegers (Editors). Regolith Exploration Geochemistry in Tropical and Subtropical terrains. Elsevier, Amsterdam. pp. 461-482.

Johnson, S.F., Sauter, P.C.C., Hyland, S.J. and Bradley, T., 1990. Mount Percy gold deposits. In: F.E. Hughes (Editor). Geology of the Mineral Deposits of Australia and Papua New Guinea. Australasian Institute of Mining and Metallurgy, Melbourne. pp. 433-437.