CRCLEME
Cooperative Research Centre for
Landscape Evolution & Mineral Exploration

REGOLITH '98
Australian Regolith and Mineral Exploration

NEW APPROACHES TO AN OLD CONTINENT

FIELD GUIDE

Compiled by
I.D.M. Robertson

CRC LEME REPORT 81

5 May 1998
Kalgoorlie Field Excursion

CRC LEME is an unincorporated joint venture between The Australian National University, University of Canberra, Australian Geological Survey Organisation and CSIRO Exploration and Mining, established and supported under the Australian Government's Cooperative Research Centres Program.

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Headquarters: CRC LEME c/o CSIRO Exploration and Mining, Private Bag, PO Wembley, Western Australia, 6014

INTRODUCTION

1. SAFETY

Most of you will know that safety is a particularly sensitive issue on the Goldfields at present. We will be entering a number of mining leases and do so with the kind and generous permission of the lease owners. While we are on their properties, it is essential that we comply fully with all their safety requirements and instructions. Control of such a large party as this presents a real challenge, so your cooperation and vigilance are essential. Infringement of safety requirements will make future visits difficult.

The wearing of safety-boots, hard hats and safety glasses are a requirement in mining areas. Do not approach the edges of benches and berms too closely (particularly when taking photos) and, in disused pits, there may be an additional stability problem. When walking along a bench, do not crowd together but keep to the inner edge. If it is deemed necessary to break the party into separate groups, please cooperate by keeping these groups well separated. Care should be taken not to dislodge large pieces when sampling and be aware of the proximity of colleagues when hammering.

3. TIMETABLE

This field trip has been designed for a very large number of people (120), time is very limited (last light is at 17:36 hrs) and there is much to see. To make it safe and feasible, the field party has been split into three groups of 40 (a bus each); each covering the same sites but in different orders. Consequently, this presents a considerable challenge to scheduling. A timetable is provided below. Departure times, defined as the time the bus drives away, must be adhered to or clashes will occur at some sites, potentially impairing safety, so you will be held up, which will cause some frustration. Please ensure you are back and seated on the bus before the specified times.

4. ACKNOWLEDGEMENTS

This field guide contains the contributions of a number of authors whose work was made possible by the support of their companies and, in the case of CRC LEME, of the sponsors of the CSIRO/AMIRA Projects 240, 241 and 409. Particular thanks are due to Roger Bateman and Paul Sauter (KCGM), John Vinar (Newcrest Mining Group), for helping us gain permission for and arranging the mine visits. All this is acknowledged with appreciation.

TIMETABLE

Bus A	Time	Interval	Bus B	Time	Interval	Bus C	Time	Interval
Leave Kal	12:45	0:04	Leave Kal	12:45	0:12	Leave Kal	12:45	0:52
Arrive Mt Percy	12:49	1:10	Arrive Superpit	12:57	0:15	Arrive Greenback	13:37	0:50
Leave	13:59	0:12	Leave	13:12	0:08	Leave	14:27	0:50
Arrive Superpit	14:11	0:15	Arrive True Sons	13:20	0:30	Arrive Mt Percy	15:17	1:10
Leave	14:26	0:07	Leave	13:50	0:35	Leave	16:27	0:12
Arrive True Sons	14:33	0:30	Arrive Greenback	14:25	1:15	Arrive Superpit	16:39	0:15
Leave	15:03	0:35	Leave	15:40	0:50	Leave	16:54	0:07
Arrive Greenback	15:38	1:00	Arrive Mt Percy	16:30	1:10	Arrive True Sons	17:01	0:25
Leave	16:38	0:52	Leave	17:40	0:04	Leave	17:26	0:20
Arrive Kal	17:30		Arrive Kal	17:44		Arrive Kal	17:46	

	Arr	Leave		Arr	Leave		Arr	Leave
Greenback	15:38	16:38	Greenback	14:25	15:40	Greenback	13:37	14:27
Mt Percy	12:49	13:59	Mt Percy	16:30	17:40	Mt Percy	15:17	16:27
Superpit	14:11	14:26	Superpit	12:57	13:12	Superpit	16:39	16:54
True Sons	14:33	15:03	True Sons	13:20	13:50	True Sons	17:01	17:26

Please be seated on the bus at departure time and keep to your bus

REGOLITH GEOCHEMISTRY, MYSTERY ZONE, MT. PERCY GOLD MINE

C.R.M. Butt
CRC for Landscape Evolution and Mineral Exploration, c/- CSIRO Exploration and Mining, Private Mail Bag, Wembley, Western Australia 6014

1. INTRODUCTION

The Mystery Zone of the Mt. Percy Mine offered the opportunity to investigate geochemical dispersion from Au mineralization at a site with a mostly complete lateritic regolith. Two sections across the mineralized zone, 15850N and 15900N, have been studied, selected on the basis of features evident from percussion and diamond drilling. Most of the samples were duplicates of those used for grade control and were collected by ripping and, deeper in the regolith, by drilling. Percussion drill samples, diamond drill core and a few special "grab" samples were also used. Some results from section 15850N are shown in this guide; they include a diamond drilled core through the mineralized zone, projected to RL 330. This account is derived from Butt (1991).

The visit to Mt. Percy will include a traverse along the west and northern walls of the Mystery pit at RL 400 m (0-8 m below surface). At the southern end of the pit, the massive duricrust, developed over the chlorite-carbonate ultramafic rocks, forms a high point in the landscape. The porphyry and fuchsite-altered rocks can be seen in the south wall.

The duricrust and, in places, upper part of the mottled clay zone and some porphyry saprolite are visible in the bench wall. The landsurface is lower to the north as the massive duricrust gives way to lateritic gravels and calcareous gravelly soils. Closer to Mt. Percy, possible Black Flag beds are visible. Mt. Percy is formed by the Golden Mile Dolerite, which has weathered to the massive lateritic duricrust visible in the mine wall. The Mystery fault runs sub-parallel to the wall beneath the water tank and is marked by a fault ironstone. Strong mottling is visible in the north-east corner of the pit, developed in clay-rich sediments of a palaeochannel. Massive exhumed boulders of cemented lateritic duricrust (cuirasse) indicate the nature of the original surface.

2. GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

Mt. Percy is about 2 km NE of the centre of Kalgoorlie. It lies at the northern end of the Kalgoorlie-Kambalda greenstone sequence, about 8 km N. of the Golden Mile and 1.5 km N. of Mt. Charlotte. At Mt. Percy, the Hannan's Lake Serpentinite, Devon Consols Basalt, Kapai Slate and Williamstown Dolerite here form part of the hinge zone and steeply east-dipping limb of the Kalgoorlie Anticline. The sequence is cross-cut by a series of north-trending, west-dipping dextral faults, including the Maritana, Reward, Charlotte and Mystery Faults. The Golden Mile Dolerite and the Black Flag Beds are west of the Mystery Zone, separated from the other units by the Golden Mile fault. In contrast to the Golden Mile and Mt. Charlotte, therefore, where primary Au mineralization occurs mainly in the Golden Mile Dolerite, mineralization at Mt. Percy is lower in the sequence, being located in the Hannan's Lake Serpentinite in the Mystery Zone and the Devon Consols Basalt in the Union Club and Sir John Zones. In the Mystery Zone (Figure 1), the chlorite talc carbonate rocks of the Hannan's Lake Serpentinite are intruded by porphyries, with strong fuchsite-carbonate alteration occurring at their contacts. Primary Au mineralization is largely confined to a series of irregular, mostly steeply-dipping lenses within the porphyries and adjacent alteration zones.

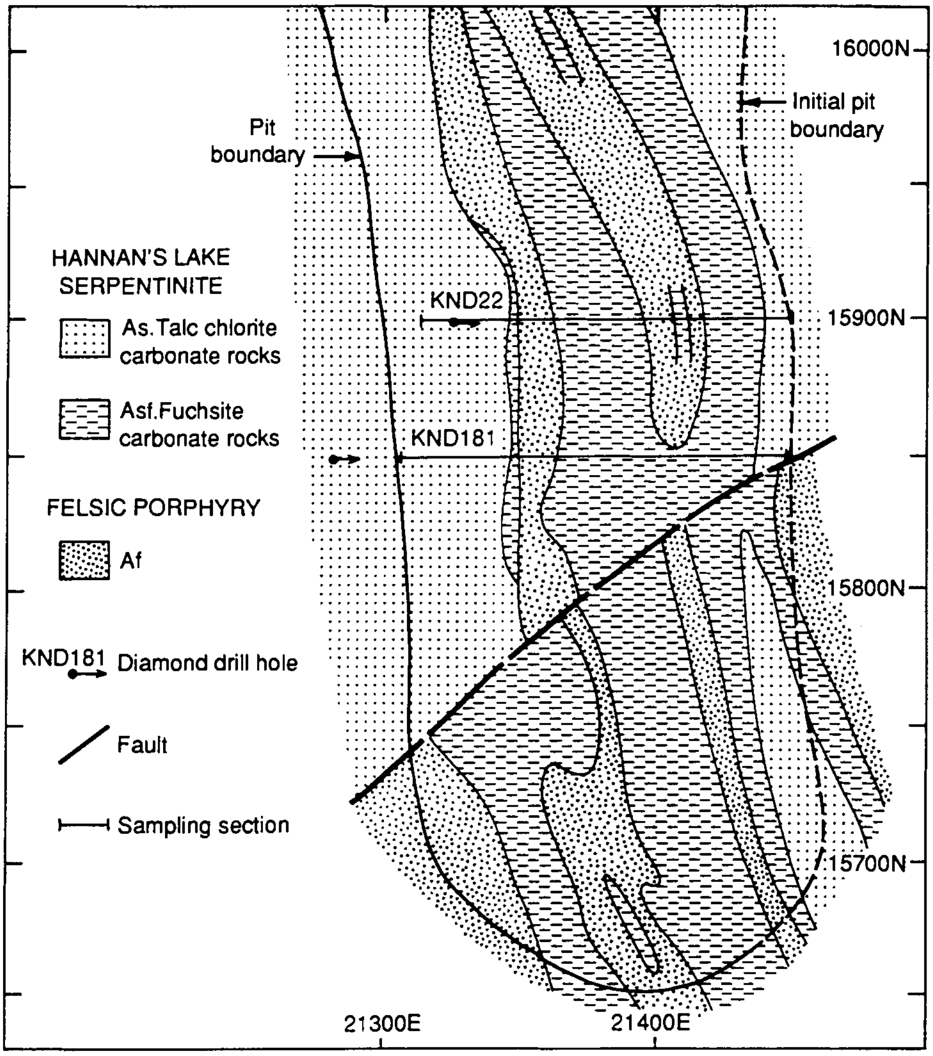

Figure 1: Geology of the southern end of the Mystery Zone, Mt. Percy, projected to 400 m RL, indicating the two sections selected for study. Information derived from pre-mine drilling, supplemented north of 15750N by in-pit mapping (T. Bradley, KCGM) and data from this study.

Mt. Percy is situated in a relatively high part of the landscape, in a region that has a total relief of only a few tens of metres. The elevation is probably due to the armouring effect of the lateritic duricrust (*cuirasse*), here developed most strongly over the Hannan's Lake Serpentinite. As a consequence, an almost complete lateritic regolith, 50-70 m thick, is present over most of the area. The duricrust is developed most strongly over the talc chlorite carbonate rocks and the Golden Mile Dolerite, and these form the highest points at the south end of the Mystery Pit and Mt. Percy, upon which the Mt. Percy water-tank is situated. The regolith is the host to secondary Au mineralization within both the lateritic duricrust and the saprolite.

Mining at Mt. Percy originally took place in the period 1893-1910, extracting about 70,000 tonnes of primary and secondary ore from underground workings. Most of the surface was dry-blown. Recent exploration commenced in 1977 by Occidental Minerals and was continued by Windsor Resources. Open cut mining at the Union Club - Sir John pit commenced in 1985. Mining of the southern end of the Mystery Zone commenced in 1987 and sampling for this study was undertaken from that time.

3. REGOLITH SETTING AND GEOCHEMISTRY

3.1 REGOLITH

Primary mineralization at Mt. Percy is overlain by an almost complete lateritic profile. Massive pisolitic cuirasse is well developed over the more ferruginous of the ultramafic units, such as the talc chlorite carbonate rocks of the Hannan's Lake Serpentinite in the western side of the Mystery pit, and these formed the higher elevations of the pre-mining landsurface. The depth of weathering is 50-60 m, with minor oxidation extending to 100 m or more along fractures. The principal regolith units present on the two sections across the Mystery Zone are shown on the element distribution plots. The mineralogical changes within the profiles over the principal lithologies are shown in Figure 2.

Saprolite. The saprolite forms a broad zone 40-50 m thick. The transition from unweathered to weathered rock (the weathering front) occurs within and beneath the deepest level sampled in the pit (*i.e.*, below 60 m depth, RL 345-350 m). The deepest rock drill samples in Section 15850N are only partly weathered: CaO concentrations of 2-5% are similar to those in the fresh rock, but it is probable that some of the sulphides have been oxidized. Accordingly, these may be classified as saprock, subject to a detailed mineralogical investigation. The saprolite becomes softer and increasingly clay-rich towards the surface and, as a result of settling, consolidation and the development of Fe oxide segregations, the rock fabrics are destroyed and it merges with the plasmic and mottled clays at about 15 m depth. Locally, however, recognizable fabrics are preserved at depths as shallow as 3-4 m, where the saprolite over ultramafic rocks has been silicified. Identification of the parent rock, at least into the three major lithological units, is possible throughout most of the saprolite and these are shown on the element distribution plots. The porphyries and fuchsitic ultramafic rocks tend to be bleached in the mid-saprolite (20-40 m), commonly emphasizing the green colour of the fuchsite; this is particularly evident along some ultramafic/porphyry contacts. Green colouration also becomes more evident towards the top of the saprolite, due to either to an originally greater abundance of fuchsite or, more probably, to the development of chromian clays during weathering. Chromium contents exceeding 1% are present over the talc chlorite ultramafic rocks, contained mainly in kaolinite. Use of the terms upper saprolite, mid saprolite and lower saprolite in the text is only descriptive; they are not formally defined.

Mottled and plasmic clay zone. This zone is transitional between the saprolite and the lateritic duricrust and gravels. It consists of pale green-grey clays and silty clays, strongly coloured by secondary Fe oxides. In the plasmic clays , the Fe oxides are present as diffuse impregnations throughout the matrix, whereas in the mottled clay, they occur as secondary structures such as pisoliths and highly irregular nodules and aggregates.

Lateritic duricrust and gravels. These were present as an almost continuous horizon over the deposit. It varied in thickness from about 5 m over the talc chlorite ultramafic rocks (*e.g.*, 320E, Section 15850N) to less than 1 m thick over some porphyries and fuchsitic ultramafic rocks, 70-80 m downslope to the east. The lateritic materials are pisolitic, nodular or, more rarely, vermiform, either strongly Fe oxide-cemented as the large cuirasse blocks over the talc chlorite rocks, or more weakly cemented as duricrusts and friable gravels elsewhere. Nodules, coatings and channel fillings of calcrete are common in the lateritic horizon, particularly in the upper, more friable material where it merges with the soil. Some lateritic materials over fuchsitic ultramafic rocks are also silicified. Some samples of calcareous soil and lateritic gravel contain 20-35wt%

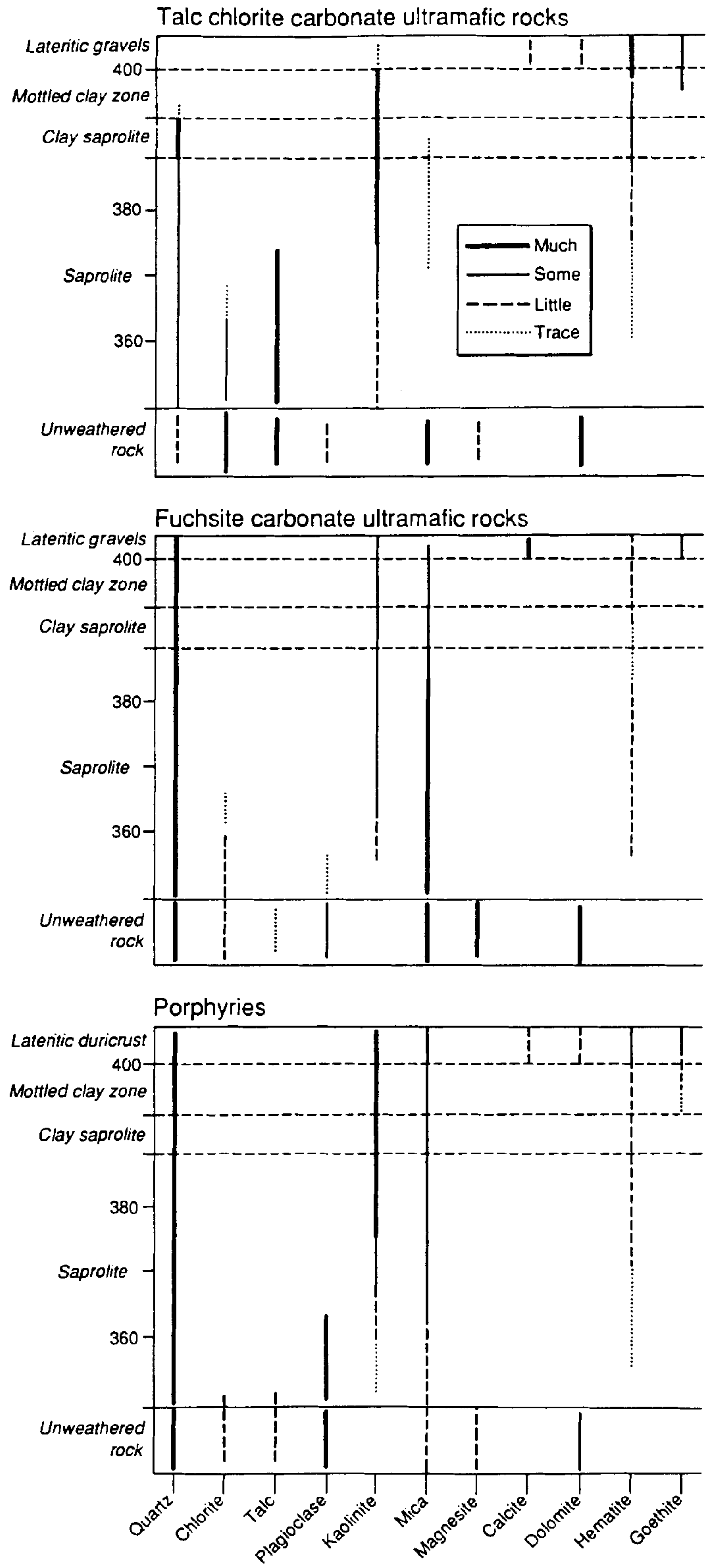

Figure 2: Mineralogy of the main regolith horizons over the three principal lithological units.

$CaCO_3$. It is probable that the development of the calcrete contributes to the destruction of the lateritic horizon and the development of the soil both physically, by the crystal growth that accompanies precipitation of the carbonate, and chemically, by replacing pre-existing minerals.

Soil. A thin cover of red-brown loamy soil, containing abundant lateritic nodules and pisoliths, was present over most of the Mystery Zone, although boulders of lateritic cuirasse outcropped in places. The soil was calcareous, with fine grained calcium carbonate dispersed in the matrix and also present as calcrete nodules, fracture fillings, rhizomorphs and coatings.

4. GEOCHEMISTRY

The distributions of some elements on Section 15850N are shown in Figure 3a and 3b.

Gold and associated elements

Primary Au mineralization is associated with the fuchsite-carbonate alteration of the ultramafic rocks and the porphyries which intrude them. The alteration zone is typically pyritic, and in addition to Au, is characterized by high abundances of S, Sb, As, Ag, Te and W. There is, however, no close correlation between Au and these elements within the alteration zone itself. Each of these elements behaves differently during weathering and has a distinctive dispersion pattern.

Gold. The distribution of Au in the regolith is characteristic of many deposits in the region. The distribution is typically patchy and presumably reflects inhomogeneities in the occurrence of both primary Au and secondarily dispersed Au, as well the variable presence of coarse particulate Au. The principal features of the distribution patterns are as follows.

i. There is a widespread zone of Au enrichment close to the surface, within the lateritic duricrust and the overlying soil. Not all Au is associated with the ferruginous material; a significant proportion is present in the pedogenic calcrete, which constitutes over 20% of some samples. The samples with the highest Au contents are generally the most calcareous, but both ferruginous and calcareous fractions of lateritic soils and gravels have high Au contents. The Fe oxides and the calcrete are very finely divided so that complete separation is not possible. However, it appears that Au does not consistently favour either component, which implies that the concentration is related to by the environment rather than with to a specific mineral host. These results are consistent with findings elsewhere in the southern Yilgarn Craton, namely that pedogenic calcrete horizons are an important site for Au enrichment. Neither these geochemical data, nor the results of panning, provide any evidence for the enrichments of Au sought by the early prospectors at the base of the lateritic duricrusts and gravels. It is not known whether the Au in these enrichments, or that recovered by dry blowing, was primary or secondary.

ii. A leached and depleted zone (mostly <100 ppb Au), 5 - 10 m thick is present just beneath the lateritic duricrust and gravels (below about 2-4 m). This corresponds approximately to the upper, clay-rich zones of the regolith, *i.e.*, the mottled and plasmic zones and some upper saprolite; it also coincides with the zone of Br concentration. Sporadic samples rich in Au indicate the occurrence of quartz veins in which Au has been protected from weathering.

iii Possible supergene enrichment is present in a zone 10 - 15 m thick from a depth of about 17 m. The distribution suggests some homogenization and dispersion within the weathered porphyry and fuchsitic ultramafic rocks. The maximum enrichment is coincident with the presence of alunite (as indicated by the S distribution) in the upper saprolite but Au is much more widespread.

iv There is only minor lateral dispersion of Au below about 30 m depth in the regolith. Although much of the Au is secondary, it appears to have remained within or close to the original host unit.

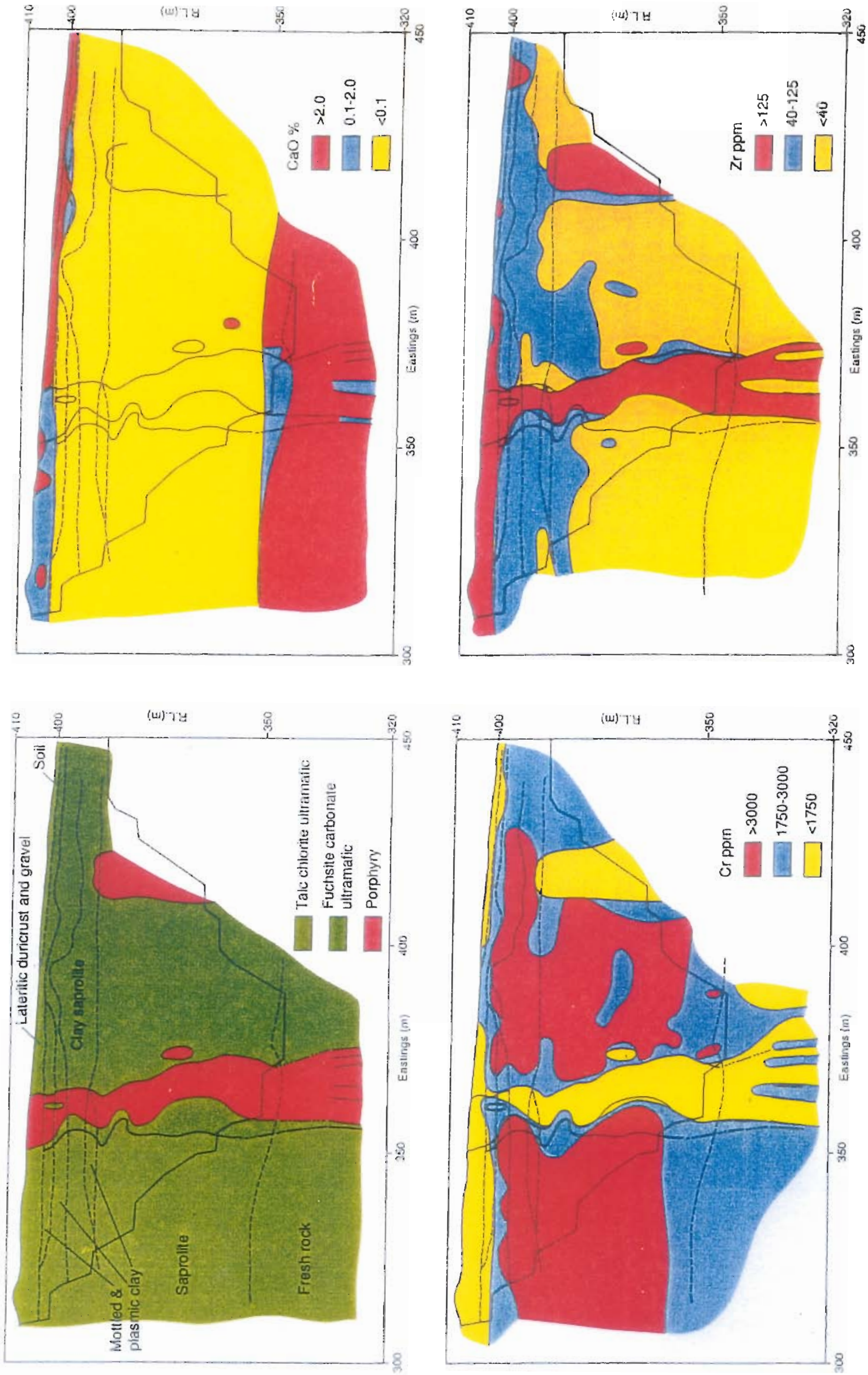

Figure 3a: Regolith section, Mystery Zone, Mt. Percy (line 15850N). Geology and distributions of CaO, Cr and Zr.

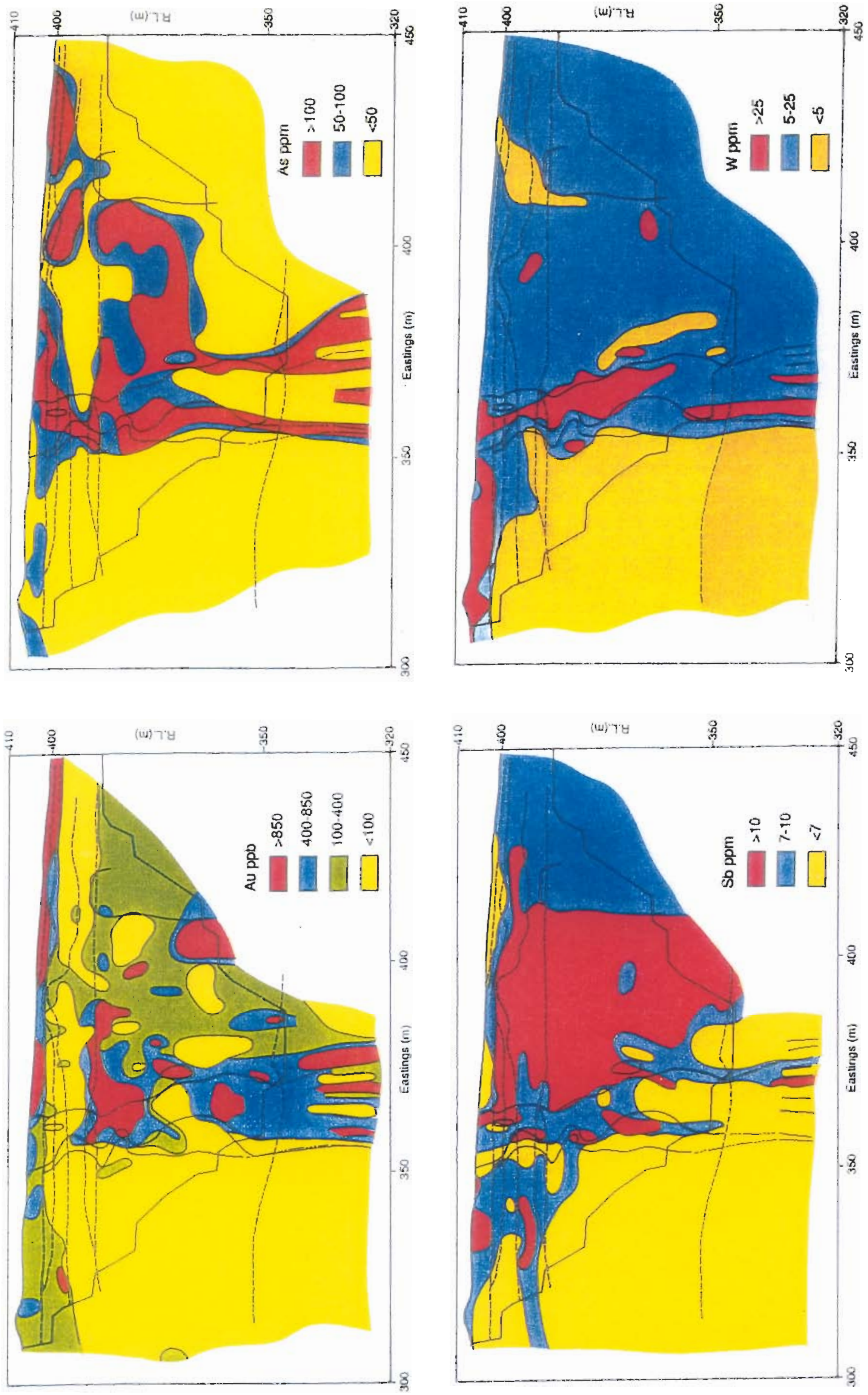

Figure 3b: Regolith section, Mystery Zone, Mt. Percy (line 15850N). Distributions of Au, As, Sb and W.

Most Au in the regolith is presumed to be secondary, on the basis of its morphology and composition. Silver-bearing grains and Au tellurides were recovered from the lower saprolite (below RL 355), in one sample almost in equal numbers with Ag-poor grains; the shallowest sample with a Ag-rich grain was from 17 m, had probably been preserved in vein quartz. All grains above this level were of Ag-poor gold.

Antimony. The mean Sb content of the primary mineralization is 6 ppm in both the porphyries and the fuchsitic ultramafic rocks, compared to 3 ppm in the talc chlorite ultramafic rocks. Apart from isolated maxima of 17 and 34 ppm in two of the most Au-rich samples (13.4 and 5.5 ppm Au respectively), there is little variation in the abundance of Sb and there is no direct correlation with the Au distribution. The Sb content of regolith materials is generally greater than that of the unweathered rocks, particularly over the fuchsitic ultramafic rocks. An increase to 10-16 ppm Sb is apparent even at the lowest level studied in the pit (RL 345-360) in both sections. This increase is coincident with the trend of weathered Au mineralization, with little lateral spread. Higher in the regolith, however, Sb becomes more widely dispersed and increases further in concentration. The highest mean Sb contents (10-20 ppm, with maxima of 20-30 ppm) occur in the most clay-rich horizons, i.e the zone leached and depleted in Au. Although this widespread dispersion and enrichment in Sb is probably secondary, sporadic maxima >50 ppm probably relate to the occurrence of quartz veins; the sample with the peak concentration (285 ppm Sb) also contains 32 ppm Mo and 110 ppm Cu. Other Sb-rich samples are also enriched in W. 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. High values are present in the duricrusts overlying the talc chlorite ultramafic rocks. These duricrusts are enriched in a number of other, mostly "immobile", elements, as discussed further below.

Arsenic. Primary mineralization is characterized by moderate enrichment in As, with mean concentrations of 30 ppm in the porphyries and 185 ppm in the fuchsitic ultramafic rocks. Some, but not all, of the highest concentrations occur adjacent to lithological contacts and As enrichment extends beyond other alteration effects associated with mineralization into the talc chlorite ultramafic wallrocks. The As content increases from a background of 1-5 ppm in the talc chlorite rocks to over 250 ppm within 2.5m of the contact with the fuchsite-altered rocks. There is, however, no particular association with Au. Like Sb, As has restricted dispersion in the lower part of the regolith but becomes more widely dispersed in the upper saprolite. However, this dispersion appears to be less homogeneous than that for Sb and there is much less overall enrichment. Peak As contents (>300 ppm) in any horizon generally occur in the more ferruginous samples. Arsenic has been leached from the clay-rich and mottled horizons of the regolith but, unlike Au, some high As values are retained, particularly in Fe-rich materials, on the presumed projection of primary mineralization at this level. The lateritic duricrusts 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. Arsenic is preferentially concentrated in the ferruginous fraction.

Tungsten. Tungsten is consistently enriched throughout the primary mineralization, particularly on 15850N, with concentrations of 18-28 ppm over the porphyries and 4-10 ppm in the fuchsitic ultramafic rocks, compared to <2 ppm in the unmineralized talc chlorite ultramafic rocks. Tungsten is probably present as scheelite, although this was not identified in heavy mineral concentrates. The abundance of W is slightly greater in the regolith, particularly over the ultramafic rocks, and the distribution is generally more homogeneous, suggesting some dispersion during weathering. Such dispersion is most evident in the clay-rich horizon over the talc chlorite ultramafic rocks on 15850N, which contains 5-15 ppm W up to 20 m from the contact with the fuchsitic rocks and the porphyry. The W distribution is less homogeneous on Section 15900N, which is characterized by a number of sporadic high values (>40 ppm W), particularly close to porphyry-fuchsite ultramafic contacts (*e.g.*, 400-420E, RL 380-400), and within the fuchsitic ultramafic rocks at 370E (RL 380-405). Some of the W-rich samples (60-100 ppm W) have high concentrations of one or more other elements (Sb, Au, Cu) but, in the majority, W is the only anomalous ore-associated element.

An important feature of the W distribution is its retention in the lateritic duricrusts and soils, in which it is present within the ferruginous fraction. Tungsten thus gives a widespread surface anomaly, broadly coincident with that of Au. The duricrusts over the talc chlorite ultramafic rocks are strongly enriched in W (25-60 ppm), especially on Section 15850N, extending the lateral dispersion evident in the underlying mottled clays. Over the porphyries and fuchsitic ultramafic rocks, however, the W contents are similar to those of the underlying regolith; this implies some mobility and loss of W, for if it were immobile, some residual enrichment would be expected.

Calcium and the alkaline earths

Magnesium, Ca and Sr have a number of similarities in their weathering behaviour, namely that they are strongly leached at the onset of weathering and almost totally depleted from some horizons of the regolith, but are re-concentrated at or close to the surface as pedogenic calcrete. Barium behaves somewhat differently, being relatively enriched through most of the regolith, possibly being leached only very close to the surface; it reprecipitates as the sulphate (barite) rather than as a carbonate and so does not occur solely with the carbonates in the calcrete-bearing horizons. The downslope increase in the abundance of the calcretes is probably more a function of the greater porosity and friability of the host horizon than of lateral dispersion. The distribution of the alkaline earth elements throughout the regolith at Mt. Percy, particularly Ca, is characteristic of the region. It has particular significance given the association between carbonate alteration and mineralization in many Archaean Au deposits and the enrichment of Au in horizons containing pedogenic carbonate. Calcrete precipitation is also an important feature of the evolution of these regoliths since it is probably one of the principal processes capable of destroying lateritic duricrust, by either displacement or replacement of pre-existing minerals and cements.

Calcium is hosted predominantly by dolomite and is enriched in the ultramafic rocks (mean 6.3% CaO) relative to the porphyries (3.6% CaO). In consequence, Ca is leached more strongly than Mg, which is present also in more resistant ferromagnesian minerals and is at concentrations below 0.1% CaO throughout much of the regolith, from RL 350 (50-57 m depth) to within 5 m of the surface. At the surface, however, Ca is precipitated in pedogenic calcretes, as calcite and, less commonly, dolomite, at concentrations of up to 10-19% CaO (18-34% $CaCO_3$). The calcretes occur as coatings on blocks and cobbles of cuirasse and silcrete, as rhizoconcretions (root casts), pendants, nodules and irregular masses, and as a friable matrix to lateritic gravels. These may be void infillings, or have displaced or replaced pre-existing material. There is a strong association between Au and pedogenic Ca carbonate, as noted above. Gypsum is present as a trace to minor constituent in some surface materials; it is suspected to be aeolian in origin.

Chromium and zirconium.

Chromium. The Cr distribution in lateritic regoliths is strongly influenced by its host mineral in unweathered rocks. In many ultramafic rocks, most Cr is hosted by chromite, which is generally resistant to weathering. Chromium thus tends to accumulate in the duricrust, commonly to concentrations of 1.0-5.0%. At Mt. Percy, however, chromite is uncommon and most Cr in the unmineralized talc chlorite ultramafic rocks is present in ferromagnesian minerals, principally chlorite. These minerals are less abundant in the fuchsitic ultramafic rocks, but the fuchsite (chromian muscovite) itself is a host to some Cr. It is not certain whether this is the principal host mineral in the unweathered rocks, but residual fuchsite is significant in the clay-rich and ferruginous upper horizons of the regolith, in which there is a close correlation between the Cr and K_2O contents (r=0.74), with abundances of both elements decreasing towards the surface.

The unweathered ultramafic rocks have mean Cr contents of approximately 2000 ppm; that of the porphyries is much lower (150 ppm). Chromium is concentrated in the saprolite and clay-rich horizons, remaining within relict ferromagnesian minerals, fuchsite or becoming incorporated within (poorly crystalline) secondary Fe oxides or in clays. A striking feature of the Cr distribution is the high concentration (means 4050-4725 ppm, max. 10000 ppm) in the saprolitic, plasmic and mottled clays over the talc chlorite rocks. These horizons are also unusually Al-rich (mean 18.5-21.2% Al_2O_3), presumably in part due to absolute enrichment by Al released from clays during the precipitation of Fe oxides and the formation of the overlying lateritic duricrust. Chromium is probably released from the clays and recrystallizing Fe oxides in the same process, becoming incorporated in neo-formed clays (dominantly kaolinite) and Fe oxides in the underlying horizons. The clays are green, due to the presence of Cr. The equivalent horizons on the fuchsitic ultramafic rocks are coarser grained and more porous and have lower Al and Cr contents (means 12.8-18.0% Al_2O_3; 2030-3920 ppm Cr). These characteristics reflect the presence of residual fuchsite in the latter, which has retained and immobilized much of the Al and Cr. The correlation between Cr and K_2O in the upper regolith further suggests the importance of residual fuchsite as the mineral dominating Cr distribution in these horizons. Deeper in the saprolite, however, the correlation is poorer; some Cr is held by ferromagnesian minerals and their weathering products and K is also present as alunite. The weathered porphyries are strongly enriched in Cr, particularly in the clay-rich horizons. Although these rocks contain minor ferromagnesian minerals and xenoliths of fuchsitic ultramafic rocks, the enrichment is largely absolute, with Cr being derived from the duricrusts and clays of the adjacent ultramafic rocks.

The Cr contents of the lateritic duricrusts developed over the ultramafic rocks are unusually low and indicate that Cr abundance alone cannot be used to distinguish lithology. The low Cr abundance is largely a consequence of its occurrence in weatherable minerals such as chlorite, rather than in chromite. The higher Cr content of the lateritic duricrusts over the fuchsitic ultramafic rocks reflects the greater stability of fuchsite, although this too has been partly destroyed.

Zirconium generally exhibits little chemical mobility in the weathering environment and follows this behaviour at Mt. Percy. Zirconium, Hf, Nb and Ta are all members of the second and third transition series and have very similar chemical characteristics. In particular, the chemical behaviours of Zr and Hf are almost identical, and Nb and Ta almost invariably occur together.. Zircon is probably the principal host mineral for each of these elements and hence the stability of zircon determines their distribution and dispersion in the regolith. Some Th may be present as monazite, but if so it is present at very low abundances and has not been detected in the heavy mineral concentrates.

The Zr, Hf and Th contents increase upwards through the regolith, even over ultramafic rocks, and are enriched in the lateritic duricrusts and soils. The greater abundance of Zr, Hf and Th in the porphyries compared to the ultramafic rocks discriminates the porphyries quite clearly in the unweathered rocks and throughout the regolith except for the upper lateritic horizons. The location of the porphyry is readily seen from the distribution of these three elements, even in the clay-rich horizons.

One of the most significant features of the distributions of Zr is its accumulation in the lateritic duricrust, particularly over the talc chlorite rocks. The highest concentrations, together with those of Fe, TiO_2, V, W and some REE, are present in the massive duricrust on these rocks on Section 15850N. The duricrust has relatively low Cr contents, as discussed above, so that its trace element composition indicates a felsic rather than an ultramafic rock, although major element composition, especially the Fe content, relates to an ultramafic parent material. The porphyries are the probable source of the immobile elements, which now form a residual accumulation. A curious feature of the accumulation is that it is mainly upslope of the subcrop of the porphyry. The distribution patterns suggest that this may have been caused by the apparent flattening of the dip of the porphyry, brought about, for example, by landscape reduction during weathering. There is, however, some downslope dispersion, shown by enrichments in the soil and the uppermost duricrust horizons.

The enrichments of Zr and other immobile elements in the upper saprolite and clay-rich horizons may be due to either of two processes:

i. residual, or *relative*, accumulation, as the result of the leaching of other, more mobile components;
ii *absolute* accumulation, by illuviation of host minerals. Such illuviation may involve the translocation of fine zircon grains (*e.g.* <5 µm) down cracks and fissures by infiltrating waters, or the movement of coarser particles in root channels and larger fractures. Infilled roots and fractures have been observed to depths of >20 m at Mt. Percy. In some locations in the Mystery Zone, such infillings apparently occupy as much as 5% by volume - readily visible as red-brown earths in the bleached upper saprolite of the porphyries and fuchsitic ultramafic rocks.

5. REGOLITH EVOLUTION

The principal stages in the evolution of the regolith at Mt. Percy can be summarized as follows:

i.. Lateritic weathering under warm humid conditions
  a. progressive weathering of sulphides, carbonates, feldspars and ferromagnesian minerals and the leaching of their mobile constituents (S, Na, Cs, Ca, Mg, Sr, Mn, Co, Ni, Cu, Zn).
  b. 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).
  c. dissolution or replacement of secondary minerals (*e.g.*, kaolinite, barite) and some resistant primary minerals (*e.g.*, muscovite) during the formation of the ferruginous horizon. This was accompanied by remobilization and some loss of constituents (Si, Al, Cr, Ba, K, Rb) and the recrystallization and accumulation of Fe oxides in secondary structures. Primary Au was probably dissolved from the ferruginous horizon by complexation with organic ligands in neutral to acid conditions, and reprecipitated as fine grained particles, probably with secondary Fe oxides.
  d. accumulation of immobilized elements in resistant primary minerals (*e.g.*, Zr, Hf in zircon; K, Rb in muscovite; Ti in rutile; REE, Ta, Nb, Th, W) or in stable secondary minerals (Ti in anatase; V in Fe oxides).

ii Weathering under warm, semi-arid conditions
  a. decline of the water-table, with arid conditions leading to vegetation changes that in turn induced instability of the landsurface and possibly initiated minor erosion. Slow weathering continued, mainly at the base of the profile. The gradual accumulation of the dissolved weathering products due to evaporation exceeding precipitation, the development of an internal drainage and the accession of marine salts associated with rainfall, resulted in progressive salinization of the groundwater.
  b. dehydration and hardening of lateritic duricrusts, especially those derived from the talc chlorite ultramafic rocks.
  c. mobilization of Au and Ag, particularly in the near-surface, as halide complexes. Mobilization has probably continued intermittently to the present day, with progressively lower water-tables, with Au precipitation occurring close to the water-table or at redox fronts beneath and related to it.

d. precipitation of alunite, probably under acid conditions with relatively high water-tables, apparently post-dating at least some Au mobilization. Precipitation of silica, introduced into the profile or derived from dissolving clay minerals, in saprolites of fuchsitic ultramafic rocks, may have occurred under similar conditions.
e. continued leaching of base and transition metals (Cu, Co, Pb, Mn, Ni) with minor precipitation in the mid to lower saprolite.
f. dissolution of primary minerals containing REE and the precipitation of REE as absolute accumulations at a probable porosity barrier in the lower saprolite. The barrier may mark a past water-table, or underlie a perched water-table.
g. release of soluble alkaline earth metals at the weathering front and their transport to the surface, probably by evaporation and/or evapotranspiration; vegetative cycling of these elements and Au has led to their gradual accumulation in the near-surface horizons.

The general preservation of the regolith at Mt. Percy implies that there has been little erosion at the site. Nevertheless, the distributions of the immobile elements in the lateritic horizons suggest there may have been sufficient erosion to cause local topographic inversion. In addition to Fe oxides, Ga, Nb, Ta, Th, Ti, V, W, Y, REE, Zr and Hf (but not Au) are all strongly concentrated in the massive duricrusts developed on the talc chlorite rocks. Although accumulations of Fe and V are expected over ultramafic rocks, the other elements are more characteristic of felsic lithologies such as the porphyries and the distributions strongly indicate these rocks to be the source. The duricrusts are upslope from the subcrop of porphyries to the east, west and south. The most probable explanation is that the talc chlorite rocks once occupied lower ground and the porphyries and fuchsitic ultramafic rocks higher ground. The resistant minerals released from the porphyries were transported downslope to accumulate over the talc chlorite rocks; some chemically mobilized Fe was also precipitated at this site. Preferential erosion of the less indurated upper horizons of the regolith developed on the porphyries and fuchsitic ultramafic rocks has led to topographic inversion.

6. IMPLICATIONS FOR EXPLORATION

6.1 GEOCHEMICAL DISPERSION

The multi-element dispersion patterns at Mt. Percy have several implications for Au exploration in the region. In general, the data support the contention that at local to sub-regional scales, Au itself is one of the best indicators of Au mineralization, despite (or perhaps because of) its chemical mobility during weathering. The principal proviso to this observation is that sampling must take into account the distribution of Au in the regolith as exemplified by Mt. Percy and numerous other sites in the Yilgarn Craton. In particular, the accumulation of Au in calcareous and ferruginous surface horizons and its depletion for 5-20 m below them, implies that sampling has to be carefully directed.

Primary and saprolitic Au mineralization at Mt. Percy is indicated by a broad superjacent Au anomaly in the soils and lateritic horizons. This anomaly is comprised of Au (i) associated with Fe oxides and presumably accumulated during lateritic weathering and (ii) associated with pedogenic carbonates and accumulated during more recent arid phases, continuing to the present. The distribution of the Au, its partition between the ferruginous and calcareous fractions and the apparent absence of particulate primary Au from these materials suggest that the Au precipitated in more recent calcareous environments is quantitatively more important than that accumulated earlier during lateritization. The absence of a Au enrichment in the massive duricrust over the talc chlorite ultramafic rocks lends further support to this interpretation. Tungsten and, to a lesser extent, Sb, presumed to be hosted by detrital resistant minerals derived from the mineralized porphyry, have accumulated in this duricrust and any primary Au would be expected to accumulate also. Mt. Percy represents an example of the surface expression of Au mineralization being enhanced by the association of Au with surficial, pedogenic carbonates. This association is prevalent throughout the southern Yilgarn Craton.

Mineralization is also indicated by high concentrations of other ore-associated elements in the surface horizons, principally W, Sb and As. These are all present at concentrations similar to those in laterites at some other deposits (*e.g.*, Mt. Gibson), but do not appear to have wider or more consistent dispersion haloes than Au. From limited data, it appears that K contents give a surface expression to the alteration zones, commonly wider targets than mineralization itself, and also offer potential for detection by radiometric surveys.

The mottled and plasmic clay zones are the horizons with the lowest Au contents and represent the "depleted zone" present over most Au deposits in the Yilgarn Craton. The thickness of the depletion is less at Mt. Percy than in many other locations, in which it extends deep into the saprolite, but the presence of depletion illustrates the care that must be taken when sampling the top 3-20 m of the regolith - *i.e.* in the mottled and plasmic clays and the upper saprolite. Gold contents in the depleted zone are generally <100 ppb, even where there are quartz veins, and give little indication of the underlying mineralization. However, it is important to note that the other ore- and alteration-associated elements Sb, W and, to a lesser extent, As are anomalous through the zone. Similarly, high Ba concentrations are maintained through the clay-rich horizons. Although here the distribution of Ba reflects that of the porphyries, it is similarly retained where there is an association with mineralization. These data have particular significance when applied to areas in which the lateritic regolith has been partially truncated and soils are developed on clays and saprolites depleted in Au. Antimony, W, As, K and Ba would be expected to be anomalous even if Au contents have been depleted to near background values. If pedogenic carbonates are present, the depletion may be offset by some surface enrichment.

Gold is present throughout the saprolite at abundances broadly similar to those in the fresh rock. Some concentration and possible lateral dispersion, particularly in the clay saprolite, enhances the weathered expression of the primary mineralization and, of course, has been an exploitable resource in its own right. "Refining" of Au by the loss of Ag during weathering has increased the value of this supergene mineralization. The distributions of the other ore-associated elements generally show greater consistency in the saprolite than in fresh, mineralized bedrock, due to mobilization during weathering. Concentrations of As, Sb and K have been homogenized over 5-10 m in the mineralized porphyries and fuchsitic ultramafic rocks, and high Sb and W concentrations extend for 35 m and 15 m, respectively, into the clay saprolites developed over the talc chlorite ultramafic rocks.

The precipitation of alunite in the mid to upper saprolite is a feature that has possible exploration significance. Alunite occurs directly above the sulphidic mineralization in the porphyries and fuchsitic ultramafic rocks, but is at low concentrations in the equivalent horizon over the unmineralized, sulphide-free, K-poor, talc chlorite rocks. The distribution suggest there may be a genetic link between alunite and underlying primary sulphides, analogous to that between pedogenic carbonates and Ca-rich bedrock, but the mechanism involved, and the timing, are not known. However, sulphur is a very labile component in the present environment. Sulphur accession is presumed to occur as aerosols of marine origin and as aeolian gypsum, probably derived from the deflation of playas; thin gypsiferous horizons are present in many soils in the region. It is possible, therefore, that S in the alunite also has an exotic source and its presence and location in the regolith are related to factors such as permeability, availability of K, depth of water-table and redox conditions, now or in the past, rather than to the presence of sparse disseminated sulphides at depth.

6.2 LITHOLOGICAL DISCRIMINATION

The identification of the fresh parent rocks from their weathering products by geochemical means depends largely on the presence of diagnostic immobile elements, or elements immobilized in resistant minerals; ratios and plots of Ti, Zr and Cr contents are commonly the most effective in discriminating between the major lithological groupings. At Mt. Percy, fresh porphyries and ultramafic rocks are readily distinguished on Ti-Zr plots, by high concentrations in the porphyries of several minor and trace elements, including Ba, Hf, Nb, Ta, Th and REE, and by high concentrations in the ultramafic rocks of Cr, V and Sc. These characteristics are retained throughout most of the regolith, excluding the ferruginous lateritic horizons and soils, although dispersion of the REE in the lower saprolite suggests that these elements may not always be reliable for rock identification. The Ti-Zr plots show increasing abundances of both elements over all lithologies higher in the regolith, reflecting their relative accumulation during weathering. Discrimination between different unweathered ultramafic rocks is complicated by similarities in Ti, Zr and Cr abundances, and between the K contents of the biotitic and fuchsitic rocks. However, in the regolith, the relative resistance of fuchsite (chromian muscovite) compared to biotite results in K content being diagnostic. Lithological discrimination is far less distinct in the mottled and plasmic clays, with increased scatter of Ti and Zr contents, presumably due to chemical and physical mixing. Discrimination is more difficult still in the lateritic gravels and massive duricrust, and the soils derived from them and may be related to local topographic inversion.

7. ACKNOWLEDGEMENTS

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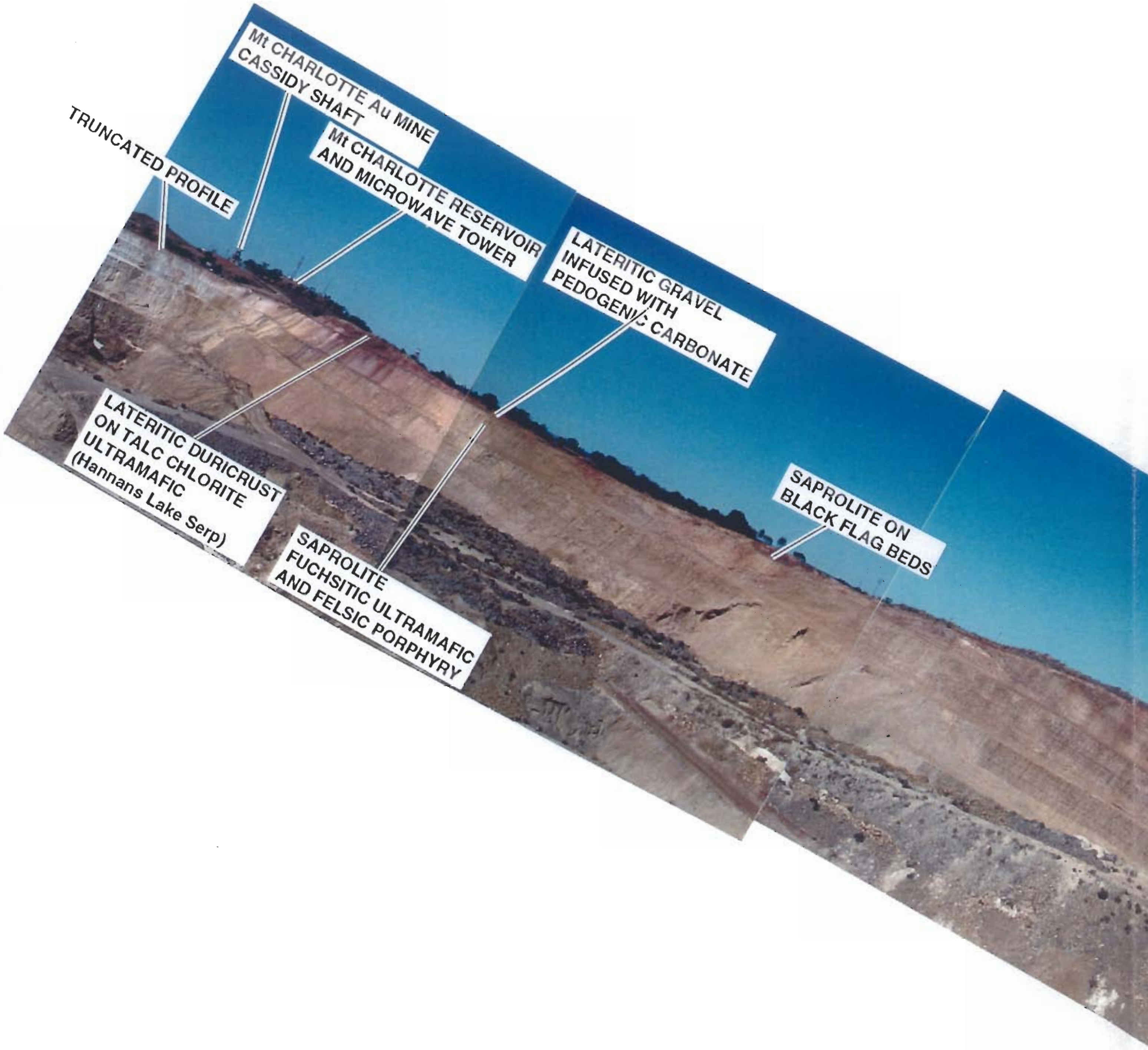
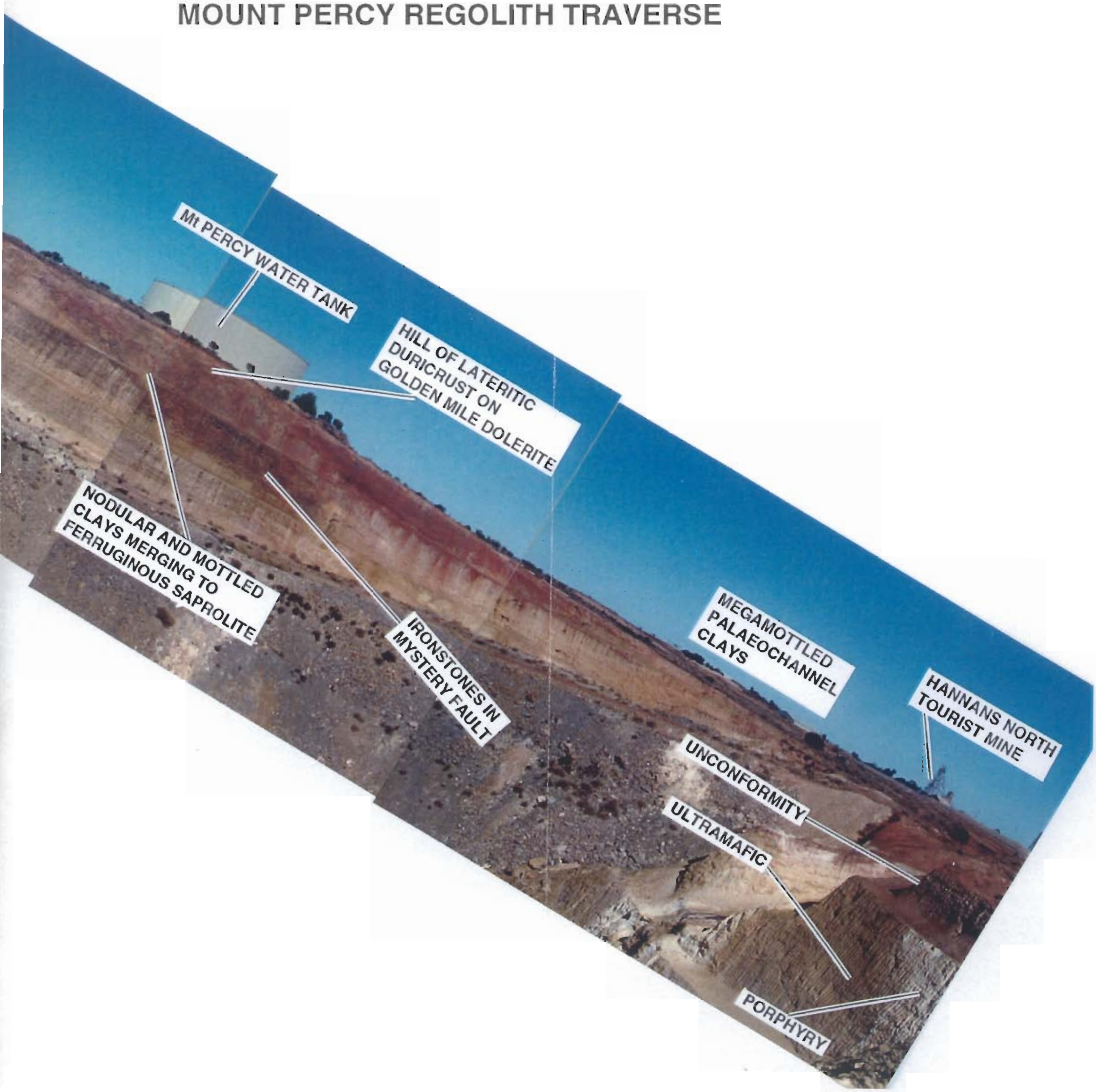


Mt CHARLOTTE Au MINE
CASSIDY SHAFT
TRUNCATED PROFILE
Mt CHARLOTTE RESERVOIR
AND MICROWAVE TOWER
LATERITIC GRAVEL
INFUSED WITH
PEDOGENIC CARBONATE
LATERITIC DURICRUST
ON TALC CHLORITE
ULTRAMAFIC
(Hannans Lake Serp)
SAPROLITE
FUCHSITIC ULTRAMAFIC
AND FELSIC PORPHYRY
SAPROLITE ON
BLACK FLAG BEDS

MOUNT PERCY REGOLITH TRAVERSE



THE SUPER PIT - KALGOORLIE

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1. HISTORY AND PRODUCTION

The Kalgoorlie Gold Field is Australia's major economic Au resource and consists of a number of deposits, including the Golden Mile (1325t Au), Mt Charlotte (106t Au), Hannans North lode (8.5t), Mount Percy (8.5t) and a number of other, smaller producers. It has been producing since its discovery in June 1893. The goldfield occupies an area of 10 x 2 km.

Initial activity was concentrated at the north end, where Au occurred in quartz veins and surficial deposits familiar to the prospectors. Two years passed before the full significance of the relatively inconspicuous, ferruginous and oxidised outcrops (regolith) at the south end of the field was recognised.

Gold production reached its peak in 1903 with production coming from the richer, more accessible oxidised ore where extraction was metallurgically simple. Production declined as grade decreased with depth and primary, refractory ores were encountered. Many mines closed due to increased costs related to inflation after World War I but production revived after revaluation of Au in 1932-33. Production declined again from the late 1960's and only Mt Charlotte remained by the end of 1975.

Following the marked rise in the Au price in the late 1970's, numerous mines were progressively opened and new open pit mines were established. By the mid 1980's, all mining operations in Kalgoorlie, from Mt Percy and Mt Charlotte at the northern end to Chaffers at the southern end, were effectively controlled by three companies. These companies eventually amalgamated in March 1989 to form Kalgoorlie Consolidated Gold Mines Pty. Ltd. (KCGM), then jointly owned by Bond Gold/North Kalgurli Mines and Homestake Gold of Australia. Bond Gold sold their interest to the Normandy Poseidon Group, now Normandy Mining Ltd.

Current mining operations are carried out at the Super Pit at Fimiston (Golden Mile) and at the modern underground mine of Mt Charlotte. Combined 1996/1997 production, now treated at a single milling operation, was 833,000 oz Au.

2. REGIONAL GEOLOGY

The Kalgoorlie goldfield lies within the Norseman-Wiluna Belt, a belt of basaltic volcanic rocks (greenstones) intruded by a number of dolerite sills. Slightly younger quartz-bearing volcanics and sediments overlie this sequence. Extensive areas of granite surround the greenstone belt. This granite-greenstone terrain is between 2.9 and 2.6 10^9 years old.

3. ORE TYPES AND STRUCTURAL SETTING

The main host for the ores is the Golden Mile Dolerite, the largest of the intrusive sills in the district. The Kalgoorlie-Boulder ores occur in two very distinct forms: i) the Golden Mile lodes and (ii) the younger quartz vein network at Mt Charlotte. This quartz vein style is sporadically present as a relatively minor form of mineralisation throughout the district.

Structurally, the goldfield is characterised by early thrust faulting, folding and later strike-slip faulting. Golden Mile lode mineralisation is associated with fracturing and shearing during the latter phase of deformation. The Mt Charlotte-style quartz veining is associated with a final period of faulting.

Intensive fluid flow through faults and fractures were integral aspects of both episodes of mineralisation. The invading fluids carried a variety of solutes that altered the original minerals in the host rocks, and formed suites of new minerals that vary with proximity to the loci of mineralisation. These fluids precipitated pyrite and also carried the gold.

Golden Mile mineralisation is characterised by a very complex pattern of closely spaced faulting, shearing and intense shattering of the rocks. Lodes have several characteristic orientations, with slightly different mineralisation styles. Individual lodes may be up to 1800 metres long, 1200 metres in vertical extent, and 10 metres wide. Highest gold grades are typically associated with gold-silver-mercury tellurides and alteration minerals with high vanadium contents. The gold is mineralogically complex and refractory.

Mt Charlotte ore is different. It formed in response to faulting within a very rigid portion of the Golden Mile Dolerite, and quartz veins filled open fractures. The fluid that precipitated the quartz infiltrated the wall rock, altered the primary mineralogy, and deposited pyrite and gold in the haloes to the veins. The ore is free milling.

4. SUPER PIT VIEW

Immediately below the tourist lookout lie the Western Lodes, where the mineralisation is concentrated in the Golden Mile Dolerite (Figure 1). Further in the distance, across the Golden Mile Fault (the 'Boulder Dyke', consisting of black shales of the Black Flag Beds) are the Eastern Lodes. In the Main pit, the lodes have all been stoped out and are visible in the walls as orange-brown bands, which mark stope-fill (calcines and other waste). Their trace along the pit floor is marked by plastic tape. The haloes to the lodes are all that is left for present day mining. The far wall, to the east, is in the Paringa Basalt, stratigraphically below the Golden Mile Dolerite. The wall at the far northern end is the Paringa pillar, which formerly separated pits held under different mining leases and was once occupied by a mill that has since been demolished. Pits eventually will be amalgamated. Mining here is proceeding at a million tonnes a month, and the pit eventually will reach about 550 metres depth (depending on economic factors).

SUPER PIT

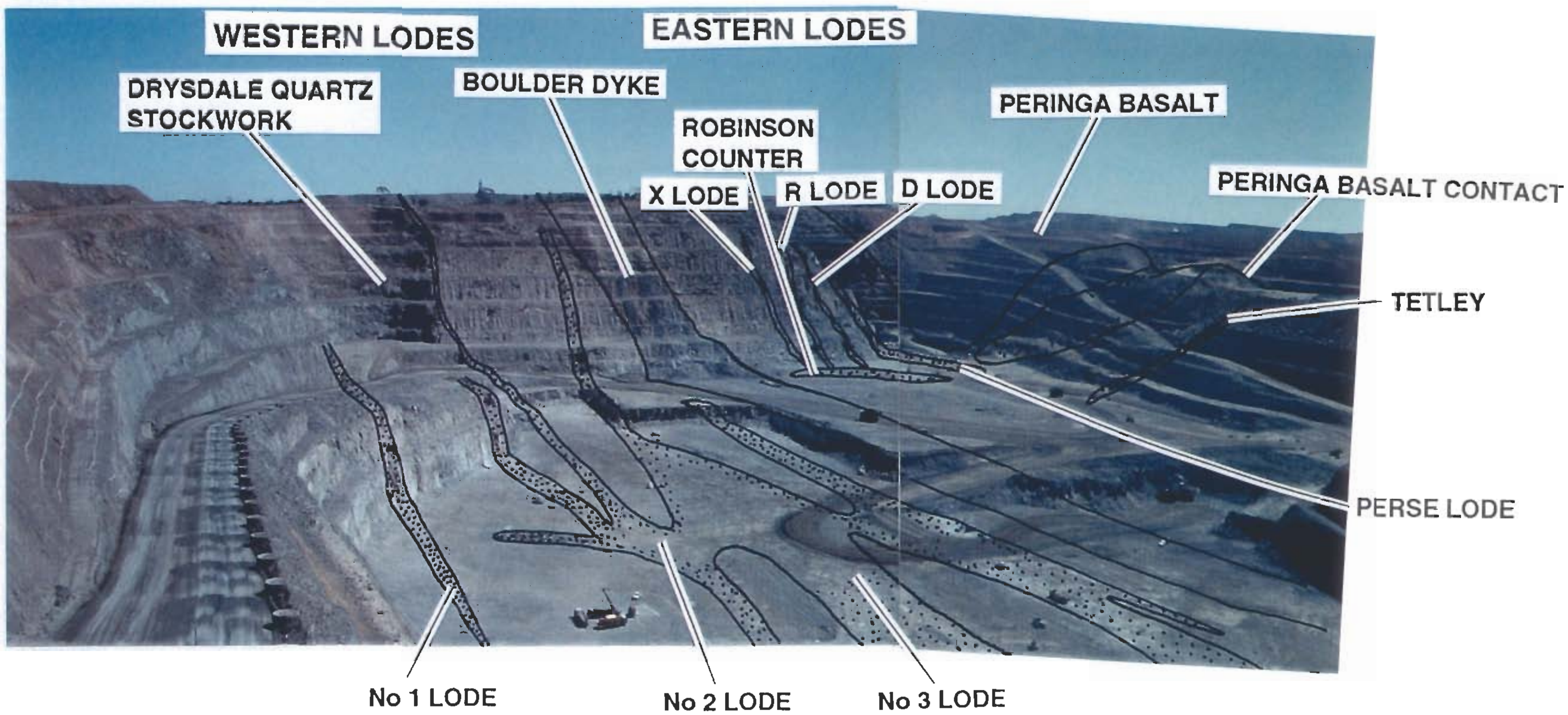

Figure 1. Some of the lodes exposed by the Super Pit at Kalgoorlie. Many are marked by stope fill and the auriferous, low grade halos are being mined. This picture was taken on 16th March, 1998 (IDMR).

TRUE SONS

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The True Sons Joint Venture tenements are located directly south of Kalgoorlie-Boulder and are reached via the Celebration Road. The Joint Venture is managed by KCGM.

The tenements lie to the southwest of the Golden Mile and cover the north-northwest trending Mt. Hunt and Abbatoir East Faults. Greywackes and shales of the Black Flag Beds are located to the west of the Mt. Hunt Fault; to the east, the geology comprises a portion of the Kalgoorlie Stratigraphic Sequence. The Black Flag Beds dominate the sequence over the True Sons leases and are steeply west dipping. The sediments lie in faulted contact with the adjacent northwest striking Abbatoir Sill to the west, which consists of a medium to coarse grained gabbro.

The regolith materials are mottled zone and mottled saprolites developed on the Black Flag Beds, together with mottled lacustrine clays and colluvium.

To the north-west is a well-developed breakaway in mottled zone with a ferruginous cap. Detailed examination shows remnants of quartz veins and relics of sedimentary structures (Black Flag Beds). The nearby road cutting exposes similar, highly mottled material with sedimentary remnants but this passes almost indistinguishably into mottled lacustrine clays.

Drillhole logging in such an area is made very difficult by the similarity, after weathering, of sediments of the basement and of the much later palaeochannels. Distinction may be made by appearance of fine, white mica in the basement rocks, which is absent from the palaeochannel clays; however this distinction is difficult in the field and may require sophisticated instrumentation (XRD or PIMA). Behind the road cutting, some very fine lag may be found, typical of that often found on and weathered out of palaeochannel sediments.

PALAEOCHANNEL LITHOLOGY AT THE GREENBACK GOLD DEPOSIT

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1. INTRODUCTION

The Greenback deposit (31° 0' 13"S, 121° 25' 25"E) is located about 25 km southwest of Kalgoorlie and 16 km west of the New Celebration mine beneath calcareous soils on an aggradational plain. It lies adjacent to a regional contact between mafic-ultramafic rocks and overlying intermediate to felsic volcanic and sedimentary rocks. Most of the area is deeply weathered, with a cover of clay-rich transported overburden. Gold mineralisation at Greenback occurs within and beneath flat-lying, gently undulating sediments of a north-trending, possibly Eocene palaeochannel (Figure 1). There are three styles of mineralisation, an upper, flat-lying supergene zone within ferruginous, mottled, pisolitic clays of the palaeochannel, a middle, supergene zone within the basal sandy clays of the palaeochannel and the upper saprolite and an east-dipping lower primary zone along the andesite-amphibolite contact marked by strong silica-carbonate-chlorite-biotite alteration (Vinar, 1996).

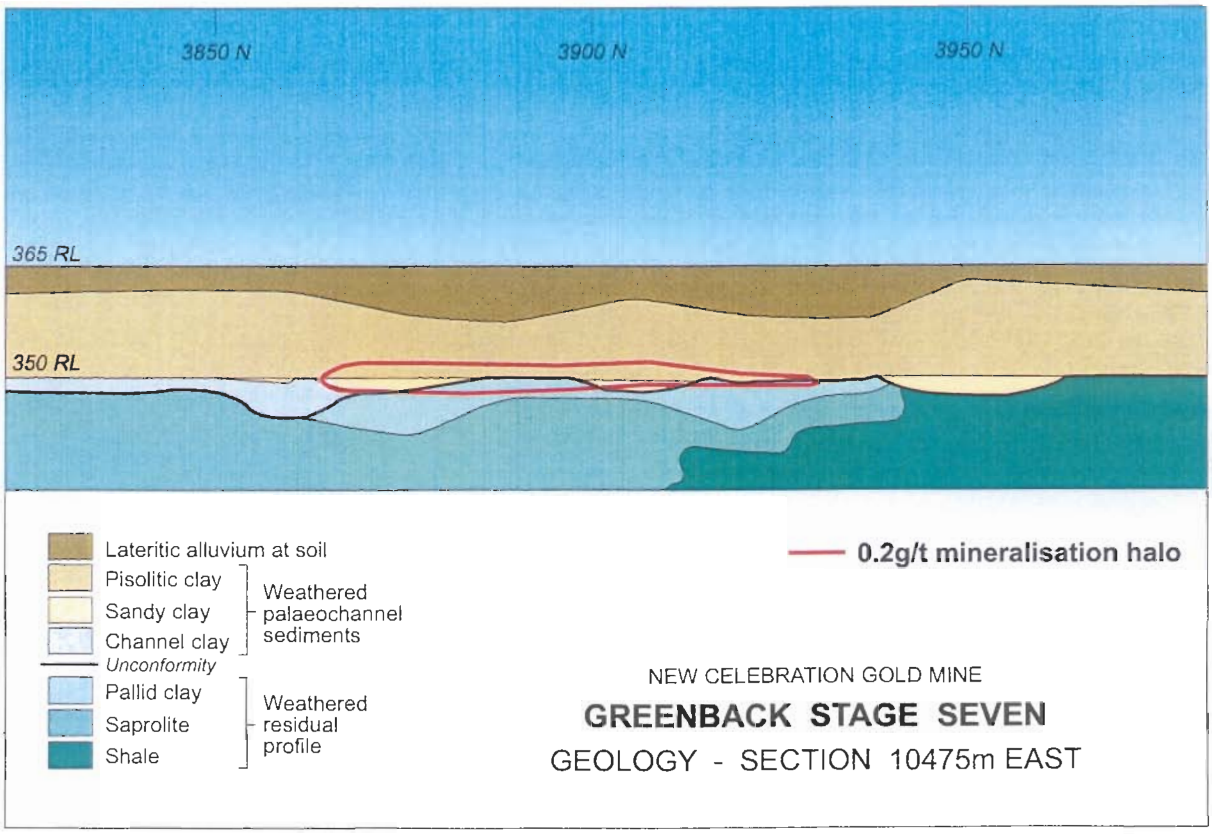

Figure 1 Longitudinal section through the Greenback deposit (modified from Vinar, 1996).

2. STRATIGRAPHY

The base of the palaeochannel is filled with a pale grey-brown, quartz-rich, sandy clay (CS in Figure 2) which is a possible equivalent of the Wollubar Sandstone. This is overlain by about 15 m of massive, pale-yellow, smectite-kaolinite clay (YC in Figure 2) which is possibly equivalent to the Perkollili Shale. The lower part of this clay is unmottled but its upper 8 m (MC in Figure 2) is strongly mottled. Its upper contact is lobate and penetrated by tongues of a brown, pisolitic clay (FC in Figure 2) that appears to have suffered solution collapse. The clay in the upper part of this layer (LP in Figure 2) is crumbly and is very rich in pisoliths. Alluvial deposits, containing lenses of lateritic gravel (AG in Figure 2) overlie the palaeochannel and, in turn, are overlain by a red, earthy, calcareous soil (SC).

3. LITHOLOGIES

Clayey sand (CS)

The sand is grey, mottled and irregularly stained with yellow-brown goethite and red hematite. It consists of rounded to angular grains of quartz (2.0-0.1 mm) and a few smaller grains of tourmaline, closely packed into a cement of goethite and hematite-stained kaolinite and anatase. This layer is more permeable than the overlying clay and tends to be damp and, as the groundwater is saline, the sand contains minor halite.

Yellow clay (YC)

It is a yellow, waxy clay; cracked when dry and puggy when wet. In detail, it consists of a mass of small pellets of weakly birefringent smectite (montmorillonite) set in less birefringent kaolinite. There are also a few subangular but equant quartz grains scattered throughout. Small vesicles are lined with eluviated, birefringent clay. The detrital suite, comprising a very small proportion of the whole, consists of glassy, angular quartz (0.2-0.5 mm), with lesser quantities of angular, fresh tourmaline (schorlite, 0.3 mm), staurolite and a few small, clay-rich ooliths (0.5 mm). Even the larger quartz grains (1.5 mm) show no sign of wear. Some quartz grains contain tourmaline inclusions. This suggests transportation from a local source, probably metapelites with quartz-tourmaline veins.

Mottled clay (MC)

This pinkish to yellow mottled kaolinite also consists of clay pellets; the pellet structure is accentuated by hematitic mottling. Where the clay is cracked, the mottles are partly bleached near the cracks. Small subround pisoliths (2-5 mm) occur as a small component and are coated in honey-brown, banded goethite. The clay is also set with small quartz crystals (0.5-1.0 mm).

Ferruginous, pisolitic clay (FC)

This material has a similar micro-clastic kaolinite fabric to the clays beneath, but is lightly stained brown by goethite and contains numerous pisoliths of goethite (1-5 mm) with thin, layered cutans and contains more quartz (0.1 mm) than those beneath. The cores of some pisoliths are of massive goethite, but others are of ferruginised fossil wood. Ferruginisation of the fossils is most likely to have occurred prior to incorporation in the clay-rich sediments as detritus as they are broken and clastic but their coating was probably diagenetic.

Loose, pisolitic clay (LP)

This crumbly material consists of approximately equal quantities of yellow-brown ferruginous clay and red-brown pisoliths. The pisoliths have formed around a variety of nuclei; some are of partly dehydrated massive goethite and hematite with dehydration cracks or ferruginous clay, others are of fossil wood. The cell patterns and their scale is typical of woody tissue. A cross section suggests large vessels, with thick walls surrounded by parenchyma packing cells and ray cells. Longitudinal sections suggest some of the larger vessels may be xylem, indicating flowering plants. These fossil and lithic clasts are coated with layered cutans of honey-brown goethite which are complex, indicating cycles of dissolution and reprecipitation of Fe oxides. The final thin coat on the pisoliths is of clay. It is likely that this loose, pisolitic clay was derived from the pisolitic clay below by solution and partial removal of the clay.

Alluvial polymictic gravel (AG)

This alluvial deposit consists of a closely packed polymictic gravel of angular to subrounded, black to brown, hematite and partly dehydrated goethite granules and lithorelics, quartz grains and granules of ferruginous kaolinite, lightly cemented by a mottled, light greenish to reddish kaolinite. The ferruginous clasts have a variety of internal fabrics and are covered by extensively worn goethite and ferruginous clay cutans. This appears to represent material eroded from nearby lateritic terrain and was deposited after the main period of deep weathering; it is regarded as a cover to the valley-fill clays.

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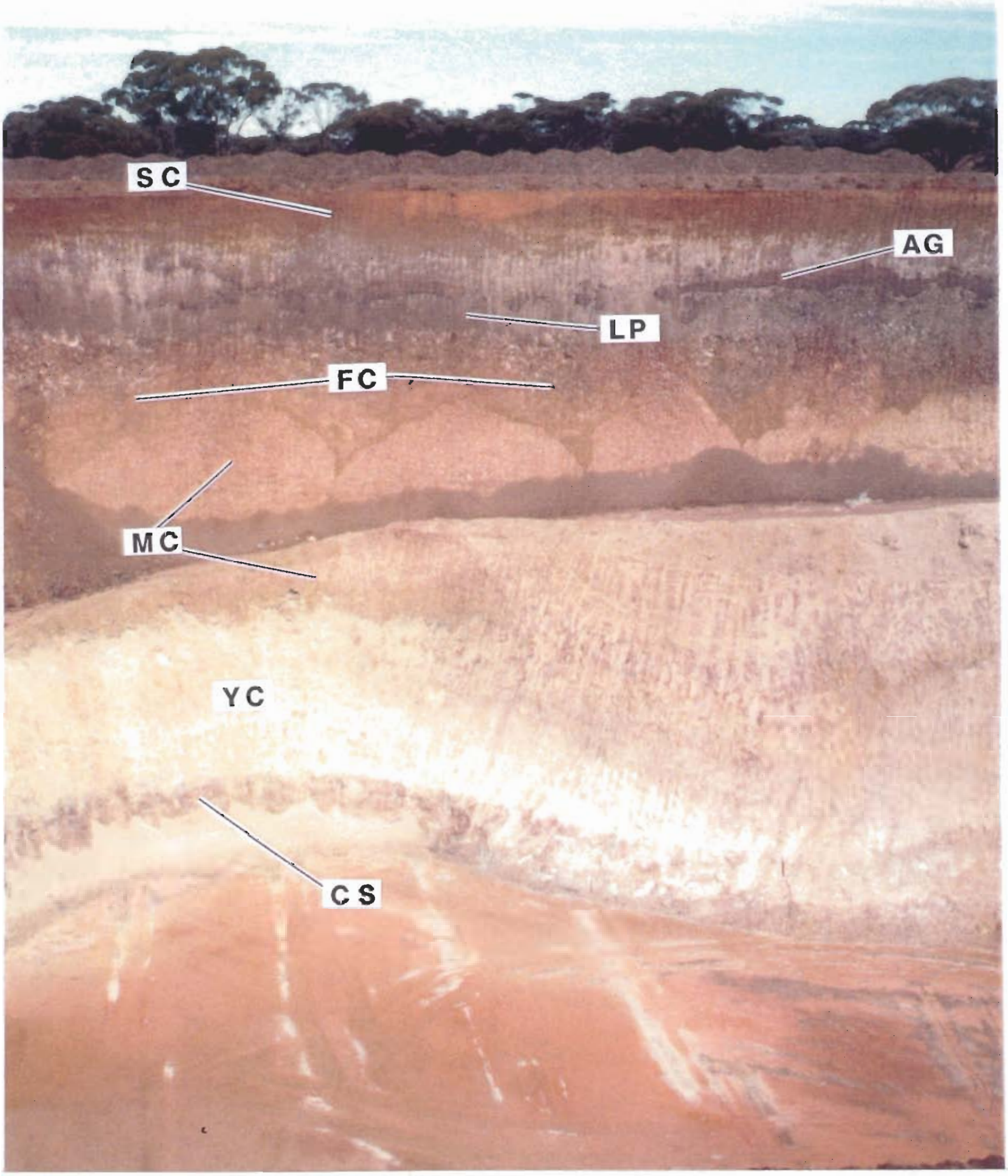

Figure 2. Face of the pit at Greenback showing the basal clayey sand (CS), smectitic yellow clay (YC), mottled clay (MC), ferruginous, pisolitic clay (FC) and loose, pisolitic clay (LP). Alluvial, polymictic gravel (AG) forms the base of further transported cover in which a calcareous soil (SC) is developed.

STEINWAY - SURFACE EXPRESSION OF DEEPLY BURIED GOLD MINERALISATION OR A "FALSE" ANOMALY?

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It is of paramount importance to establish whether relatively inexpensive surficial sampling techniques can be used *in lieu* of deep drilling for exploration in areas of transported overburden. Many accounts in the open literature and company reports claim that surface sampling can be used successfully to explore in areas with substantial transported overburden. However, independent verification of these case studies by rigorous scientific methods has not been routinely undertaken. This is an unsatisfactory state of affairs since it has left the exploration industry in doubt as to whether they can safely relinquish ground that has no anomalies and is thus supposedly barren. The example of Steinway (Yilgarn Craton, Western Australia) is used to show how surface expression to buried Au mineralisation may not be all that it seems.

Steinway is a sub-economic Au deposit located 25 km south of Kalgoorlie, WA. The central and northern parts of the area have a variable thickness (>20 m) of transported overburden of presumed Tertiary age consisting of partly consolidated clays, sands and silts. Beneath the transported overburden, saprolite overlies a bedrock of mafic andesites, trachytes, porphyritic tuffs and black shales. There are two types of mineralisation at Steinway: (i) saprolite-hosted supergene mineralisation located at ~30 to 40 m and (ii) primary mineralisation associated with quartz stockwork veining within mafic andesites. The Ca- (as calcrete) and Fe-rich soil (0–1m) overlying Steinway is anomalous in Au, with a maximum concentration of 150 ppb compared to a local threshold of 24 ppb. This Au anomaly is one of the strongest in the area that has been drill-tested. Not all the anomalies have proved to have mineralisation beneath them, but a much weaker anomaly to the west, Greenback, does and this has subsequently been mined. A more detailed study of the nature of Au in the surficial material was undertaken to verify whether the Au at the surface was being sourced from the underlying mineralisation or elsewhere.

The distribution of gold in the sediments and anomalous soil overlying the mineralization was investigated.. Nearly black, vitreous, sub-rounded ferruginous granules, a few millimetres in size, were found to be abundant in the soil and were separated for detailed study. The principal results are summarised as follows:

1. Gold is associated with both ferruginous granules and calcrete (pedogenic carbonate) in the soil.
2. Some Au in carbonate is highly soluble, and probably present in colloid particles or in a 'chemical' form.
3. Some, but not all, ferruginous granules contain microscopically-visible particulate Au.
4. Gold concentrations of individual, ferruginous granules are extremely variable (<40–15000 ppb).
5. Relict primary fabrics were observed in ferruginous granules.
6. The sediments beneath the soil are essentially barren of gold.

These results suggest that the ferruginous granules are the immediate source of Au in the soil, and that both are derived by mechanical dispersion from upslope, rather than Au migrating chemically (into the ferruginous granules) from the mineralisation below. The relatively-soluble Au in the calcrete is probably derived from either (i) the ferruginous granules, which have weathered and released Au, or (ii) direct chemical dispersion from a similar upslope source as the ferruginous granules themselves.

Previous studies have shown that in relict and erosional regimes, sampling of the calcareous horizon may accurately define drilling targets. However, in depositional regimes, such as Steinway, results indicate that there may be no causal link with underlying mineralisation and that, in certain depositional areas, sampling of calcareous material, at best, may indicate the potential of the (sub-)catchment. It is suggested, therefore, that for such landscape regimes, wider sampling intervals could be used, with a follow-up requirement that deep samples be collected, including basal sediments and/or ferruginous saprolite.

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