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GEOCHEMICAL EXPLORATION IN AREAS OF TRANSPORTED OVERBURDEN, YILGARN CRATON AND ENVIRONS

MURCHISON FIELD TRIP

C.R.M. Butt, I.D.M. Robertson, R.R. Anand, D.J. King, T.J. Munday, C. Phang and R.E. Smith

CRC LEME OPEN FILE REPORT 110

June 2001

(CSIRO Division of Exploration and Mining Report 164R, 1995.
2nd Impression 2001.)

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 No 5, PO Wembley, Western Australia, 6913.

RESEARCH ARISING FROM CSIRO/AMIRA YILGARN REGOLITH GEOCHEMISTRY PROJECTS 1987-1996

In 1987, CSIRO commenced a series of multi-client research projects in regolith geology and geochemistry which were sponsored by companies in the Australian mining industry, through the Australian Mineral Industries Research Association Limited (AMIRA). The initial research program, "Exploration for concealed gold deposits, Yilgarn Block, Western Australia" had the aim of developing improved geological, geochemical and geophysical methods for mineral exploration that would facilitate the location of blind, buried or deeply weathered gold deposits. The program commenced with the following projects:

P240: Laterite geochemistry for detecting concealed mineral deposits (1987-1991). Leader: Dr R.E. Smith.
Its scope was development of methods for sampling and interpretation of multi-element laterite geochemistry data and application of multi-element techniques to gold and polymetallic mineral exploration in weathered terrain. The project emphasised viewing laterite geochemical dispersion patterns in their regolith-landform context at local and district scales. It was supported by 30 companies.

P241: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1987-1991). Leader: Dr C.R.M. Butt.
The project investigated the distribution of ore and indicator elements in the regolith. It included studies of the mineralogical and geochemical characteristics of weathered ore deposits and wall rocks, and the chemical controls on element dispersion and concentration during regolith evolution. This was to increase the effectiveness of geochemical exploration in weathered terrain through improved understanding of weathering processes. It was supported by 26 companies.

These projects represented 'an opportunity for the mineral industry to participate in a multi-disciplinary program of geoscience research aimed at developing new geological, geochemical and geophysical methods for exploration in deeply weathered Archaean terrains'. This initiative recognised the unique opportunities, created by exploration and open-cut mining, to conduct detailed studies of the weathered zone, with particular emphasis on the near-surface expression of gold mineralisation. The skills of existing and specially recruited research staff from the Floreat Park and North Ryde laboratories (of the then Divisions of Minerals and Geochemistry, and Mineral Physics and Mineralogy, subsequently Exploration Geoscience and later Exploration and Mining) were integrated to form a task force with expertise in geology, mineralogy, geochemistry and geophysics. Several staff participated in more than one project. Following completion of the original projects, two continuation projects were developed.

P240A: Geochemical exploration in complex lateritic environments of the Yilgarn Craton, Western Australia (1991-1993). Leaders: Drs R.E. Smith and R.R. Anand.
The approach of viewing geochemical dispersion within a well-controlled and well-understood regolith-landform and bedrock framework at detailed and district scales continued. In this extension, focus was particularly on areas of transported cover and on more complex lateritic environments typified by the Kalgoorlie regional study. This was supported by 17 companies.

P241A: Gold and associated elements in the regolith - dispersion processes and implications for exploration (1991-1993). Leader: Dr. C.R.M. Butt.
The significance of gold mobilisation under present-day conditions, particularly the important relationship with pedogenic carbonate, was investigated further. In addition, attention was focussed on the recognition of primary lithologies from their weathered equivalents. This project was supported by 14 companies.

Most reports related to the above research projects were published as CRC LEME Open File Reports Series (Nos 1-74), with an index (Report 75), by June 1999. Publication now continues with release of reports from further projects.

P252: Geochemical exploration for platinum group elements in weathered terrain. Leader: Dr C.R.M. Butt.
This project was designed to gather information on the geochemical behaviour of the platinum group elements under weathering conditions using both laboratory and field studies, to determine their dispersion in the regolith and to apply this to concepts for use in exploration. The research was commenced in 1988 by CSIRO Exploration Geoscience and the University of Wales (Cardiff). The Final Report was completed in December 1992. It was supported by 9 companies.

P409: Geochemical exploration in areas of transported overburden, Yilgarn Craton and environs, WA.
Leaders: Drs C.R.M. Butt and R.E. Smith.
About 50% or more of prospective terrain in the Yilgarn is obscured by substantial thicknesses of transported overburden that varies in age from Permian to Recent. Some of this cover has undergone substantial weathering. Exploration problems in these covered areas were the focus of Project 409. The research was commenced in June 1993 by CSIRO Exploration and Mining but was subsequently incorporated into the activities of CRC LEME in July 1995 and was concluded in July 1996. It was supported by 22 companies.

Although the confidentiality periods of Projects P252 and P409 expired in 1994 and 1998, respectively, the reports have not been released previously. CRC LEME acknowledges the Australian Mineral Industries Research Association and CSIRO Division of Exploration and Mining for authority to publish these reports. It is intended that publication of the reports will be a substantial additional factor in transferring technology to aid the Australian mineral industry.

This report (CRC LEME Open File Report 110) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 164R, first issued in 1995, which formed part of the CSIRO/AMIRA Project P409.

Copies of this publication can be obtained from:
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INTRODUCTION

AMIRA Project 409, *Geochemical exploration in areas of transported overburden, Yilgarn Craton and environs*, has, as its principal objective, the development of geochemical exploration methods for areas having a substantial cover of surficial sediments, through investigations of the processes of geochemical dispersion from concealed mineralization. An important aspect of the project is to translate research findings into practical outcomes. Field excursions have a significant role in this process, for they permit geologists and geochemists from the research group and the supporting companies to examine key sites together. This interaction promotes a much freer exchange of ideas than is possible in the formal atmosphere of seminars. The project has several important research sites and districts across the Yilgarn Craton. It is impractical to visit all of these at once, hence there will be at least two excursions during the course of the final year of the project. This, the first excursion, examines sites in the Murchison and adjacent areas: their wide separation necessitates extensive travel. The locations are shown on Figure 1. All are characterized by the development of red-brown hardpan in the surface horizons. Pedogenic carbonates are also present at Mt. Gibson and, in places, Mt. Magnet, but are generally absent from the other sites. The first visit is to the Mt. Gibson gold mine. This has not, in fact, been studied during this project, but it was an important site for Project 240, *Yilgarn Lateritic Environments*, and serves as an excellent introduction to many of the important features of the regolith and to the value of regolith-landform mapping. Transported overburden is a feature of the district, so that many of the findings at Mt. Gibson are of direct relevance to the objectives of the present project. The second series of visits is to locations in the Boogardie Synform in the Mt. Magnet district, including the Quasar and Stellar gold deposits, the subjects of detailed regolith mapping and geochemical orientation. Several different regolith-landform settings will be examined, including near-complete and truncated residual profiles overlain by colluvial and palaeochannel sediments. On the third day, the excursion will visit the Harmony deposit at Baxter, near Peak Hill. This is a new development, mining having commenced in July, and provides a first opportunity for close inspection of the regolith at this location. The excursion will demonstrate the regional landform setting of the deposit and examine the regolith as exposed in the new pit and as seen in drill core and drill cuttings. Finally, there will be a brief visit to the Fender deposit, about 2 km south of the Big Bell mine, near Cue. Mining was due to commence in July but, unfortunately, this has been delayed and it is now improbable that the anticipated exposure of the upper regolith will have occurred. The site is important, because it appears to be completely blind, even though the cover is thin and, in places, directly overlies ore-grade mineralization. The visit will examine the setting of the deposit and inspect samples of the regolith in core and cuttings.

The authors of the articles in the guide wish to thank Colin Steel and Angelo Vartesi for drafting the diagrams, and Gill Ashton and Pearl Phillips for preparing and compiling the final manuscript. Gill Ashton undertook much of the organisation of the excursion and her assistance is gratefully acknowledged.

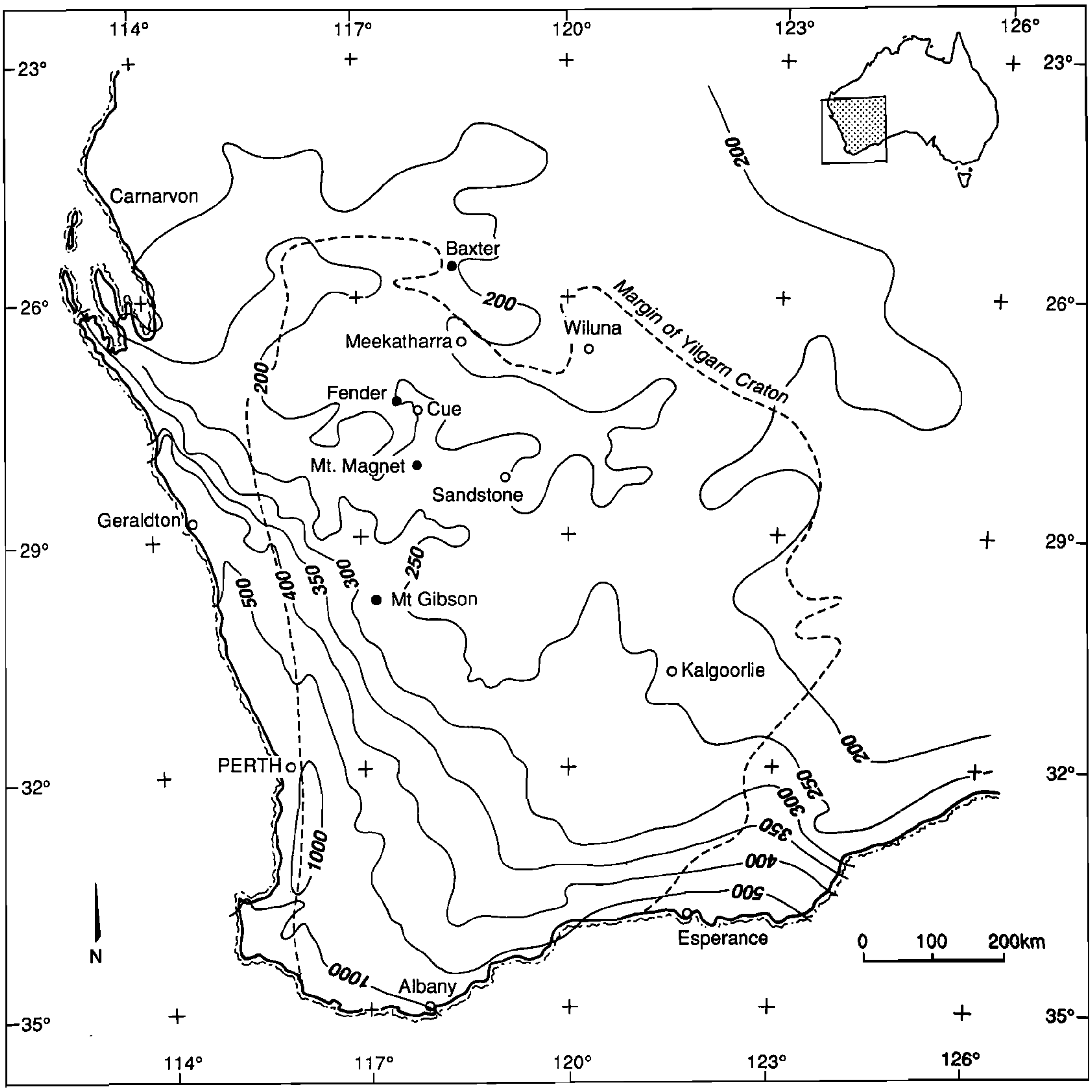


Figure 1 - Locations of sites to be visited during the excursion.

MT. GIBSON DISTRICT

R. R. Anand and R. E. Smith

1. INTRODUCTION

The Gibson gold deposit lies in the Murchison district at lat. 29°45'S, long. 117°10'E. It is 350 km NNE from Perth, within 12 km of the Great Northern Highway, 15 km south of Mt. Gibson (Figure 1) and 28 km SW of Mt. Gibson homestead. The Gibson deposit, and the similar Boddington deposit, are regarded as archetypes for lateritic gold mineralization (Monti, 1987; Davy and El-Ansary, 1986; Davy *et al.*, 1988). Few operations of any importance have been supported entirely by ore from laterite. However, although generally of low grade, the economic advantage of the relatively low overburden ratios characteristic of these deposits makes them attractive exploration and development targets.

The Mt. Gibson gold mines commenced operations in 1985, based on low grade lateritic ore. Continued exploration led to delineation of a series of deposits with resources of 6 tonnes of Au, including some primary mineralization (Gee, 1989, 1990). The ores are the strongest parts of a geochemical anomaly of more than 7 x 1 km developed above intermittent shoots of primary Au and disseminated sulphide mineralization. A small prospect, Tobias Find, discovered during the period 1910-1916, is 100 m from one of the present pits but production (1 kg Au) was not significant. The auriferous nature of the laterites was not recognized until 1982. This account is derived largely from reports by Anand *et al.* (1989a; 1991b); Smith and Anand (1992); Davy *et al.* (1988; 1989) and Gee (1990).

Sporadic secondary mineralization has been found along 7 km of strike with individual deposits known in the SCN area (southern, central and northern pits) and at Midway North (Hornet Zone). Primary mineralization is associated with quartz veins in shears within a sequence of weathered mafic and felsic rocks, metamorphosed to lower amphibolite and greenschist facies. In the Hornet zone, Au occurs at the structural contact of a western suite of sheared basic rocks, quartz-phyric felsic schist and possible Fe-rich sediments against an eastern suite of less deformed basalts (Gee, 1989). Gold is found particularly in K-Si-S alteration zones within and marginal to the quartz-phyric rock and with sulphidic laminae (pyrite and pyrrhotite with minor chalcopyrite and sphalerite) in chlorite tremolite (cordierite garnet) schists. Preliminary geochemical studies suggest a variable primary association of Au with Ag, Cu, Pb, Zn, As, Sb, Bi, W, Se and Ge.

2. REGIONAL GEOLOGICAL SETTING

The deposit lies at the southern end of the Archaean Retaliation greenstone belt (Lipple *et al.*, 1983), in the southern Murchison Province (Figure 1). The southward termination of this greenstone belt is due both to granitic intrusion and structural attenuation, a complexity which makes structural and stratigraphic interpretation difficult.

Two unrelated and probably convergently facing greenstone terrains are juxtaposed by a major N-S structural dislocation. Between these two terrains, and obscuring the actual boundary, is a synclinal zone occupied by a stratigraphically high sequence of epiclastic sediments. The western contact of this sequence is faulted, whereas the eastern contact has the characteristics of a regional unconformity.

The eastern terrain consists of tholeiitic metabasalt with abundant gabbro sills and minor interflow cherty sediments, folded into broad synclines and anticlines on NNW doubly plunging axes.

The western terrain is an east facing sequence of tholeiitic and high magnesium metabasalt, gabbro sills, felsic schist (probably after felsic volcanics, related sediments and intrusive porphyry), banded iron formation (BIF) and cherty interflow sediments. The western terrain is tightly deformed by steeply north plunging isoclinal folds and cut by transpressional shear zones of predominantly sinistral movement. The old gold workings, such as Tobias Find, Leakes Find, McDonalds Find and Paynes Crusoe, and the newly discovered Hornet (Figure 1), are probably related to these shear zones.

3. GEOMORPHOLOGY

The District is one of gently undulating, subdued relief broken by greenstone hills, granite mounds and low breakaways. This area has an elevation of from 310 to 360 m above mean sea level and is located on broad divide between the extensive playas of Lakes Moore and Monger, both of which occur at about 300 m asl. The broadly-convex local divides are at 340 to 360 m asl and these are flanked by long gentle slopes that grade at 1 in 50 (2%) on the upper slopes to 1 in 200 overall (0.5%), leading to a local drainage sump (Lake Karpa) at 310 m asl. Emergent above the general plateau are a few prominent crests and monadnocks, flanked by steep irregular slopes just beyond the NE limit of the area. The most prominent are Mt. Gibson (480 m) and Mt. Singleton (620 m).

Deep lateritic weathering profiles are widespread and there has been partial differential stripping. Detritus derived from partial erosion of the lateritic mantle is widely distributed. Sporadic areas of outcrop and subcrop of fresh mafic lithologies and saprolite of a variety of types occur in zones of local erosion. Exposures of fresh granitoid rocks often take the form of low domes, local pavements and tors whereas kaolinized granitoid rocks are exposed in a few low breakaways.

4. REGOLITH

Regolith-landform mapping has demonstrated the importance of understanding the erosional and depositional dynamics of the geochemical dispersion. The principal regolith units are:

Soils

1. yellow sands and orange sandy clays, typically gravelly below 20-50 cm, directly overlying residual lateritic gravels and duricrust.

2. red clays, which overlie either saprolite in the erosional regimes, or clay and sandy materials transported for up to 500 m and deposited upon relatively complete laterite profiles. The main minerals present are quartz and kaolinite, calcite and dolomite.

The red clay soils are characterized by eucalyptus woodland vegetation, whereas the yellow and orange soils derived from the lateritic residuum support an acacia shrubland (Figure 2).

Hardpan. Hardpan, formed by silica cementation of colluvium and alluvium, is up to 3 m thick in parts of the SCN area and reaches 6 m near Midway. In the SCN area, the colluvium is locally derived and contains an abundance of lateritic pisoliths, nodules and saprolite-derived silty, sandy clay.

Lateritic residuum. There are two principal units:

1. loose pisolitic and nodular gravels with a yellow to red sandy clay matrix. This unit generally occurs as a blanket 1-2 m thick that overlies and grades downwards into pisolitic or nodular duricrust (Figure 3). The pisoliths and nodules are commonly 5-20 mm in diameter and have pale brown, brown or nearly black cores composed of Al-goethite, Al-hematite, Al-maghemite and kaolinite with abundant residual quartz grains. The outer coatings are paler and consist of Al-goethite, kaolinite and gibbsite.

2. lateritic duricrust, typically the substrate to the lateritic gravels. It is generally 1 to 2 m thick in the SCN area, and has a pisolitic, nodular, vermiform or fragmental fabric. The pisoliths and nodules, which are commonly spaced within a hardened kaolinite-rich sandy clay matrix, have a similar mineralogy to those in the lateritic gravels. Secondary calcium carbonate and/or opaline silica cements, related to post-laterite groundwater regimes, are present in places.

Mottled zone. The mottled zone has been exposed sporadically by mining and erosion. Pronounced mottling is present on foliated metasedimentary or metavolcanic rocks rather than on metadolerites. The mottling, typically on a 10 cm scale, is due to the heterogeneous distribution of ferruginous material within a clay-rich, Fe-poor matrix; in places, it is related to recent penetration of tree roots and associated leaching of Fe.

Saprolite. Saprolite thickness depends on lithology, the intensity of shearing and the degree of truncation of the lateritic profile. In the Hornet zone, at Midway North, the main mineralized shear is weathered to 60 m, whereas mafic volcanics to the east are weathered only to 20 m. In some severely truncated areas, mafic amphibolite is fresh at outcrop.

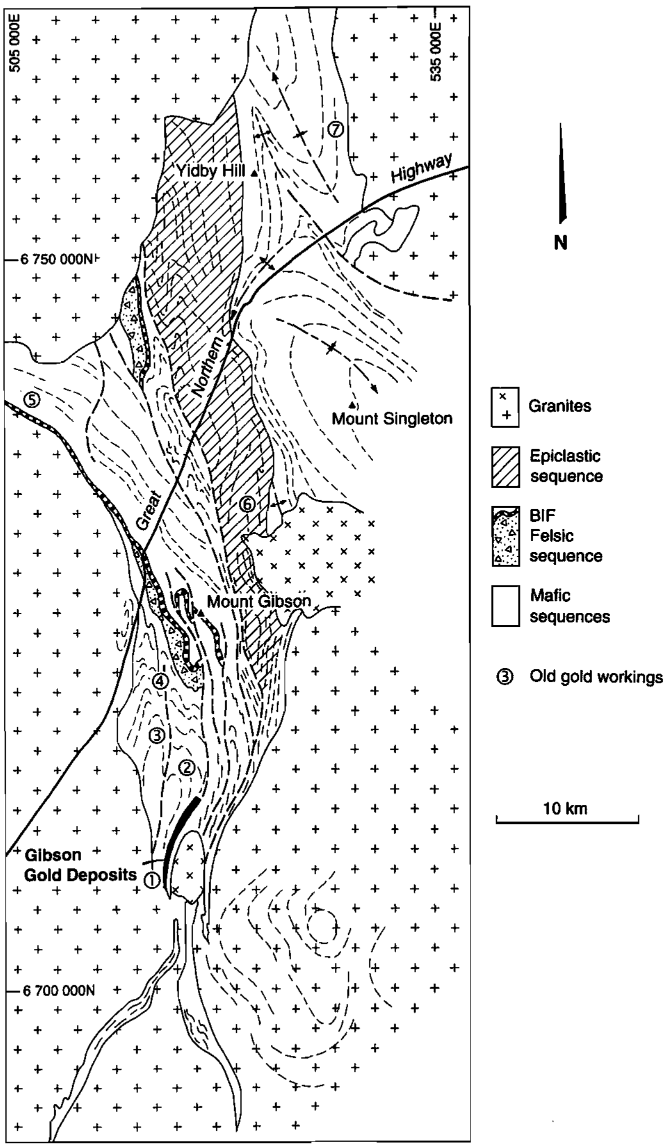


Figure 1 - Geology of the Retaliation greenstone belt showing the regional setting of the Gibson gold deposits. Old gold workings are: 1. Tobias Find; 2. McDonalds Find; 3. Leakes Find; 4. Paynes Crusoe; 5. Retaliation; 6. Bonnie Venture; 7. Kings Find. (From Gee, 1990)

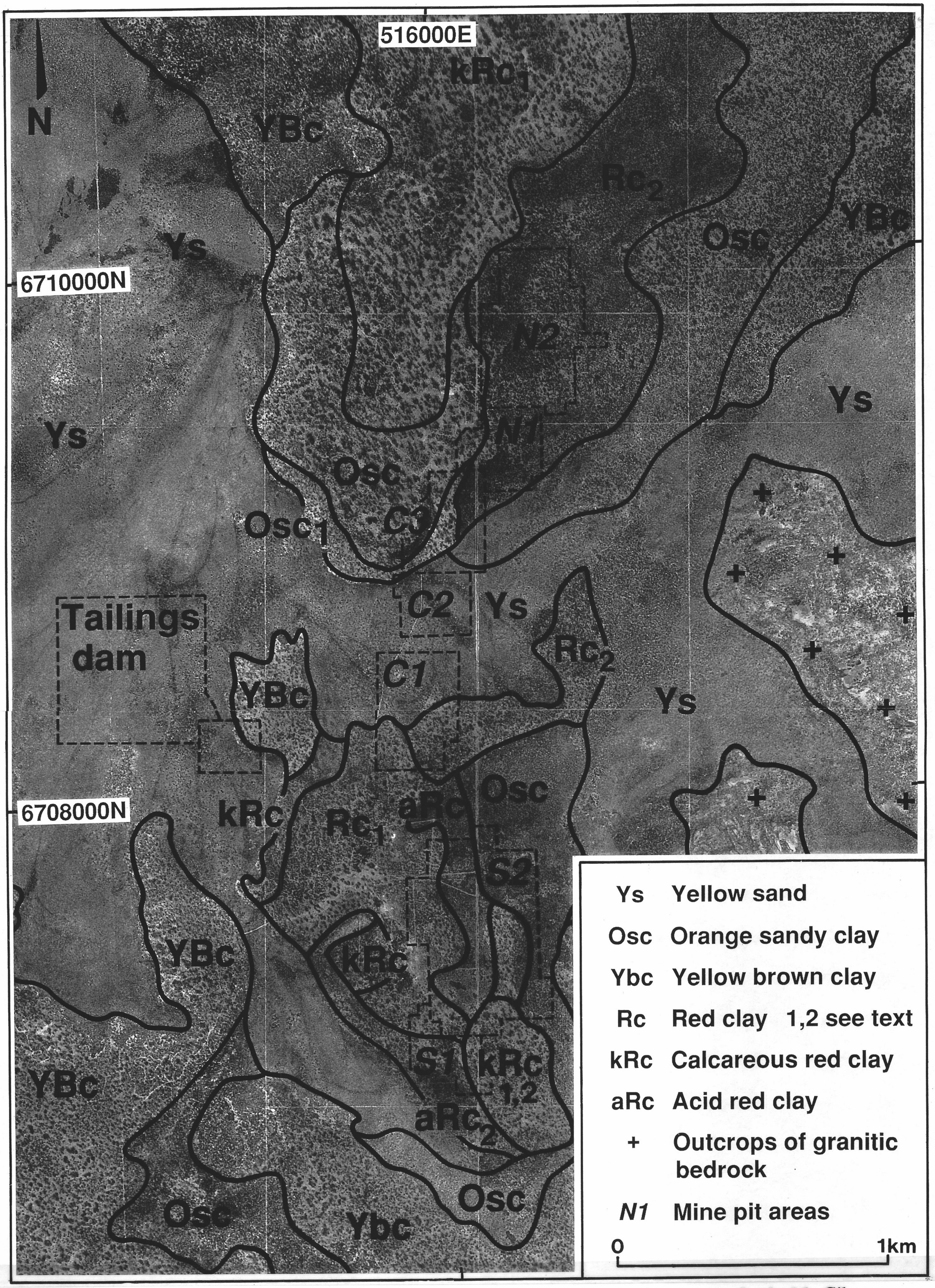


Figure 2 - Map showing the surface distribution of regolith units and vegetation patterns for the Mt. Gibson detailed orientation area as an overlay to the black and white air photograph (Ninghan run 11,5239, Sept. 1980). (From Anand *et al.*, 1989a.) DOLA Licence 548/98. WA 1929, Run 11, Frame 5239, Project 790020.

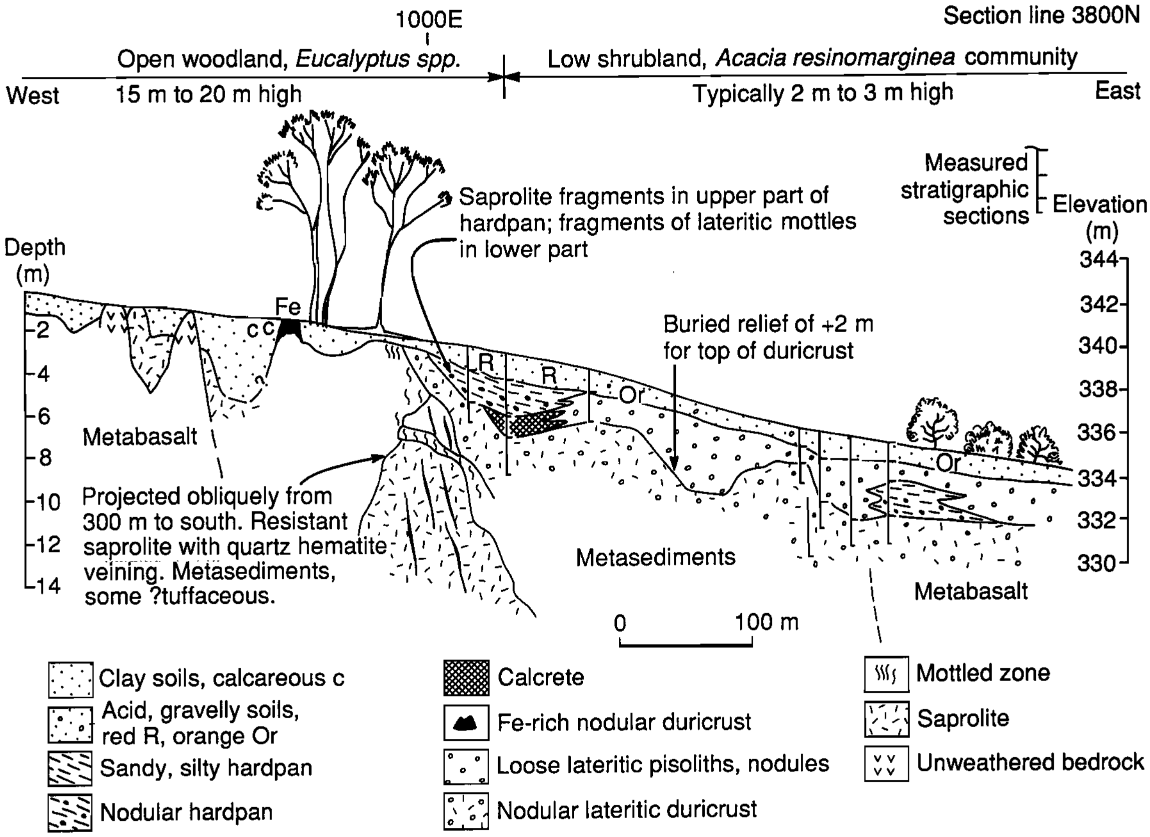


Figure 3 - Cross section through the N1 pit at Mt. Gibson (line 3800N) showing upper regolith and vegetation relationships. (From Anand *et al.*, 1989a.)

5. REGOLITH-LANDFORM MODEL

Much of the Mt. Gibson district is characterized by complex regolith-landform-vegetation patterns. An area of red clay soils within the mapped area was selected for investigation of the processes that have produced these relatively intricate patterns. Interpretations of air photos, topographic contours and vertical profiles led to the conclusion that within this detailed area there are paired erosional-depositional units. Dismantling of the laterite mantle in local uplands has commonly resulted in burial of the laterite profile in adjacent footslopes and lowlands. In the process, local erosional-depositional couples are characteristic and have resulted in colluvial/alluvial sequences. Some of these sequences show an inversion of the sequence of the former weathering profile, now dismantled. Gravelly detritus at the base of such colluvium is dominated by lateritic pisoliths and nodules, grading upwards to silty sandy detritus at the top, compatible with derivation by erosion of saprolite.

An idealized regolith-landform facies model for the Mt. Gibson area was established to act as a framework and guide in prediction of regolith relationships in comparable areas elsewhere (Figure 4).

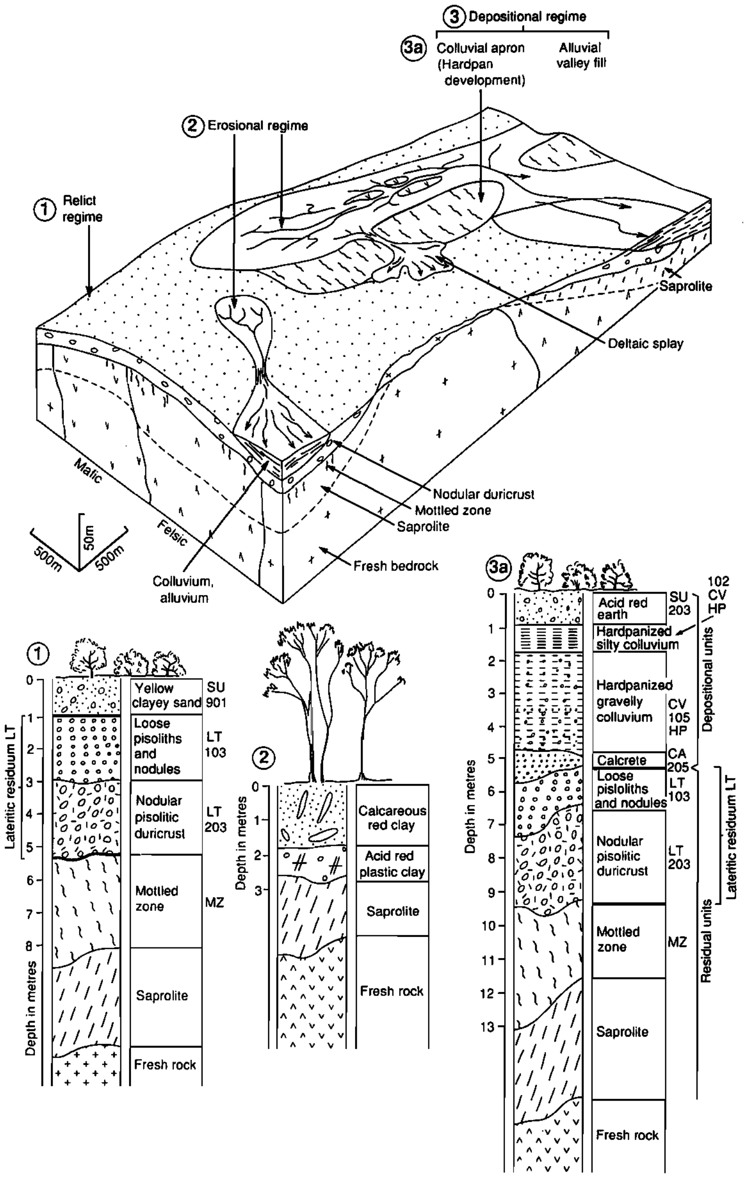


Figure 4 - Generalized regolith-landform facies model based ont he Mt. Gibson district. The three numbered columns show the regolith stratigraphy for the corresponding parts of the landscape. (From Anand *et al.*, 1991b.)

6. SUPERGENE AU MINERALIZATION

Gold at Mt. Gibson occurs at mineable grades in several regolith units. Prior to mining, some of the auriferous laterite occurred within 15-50 cm of the ground surface in the south and central pit areas. Elsewhere, it lay buried beneath several metres of partly consolidated sediments of local origin. In the SCN area, the pits are situated centrally within the geochemical anomaly, and loose lateritic gravel has been the most important ore. The high Au price, coupled with free-digging ore and efficient extractive metallurgy, allowed the mines to be worked profitably in 1985 using a cut-off of only 0.75 g/t Au, although higher cut-off grades were necessary later. Duricrust reserves are also widespread and have similar grades, but require ripping, blasting and crushing. In the Midway North area, a substantial saprolite orebody with some supergene enrichment has been mined. This lies beneath a 20 m thick depletion zone and is the weathered expression of the primary Hornet zone mineralization, together with some enrichment of the wall rocks close to the weathering front. Some lateritic ore also occurred within 10 m of the surface.

7. GEOCHEMICAL DISPERSION

Various sampling media including lateritic residuum (loose lateritic pisoliths and nodules, lateritic duricrust), and colluvium have been studied in the dispersion study at Mt. Gibson.

7.1 Lateritic residuum

The large Au anomaly in lateritic residuum (lateritic gravel and lateritic duricrust) is shown in Figure 5. Using a threshold of 30-50 ppb Au, a concentration that seems to be generally applicable for regional surveys of lateritic terrain in the Yilgarn Craton, the anomaly is 1 km wide and extends beyond the area depicted for 7 km along strike. The strongest parts of the anomaly in the SCN area are centred on a line of quartz-hematite veins. Because a number of chalcophile and associated elements (Pb, Bi, As, Sb and Ag, Figure 5 and Figure 6) show coincident anomalies also centred upon this veining, it is concluded that there is an important and close genetic link between the lateritic gravel and duricrust and the bedrock source(s). There is evidence for lateral dispersion of some Au, possibly by a combination of mechanical and hydromorphic mechanisms, with additional sources possibly 200-400 m upslope from the main axis of the anomaly.

The distribution of As (Figure 6) is probably related to the quartz-hematite veining, but appears to be displaced asymmetrically downslope by about 200 m, similar to the patterns at Golden Grove and Scuddles (Smith and Perdrix, 1983). The As abundance, as at Golden Grove, is anomalous but is low relative to many deposits elsewhere in the Yilgarn Craton. Although the Au anomaly in lateritic gravels is relatively continuous, the distribution patterns for Ag, Pb and Sb (Figure 6) are zoned, with higher relative abundances in the north. This most probably reflects zoning in the primary mineralization. The multi-element chalcophile association is typical of a Au-bearing base metal or polymetallic sulphide source. The sulphides are most probably disseminated because no massive sulphide gossans have been found in the SCN area where saprolite has been exposed by mining or erosion.

At Midway North, lateritic residuum is enriched in Cu, Pb, Zn, As and Au, which are associated with hematite and goethite (Figure 7). Systematic mineralogical and geochemical differences occur between transported and residual regolith units. For example, the colluvial units (soils, hardpanized colluvium) contain higher amounts of kaolinite and quartz relative to the underlying residual regolith units. Hematite increases upwards in the residual weathering profile.

7.2 Magnetic and non-magnetic nodules and pisoliths

Both magnetic and non-magnetic pisoliths are present within the gravelly unit of lateritic residuum and are anomalous in Au (Figure 8) and chalcophile elements. Higher concentrations of Fe, Cr, V, Pb, As, W, Sb, Bi and Zn are found in magnetic nodules than in non-magnetic nodules, whereas, Au, Al, Si, Cu, Ag and Ni are relatively more abundant in the non-magnetic nodules. The distribution of Au, As, Cu, Pb, Zn, Ag and Bi is controlled wholly or in part by the distribution of hematite, goethite and kaolinite. This is clearly shown by the differences in abundances of these elements in magnetic and non-magnetic fractions. Hematite is the major mineral in both the fractions and appears to have a strong affinity for As, Pb, Zn, Bi, Cr and V. These elements are therefore abundant in both the fractions; however, it is the difference in the abundances of goethite between the two fractions which appears to determine the abundances of Au, Cu and Ag.

7.3 Cores and cutans of loose pisoliths

Cores and cutans could only be separated where the pisoliths were large and their cutans thick. The pisoliths were spherical, 20-50 mm in diameter, and have black to red cores dominated by hematite and maghemite with lesser amounts of goethite, kaolinite, quartz and gibbsite. The cutans, generally 2-15 mm thick, have light-and dark-red banded zones and consist largely of kaolinite, hematite and gibbsite with small amounts of goethite and quartz. Maghemite is typically absent from cutans.

The cores are relatively rich in Fe_2O_3 (65%) and are poor in SiO_2 (12%) and Al_2O_3 (12%). In contrast, cutans have similar mean abundances of Fe_2O_3, Al_2O_3 and SiO_2. Both cores and cutans are rich in TiO_2 (up to 4.6%) which are significantly more Ti-rich than nodules of lateritic residuum. This suggests that the large pisoliths, with thick cutans, have developed from weathered Ti-rich mafic rocks.

Chromium, V, Pb, Zn, As and Ga are enriched in the cores relative to the cutans. The cores show very high concentrations of Au averaging about 11 ppm, compared with 2.7 ppm for the cutans (Figure 8). In contrast, Ag is more abundant in the cutans than the cores. The cutans were probably formed by the deposition from Al and Fe-rich solutions around black nuclei and therefore may not have a direct link with the formation of the cores. This suggests that Au enrichment in the cores and cutans did not occur at the same time and that Au has been mobile.

7.4 Colluvium

The colluvium samples have a high proportion of lateritic nodules and pisoliths having formed by dismantling of lateritic duricrust and include detritus derived by erosion of saprolite. The geochemical patterns within the colluvium almost coincide with the patterns in the residual lateritic gravels and the lateritic duricrust (Figure 5 and Figure 6). The geochemical patterns in the colluvium and residual lateritic gravel are, however, somewhat broader than those in the lateritic duricrust. This is compatible with (a) some degree of mechanical dispersion having taken place during laterization, when the residual lateritic gravel formed by breakdown of the duricrust; and (b) more recent colluvial transportation of lateritic gravel during partial dismantling of the laterite profile. Similar results were obtained for Midway profiles.

The gravel fraction, when separated from hardpanized colluvium, largely consists of various amounts of lateritic clasts. Amorphous silica and carbonates may coat these ferruginous clasts, which largely consist of hematite and kaolinite, with varying amounts of goethite, quartz, gibbsite and calcite. The matrix is richer in SiO_2 and Al_2O_3 than the ferruginous gravel fraction. The mean concentrations of Au, Mn, Cr, V, Pb, As, Sb, Bi, Ag and W are much higher in the gravel fraction than in the matrix. The abundances of Zn and Cu do not significantly differ in the two fractions. Nickel, Co and Ba are enriched in matrix relative to the gravel fraction.

The mean concentrations of Au (Figure 8) and Ag in the matrix of hardpanized colluvium are higher than, or, very similar to, those from nodules of lateritic residuum and the gravel fraction of soil. Gold enrichment in the hardpan matrix may reflect the original abundances of Au in the eroded materials from the upper part of the weathering profile, in upland, source areas. Introduction of Au into the hardpan matrix at a much later stage is also a possibility.

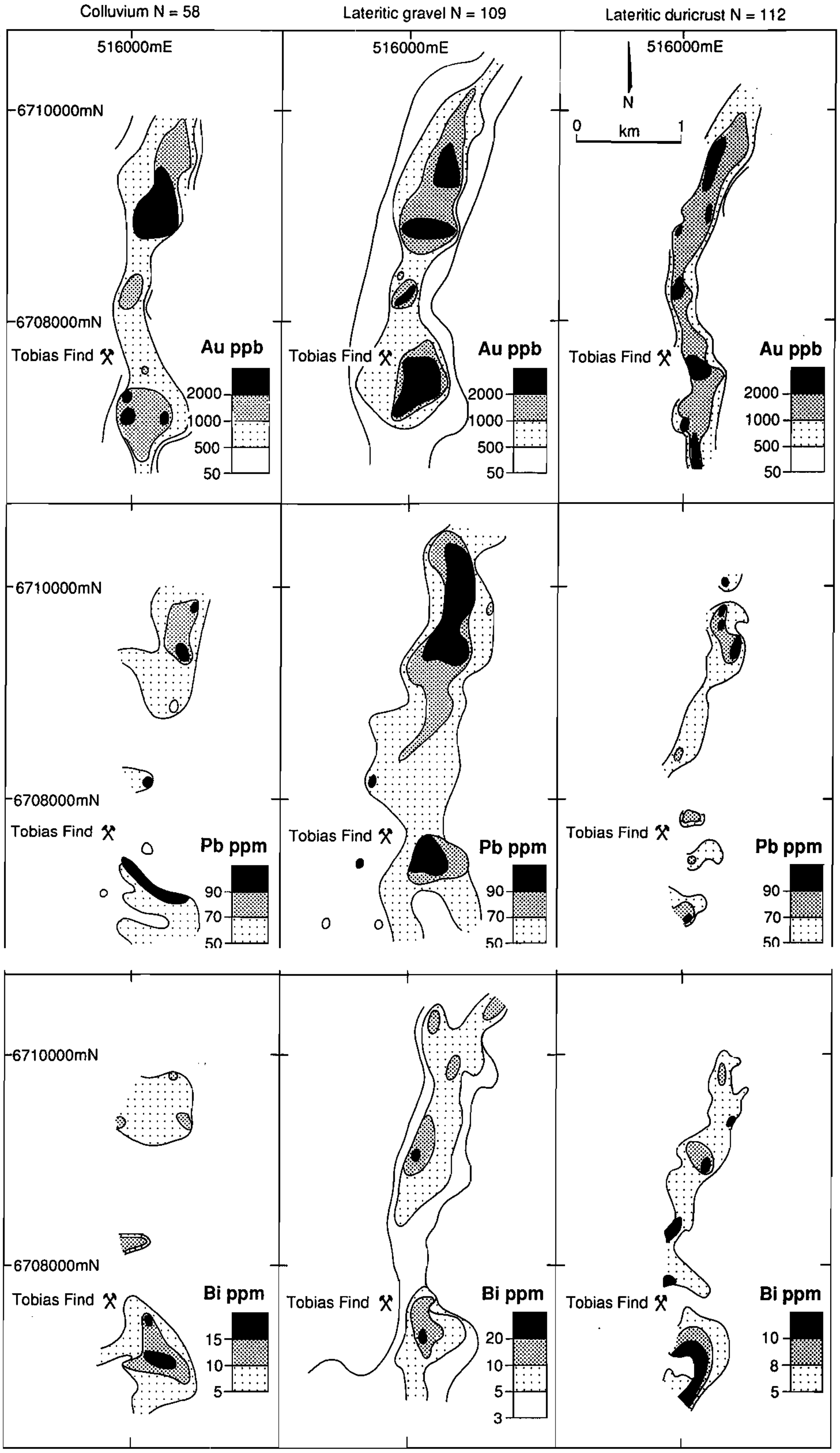


Figure 5 - Maps showing the dispersion patterns for Au, Pb and Bi for three sample media - colluvial lateritic gravel, gravelly lateritic residuum and lateritic duricrust (narrowest dispersion). (From Smith *et al.*, 1992.).

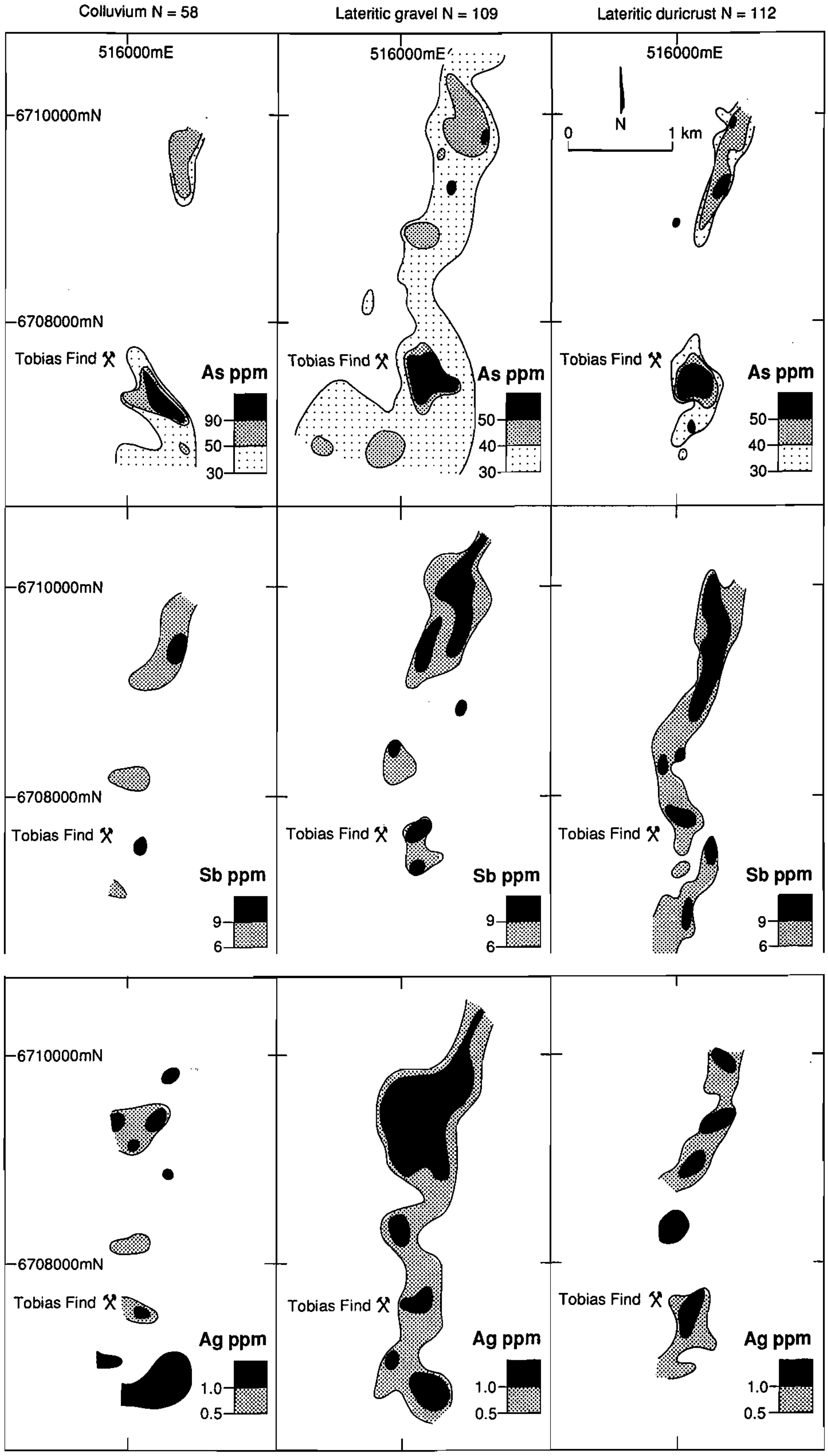


Figure 6 - Maps showing the dispersion patterns for As, Sb and Ag for three sample media - colluvial lateritic gravel, gravelly lateritic residuum and lateritic duricrust (narrowest dispersion). (From Smith *et al.*, 1992.).

7.5 Saprolite

Only limited data are available for the saprolite: Au mean 435 ppb, (maximum 3520 ppb); As 14 ppm, (85 ppm); Bi 6 ppm, (70 ppm); Cu 35 ppm, (160 ppm); Pb 105 ppm, (780 ppm). However, these data are compatible with the expectation that geochemical patterns in the saprolite, arising from both secondary dispersion and the weathering of the mineralization, will be stronger, more variable and narrower across strike than in the lateritic residuum.

7.6 Gold morphology

Native Au was observed in lateritic residuum as platelets and veining on a microscopic to handlens scale. Gold grains, observed in the lateritic nodules and pisoliths, occurred largely in voids or cracks, which are either filled with secondary goethite and kaolinite or are empty. Some grains also occurred on the surfaces of a goethite-rich area. Gold grains also showed dissolution features and surface pitting. Gold has a high purity (Ag <1%). These relatively coarse forms of Au, however, are only a small proportion of the total Au.

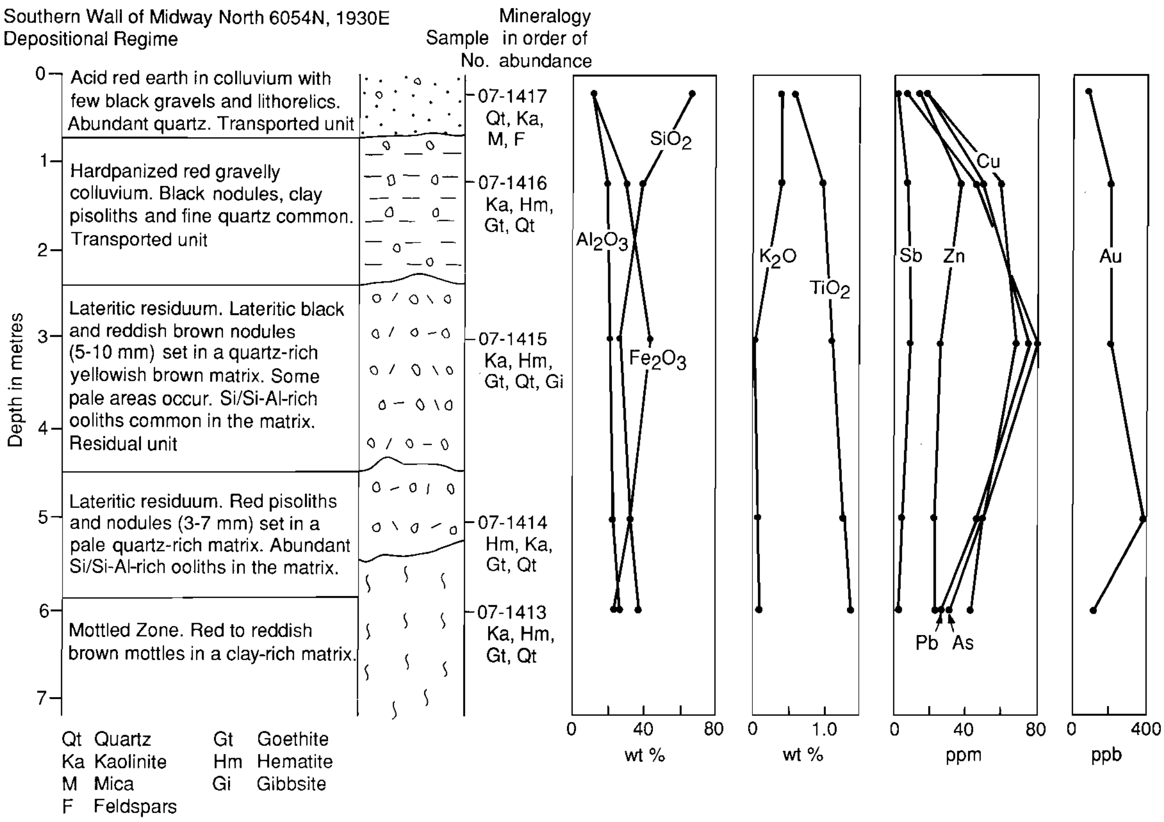


Figure 7 - Vertical profiles showing the stratigraphy, mineralogy and geochemistry of residual and transported regolith units for the depositional regime, southern wall, Midway North Pit. (From Anand *et al.*, 1991b.)

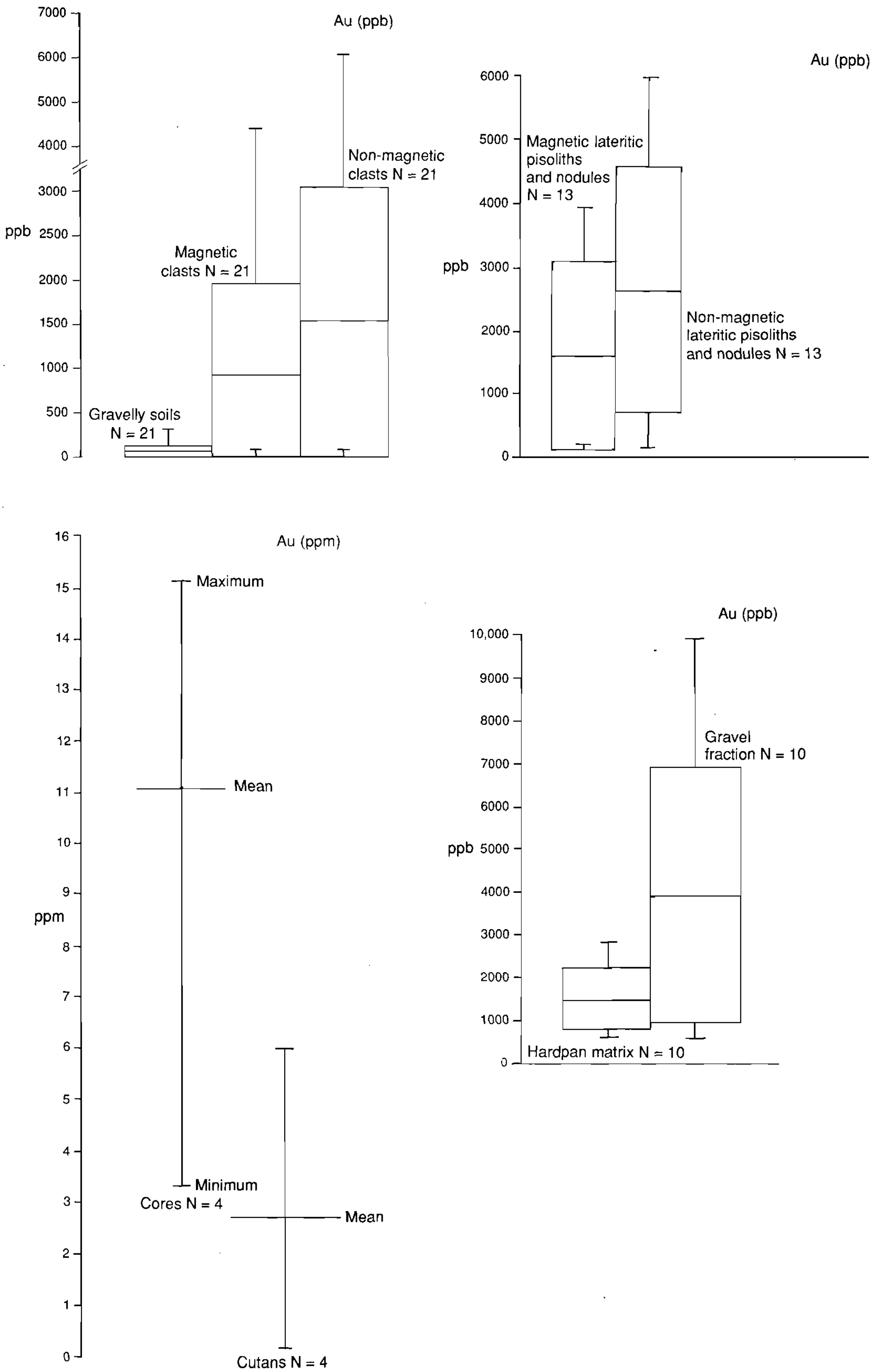


Figure 8 - The distribution of Au in magnetic and non-magnetic clasts/nodules, cores and cutans of pisoliths, hardpan matrix and gravel fraction separated from soils, lateritic residuum and hardpanized colluvium. (From Anand et al., 1991b.)

8. CONCLUSIONS

The most notable features of the geochemical expression of mineralization at Mt. Gibson are the size and regularity of the Au anomaly in the lateritic residuum. These are probably due in part to the restriction of sampling to a specific unit of the regolith, whether near the surface or buried by several metres of surficial sediments. These features confirm the validity of using wide sample spacings, such as a 500 m triangular grid, for reconnaissance exploration; a spacing of 1 km would detect an anomaly as large as that at Mt. Gibson. Even if Au had been leached to low and erratic levels in the lateritic residuum, the multi-element geochemical anomaly (Pb, As, Sb, Bi and W) would still be identifiable, provided these elements were not also significantly depleted (Anand *et al.*, 1989a). In this case, a sample spacing of 300-400 m would have been appropriate.

There appears to be no special advantage in sampling magnetic nodules and pisoliths despite the greater homogeneity of the sample. On the contrary, non-magnetic materials are more useful because both target and pathfinder elements are associated with goethite and hematite that can comprise either the core or cutans of nodules and pisoliths.

The matrix of the hardpan is highly anomalous in Au and Ag, which possibly reflects the original Au abundances in the eroded source materials. However, introduction of Au into the hardpan, through hydromorphic dispersion, is also possible.

The research findings at Mt. Gibson highlight the importance of a sound appreciation of regolith-landform relationships in planning, executing and interpreting an exploration geochemical survey in this style of deeply weathered terrain.

MT. MAGNET

For an introduction to Mt. Magnet, refer to Sections 1-3 below. Report 48C (Robertson *et al.* 1994) also refers. The locations of the stops and the route are shown on Figure A.

STOP 1

Colluvial plain east of Quasar 578350E 6892430N

Ignoring the 'fly-rock' from the pit, the lag covering this depositional plain consists of a polymictic assemblage of red jaspilite, fragments of black and grey BIF, chert, quartz, ferruginous pisolites and nodules (maghemite-rich) with worn cutans. This is typical of extensive areas in the Boogardie Synform, covered by colluvium-alluvium.

STOP 2

Quasar Ramp 578050E 6892100N

The exposure at the Quasar pit shows that the saprolite has been partly eroded and is now blanketed with colluvium-alluvium. The unconformity at the base of the cover is particularly sharply defined. Mineralisation at Quasar lies within ultramafics along the contact with felsic rocks. The mineralisation is sulphide-poor (quartz-chlorite-pyrite±carbonate).

For details of the geology and geochemistry of Quasar, refer to Section 4 below.

STOP 3

Exploration drilling near Lone Pine Pit 576630E 6894150N

Unfortunately the drilling, used to delineate the palaeochannels at Quasar and Stellar, have since suffered the inevitable depradations of the weather and minesite rehabilitation. However, some recent exploration drilling near the Line Pine open pit should suffice. The open pit at Lone Pine (behind) is in saprolite, overlain by a thin cover typical of the colluvium-alluvium mantling this part of the Boogardie Synform. A short drill section (FSI 27 - FSI 25) shows a mantle of colluvium-alluvium 8-9 m thick underlain by a progressively eroded residual profile containing duricrust (buried relict regime) in FSI27 but passing into a partly stripped profile (buried erosional regime) mantled by palaeochannel sediments (FSI 26) which deepen progressively (FSI 25). This is shown in section in Figure B.

STOP 4

Stellar Ramp 576569E 6897137N

For safety reasons, it will be necessary to divide the party into two groups which will later exchange places. The first will examine the colluvium and its contact with the underlying duricrust. Note the lenses of gravel and cobbles in the upper part of the colluvium, the downward transitions to more silty material, the subvertical cylindrical, clay-debris filled structures and the contact with an underlying duricrust.

The second party will look at the duricrust and its complex relationships with its underlying saprolite and the quartz-tourmaline mineralisation.

Please do not proceed beyond the gully and beware of the narrow berm. The two parties must cross on the ramp .

For details of the geology and geochemistry of Stellar, refer to Section 5.

STOP 5

Breakaway adjacent to Eclipse Mine 579147E 6897115N

The breakaway is developed mainly in ferruginous saprolite and the colluvium-covered pediments slope away south and south-east towards Mt. Magnet. Duricrust-filled solution hollows are well developed in felsic ferruginous saprolite. There is a small remnant of ferruginous, probably transported material, originally a valley fill, which has undergone minor topographic inversion since deposition and induration.

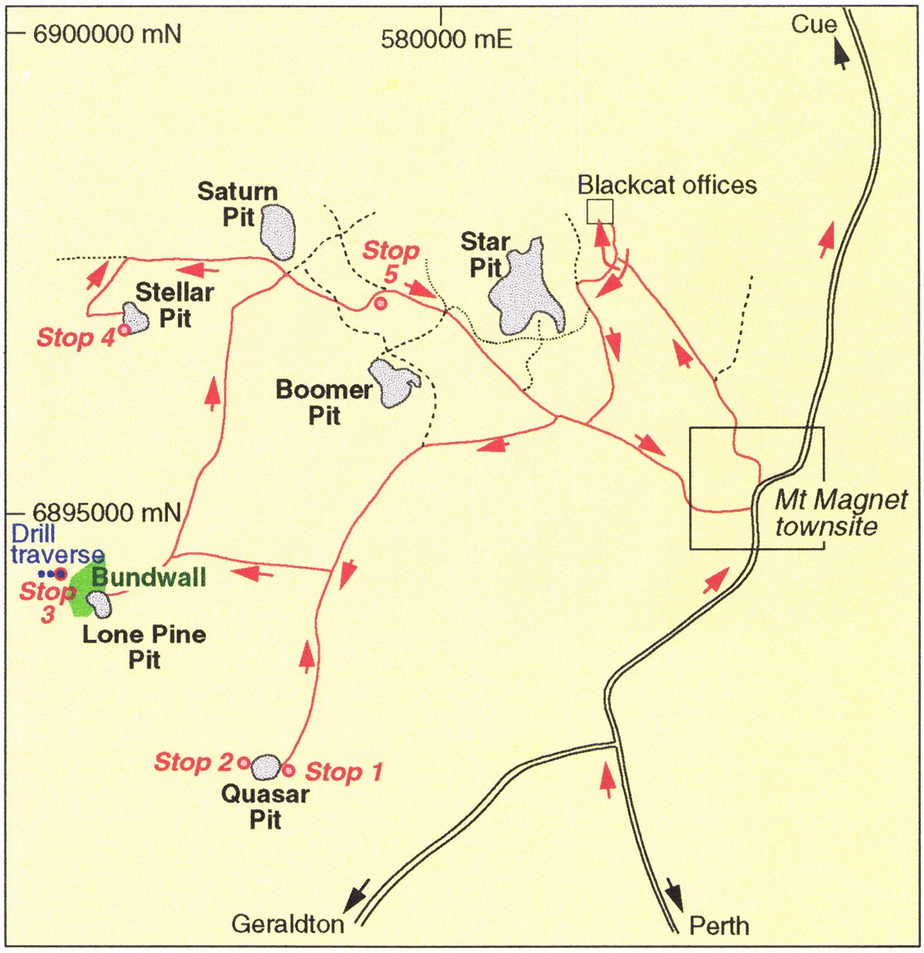


Figure A - Tour map - Mt. Magnet.

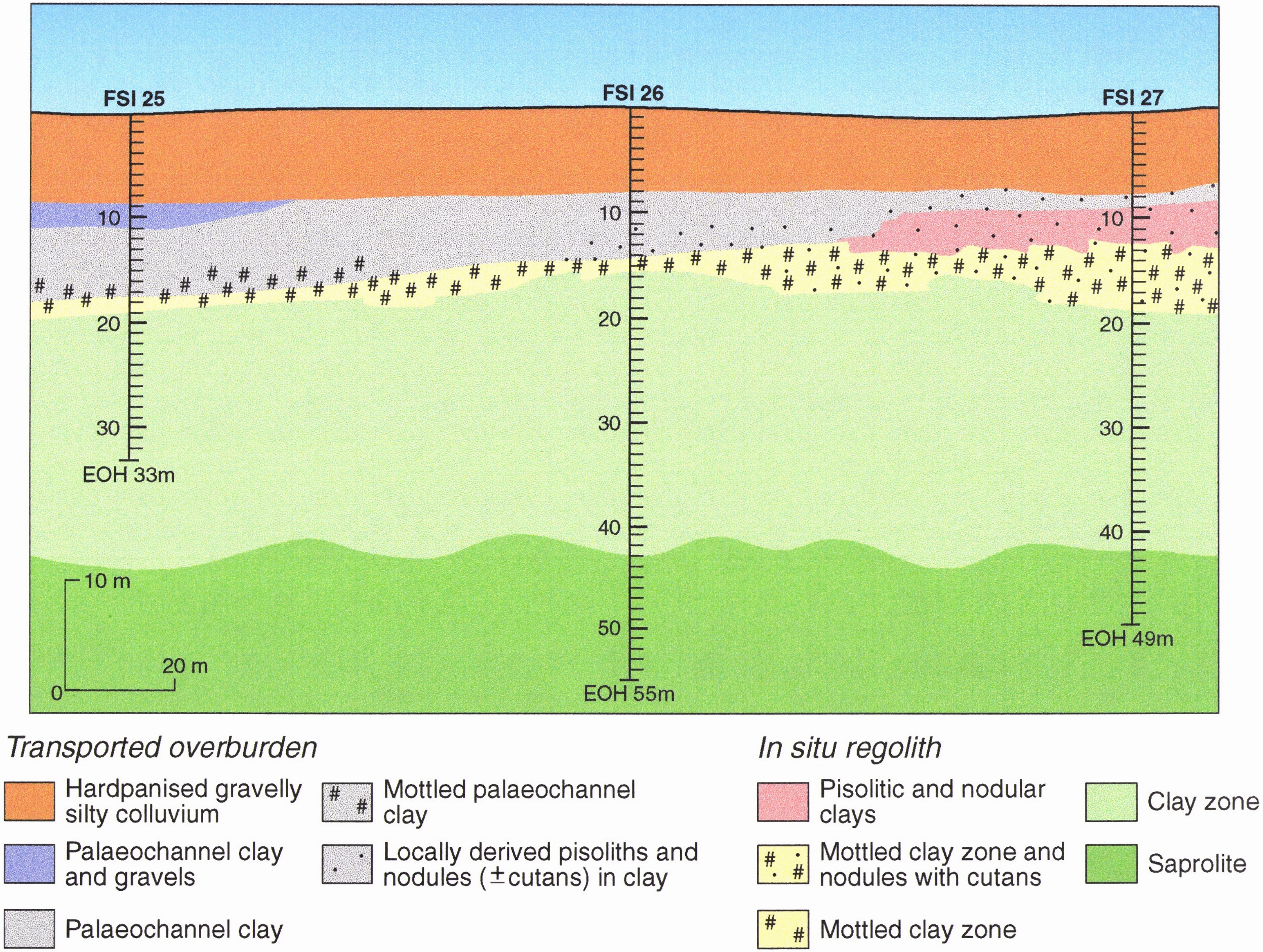


Figure B - Drill section - Lone Pine

MT. MAGNET

I.D.M. Robertson, J.D. King, R.R. Anand and C.R.M. Butt

1. INTRODUCTION

1.1 Location, access, climate and vegetation

The Stellar and Quasar Au deposits lie some 5 km to the west of Mt Magnet, within the Boogardie Synform (Figure 1). The Mount Magnet district has a semi-arid to arid climate, with a recorded average annual rainfall of 234 mm. The vegetation is dominated by mulga and by various types of poverty bush and turpentine, with isolated kurrajong trees on depositional surfaces.

1.2 Exploration history

Although outcrop in the Synform core is sparse, potential host lithologies (ultramafic schists and intrusive dacitic quartz porphyry) are exposed in Jones Creek. Mineralised structures, the Hill 50 and Hesperus Dawn faults, extend through the Synform and intersect these lithologies (Figure 1).

Systematic RAB drilling by Renison Goldfields Consolidated Ltd, through the transported cover, to recognisable bedrock, was used to target buried laterites and mottled zones. This drilling discovered mineralisation at Stellar, Milky Way, Boomer and Andromeda. The Quasar mineralisation was discovered by bedrock reconnaissance drilling by Metana Minerals. The Stellar and Quasar Au deposits represent new discoveries and were the first 'blind' orebodies to be mined by Hill 50 Gold Mines within the Synform.

1.3 Exploration problems

There are three significant exploration problems within the core of the Boogardie Synform:-

1. Buried remnants of complete, or nearly complete, deeply weathered lateritic profiles occur within the central area. Where present, these are excellent geochemical sample media. However, elsewhere, the buried profiles are partly stripped and the saprolite may be depleted in Au and pathfinder elements.

2. Structural complexity, and the variety and large number of mineralised settings, makes it difficult to establish geochemical thresholds and backgrounds. Subtle geochemical anomalies due to concealed mineralisation are difficult to distinguish within the generally high backgrounds in the district.

3. Most of the area is covered by locally-derived colluvium-alluvium, strewn with a polymictic lag of lateritic and lithic materials, including BIF fragments. The BIF fragments and the lateritic debris in the cover are commonly auriferous and tend to mask geochemical signatures from underlying rocks, so the total element composition of surficial sediments is probably unreliable, even at a district scale.

2. REGIONAL GEOLOGY

The Mount Magnet greenstone belt comprises ultramafic, mafic and felsic volcanics, with subordinate sediments, BIF and chert. The sequence is intruded by minor felsic and mafic rocks and is surrounded by variably deformed gneissic granitoids. The greenstone sequence is deformed into a domal structure, with a steeply plunging, synformal configuration, the Boogardie Synform (Figure 1). In the study area, the major units are :-

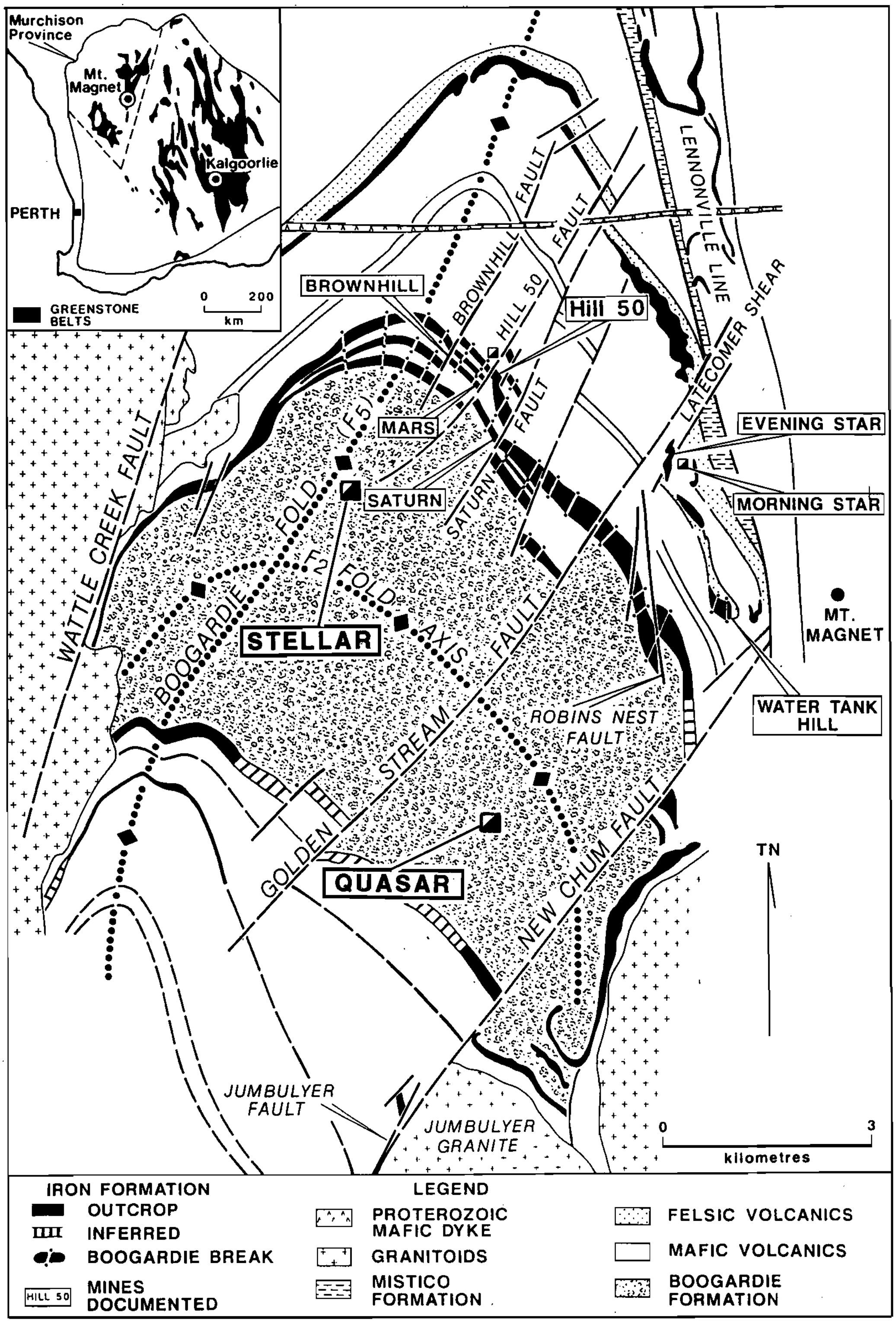


Figure 1 - Geological map of the Mt. Magnet Area (after Thompson *et al.*, 1990).

Boogardie Formation: talc-carbonate altered ultramafic flows and other Mg-rich mafic rocks. The sequence is cut by fine- to medium-grained felsic intrusives.

Sirdar Formation: BIFs and mafic flows overlain by an ultramafic flow and felsic flows and tuffs. This hosts the majority of exposed mineralisation in the Hill 50 mine area.

Cover: most of the Archaean rocks of the Boogardie Synform are obscured by colluvium-alluvium, in part underlain by palaeochannels. The thickness of the colluvial-alluvial cover is variable and generally increases away from the enclosing BIF ridges. Bedrock exposures in the interior of the Synform are restricted to the incised drainage of Jones Creek.

3. REGOLITH-LANDFORM RELATIONSHIPS

3.1 Regolith Mapping

The regolith of a 5 x 5 km area around Stellar and Quasar has been mapped at 1:25 000 (Figure 2). The regolith stratigraphy and its characteristics were determined from drill cuttings and mine exposures. There are several regolith-landform units related to deep weathering and to profile modification by erosion and deposition (Figure 2). A schematic cross section, showing regolith-landform relationships for the mapped area, is shown in Figure 3. The mapped area is dominated by erosional and depositional regimes.

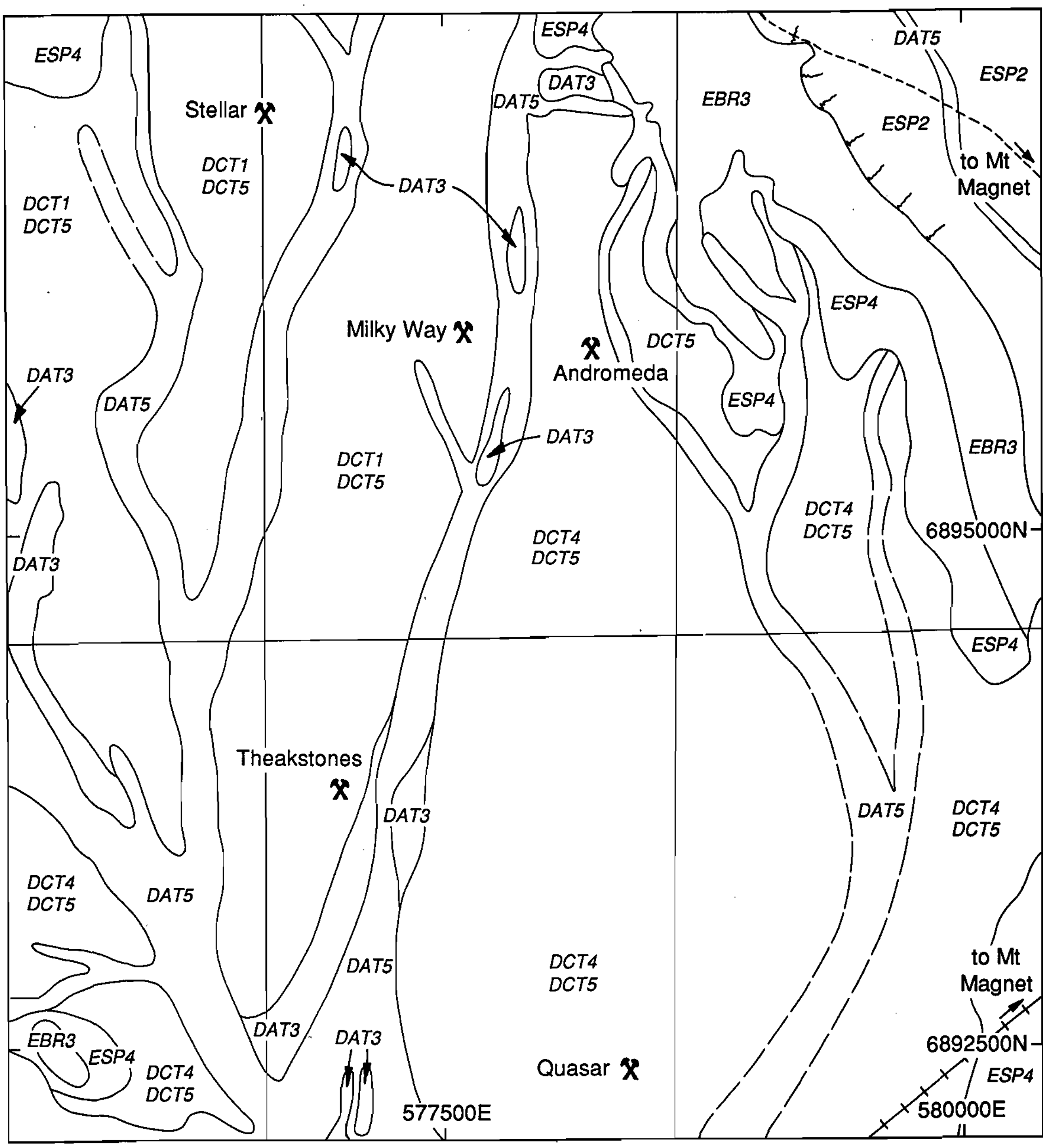
3.2 Erosional regimes

Erosional regimes (about 25% of the mapped area) are largely restricted to outcropping BIFs. Pediments to the BIF ridges form gentle slopes with acidic, red earths, and are blanketed by a coarse lag of BIF fragments, vein quartz, lateritic nodules, pisoliths and ferruginous saprolite. Some BIF outcrops within these pediments. This erosional regime may be subdivided into three mappable units.

Unit EBR3 forms the dominant relief of the Boogardie Synform and consists of outcropping, semi-continuous, BIF ridges. In places, for example north of Stellar, the BIFs are deeply weathered and lateritised.

Unit ESP4 is developed on truncated, weathered bedrock and forms concave, upland slopes, flanking the BIF ridges. These are covered by a thin, red, largely residual soil, mantled by a coarse lag of BIF and vein quartz. Bedrock commonly outcrops near the ridge top but becomes progressively buried down slope, giving way to a depositional regime. Regolith materials are commonly saprolitic and are ferruginous in some places.

Unit ESP2 occurs in the north-east of the study area and forms breakaways on the northern margin of the enclosing BIF ridges. Ferruginous saprolite is exposed on the upper surface and clay-rich or ferruginous saprolite on the lower. Both surfaces are mantled by fragments of BIF, derived from up slope, and a thin, residual soil. Scattered patches of lateritic duricrust are preserved on the upper breakaway surface. Tubular structures, up to one metre wide, are widely distributed across the erosional surface. These are interpreted as having been voids that have been infilled with lateritic nodules and pisoliths, and possibly represent relic tree root structures. The lower surface becomes progressively buried by recent sediments, up to one metre thick, but is still considered to be erosional.



Erosional regimes

ESP2	Ferruginous saprolite, pockets of laterite, shallow soils, breakaway escarpments
ESP4	Saprolite, shallow soils, pediments
EBR3	Banded iron strike ridges

Depositional regimes

DCT1	Lateritic residuum present beneath colluvial sediments, polymictic lag
DCT4	Clay zone present beneath colluvial sediments, polymictic lag
DCT5	Saprolite present beneath colluvial sediments, polymictic lag
DAT3	Ferruginous saprolite present beneath shallow (<2 m) alluvial sediments
DAT5	Saprolite present beneath shallow (<2 m) alluvial sediments

0 100 m

Figure 2 - Regolith map of part of the Boogardie Synform.

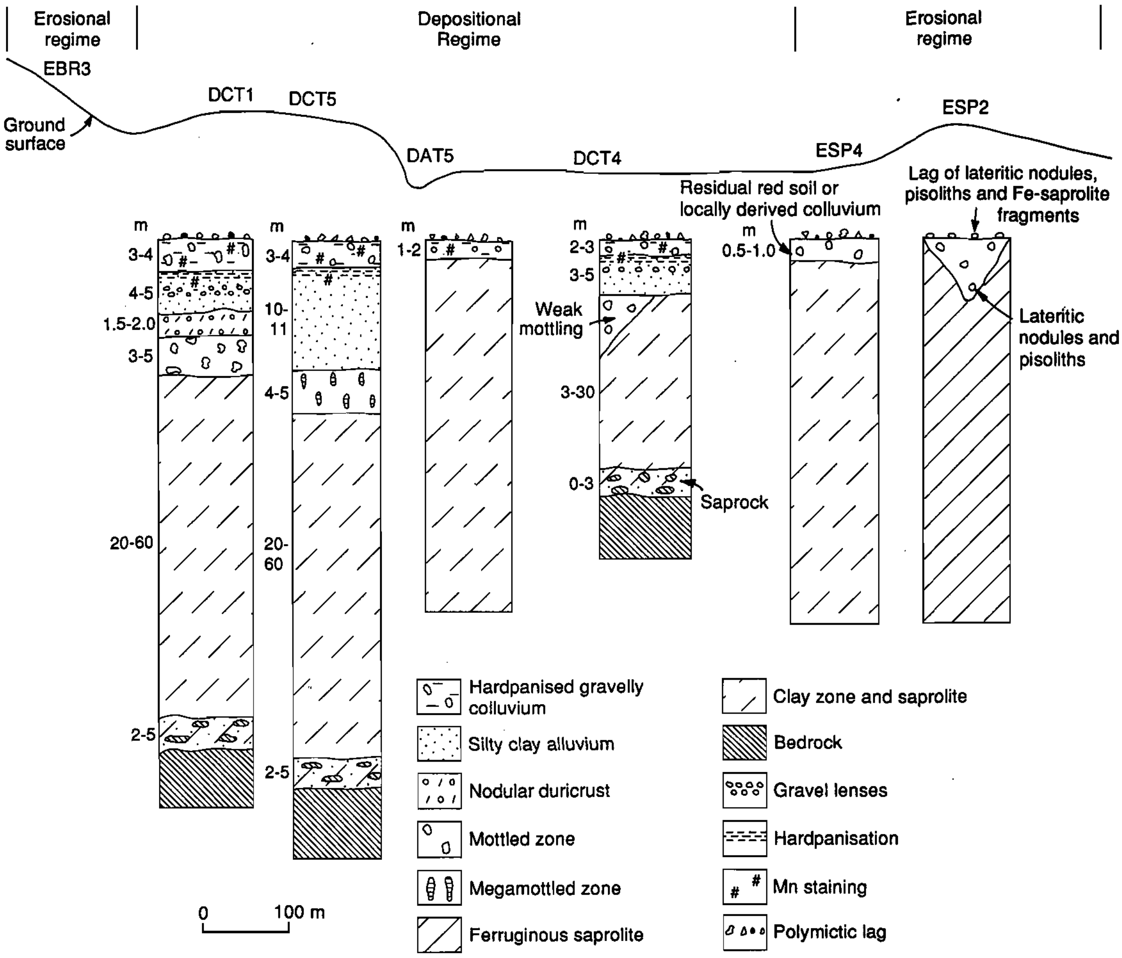


Figure 3 - Generalised regolith-landform relationships for the mapped area (see Figure 2).

3.3 Depositional regimes

Depositional regimes cover the lower slopes and the colluvial-alluvial plains and form widespread regolith-landform units that occupy about 75% of the mapped area (Figure 2). Their surfaces are strewn with polymictic lag. An extensive colluvial-alluvial blanket covers both complete and variably truncated lateritic profiles. The provenances of these sediments range from local to distal and thicknesses reach 20 m. Concealed beneath this colluvial-alluvial cover are earlier depositional regimes, consisting of mottled, clay-rich and lateritic materials, confined to palaeochannels. There are four mappable units within these depositional regimes (Figure 2).

Unit DAT5 is represented by active, modern drainage within the synform, dominated by the south-flowing Jones Creek. The drainage either rests on a hardpanised substrate of red-brown, silty clay, with interbedded gravel lenses or, as in Jones Creek, it has incised the hardpanised cover, exposing the underlying rocks.

Unit DAT3 forms overbank deposits along major drainages. The unit is apparent on the aerial photographs and has formed where high-volume, high-velocity, water flow has breached confining levees and stripped the banks of vegetation and lag. The unit is dominated by up to two metres of hardpanised cover, as described for Unit DAT5, resting on ferruginous saprolite or a saprolitic substrate.

Unit DCT4, and Unit DCT5, best exposed in the Quasar Pit, forms the dominant regolith type within the study area. It occurs as outwash plains down slope of units ESP4 and EBR3, mainly east of Jones Creek. It consists of a mixed colluvial-alluvial cover, generally less than eight metres thick, comprising polymictic gravels of lateritic nodules, pisoliths, lithic fragments and gravel lenses in a red-brown, clay-silt matrix. The upper five metres are commonly hardpanised to a variable depth. The sediments overlie a truncated, residual weathered profile, generally saprolite on ultramafic rocks and clay-saprolite on felsic rocks. The upper, ferruginous, lateritic zone is absent, with only scattered patches of weakly ferruginous saprolite remaining. Near Quasar, infilled palaeochannels increase the total thickness of transported cover to 14 m; thin dolomitic horizons have developed in these palaeochannels.

Unit DCT1 and Unit DCT5 occur as outwash plains, mainly west of Jones Creek. The surface horizons are very similar to Unit DCT4 but the transported cover is thicker and more complex. A hardpan has developed in the upper 5 m of the profile and overlies either a full or partly truncated lateritic profile. The sequence has three main units, a basal, mottled, puggy clay, overlain by red-brown clays with lenses of lateritic gravel, coarse gravel and an upper horizon of gravelly hardpan, 2-5 m thick. The surface is strewn with a coarse, polymictic lag of ferruginous, lithic fragments, maghemite-rich, lateritic gravels, ferruginous saprolite and vein quartz. This sequence is well exposed in the Stellar Pit.

4. QUASAR DEPOSIT

4.1 Geological and geomorphological setting

Gold mineralisation is associated with ductile shearing in talc-chlorite-sericite altered, high-Mg mafic-ultramafic rocks, at the contact with a felsic-porphyry stock. The mineralisation is poor in sulphides and quartz veining. Weakly mineralised quartz-tourmaline veining is restricted to the felsic porphyry, occurring marginal to the contact.

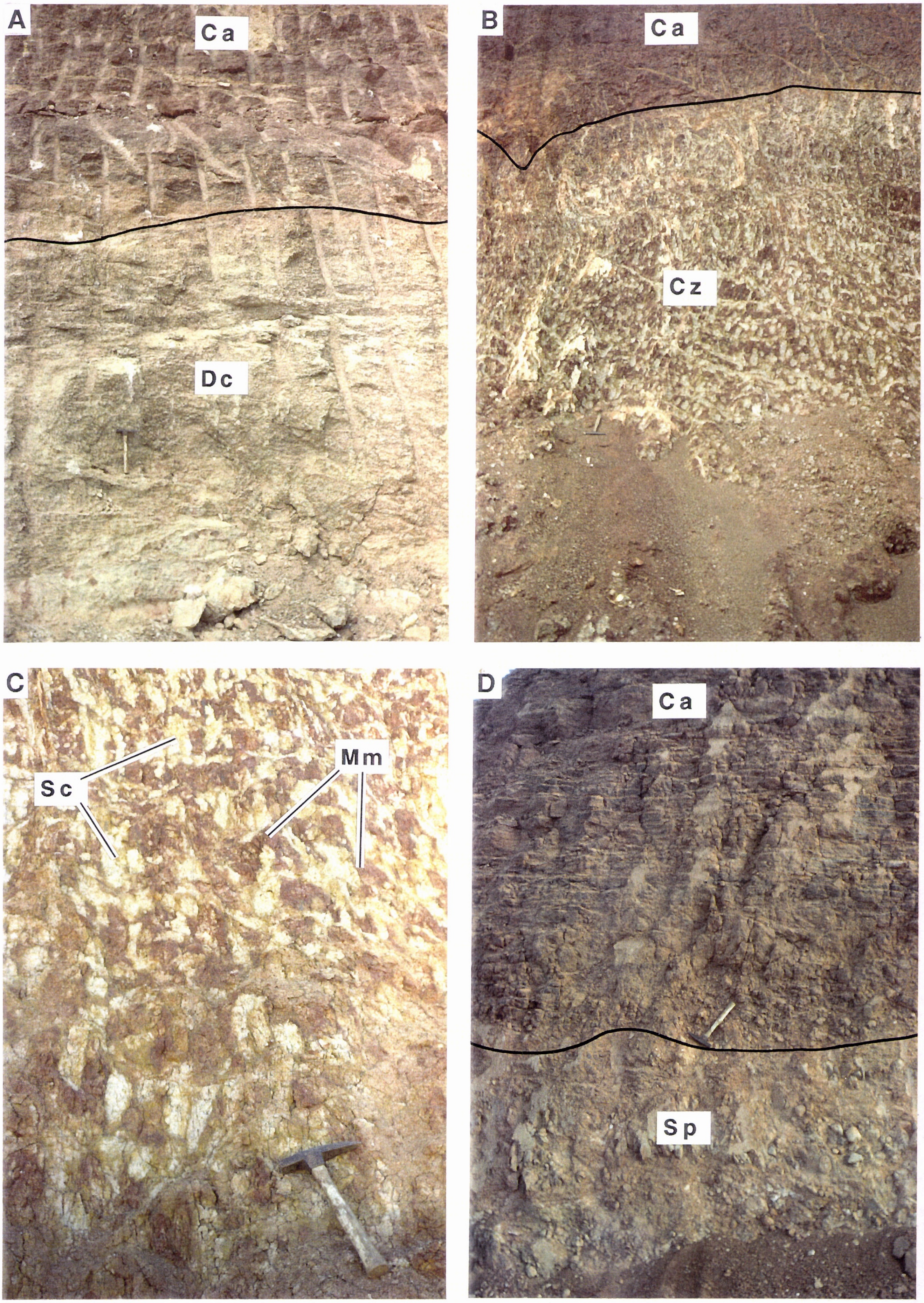


Figure 4 - Vertical profiles showing regolith stratigraphy of depositional regimes at Stellar and Quasar.

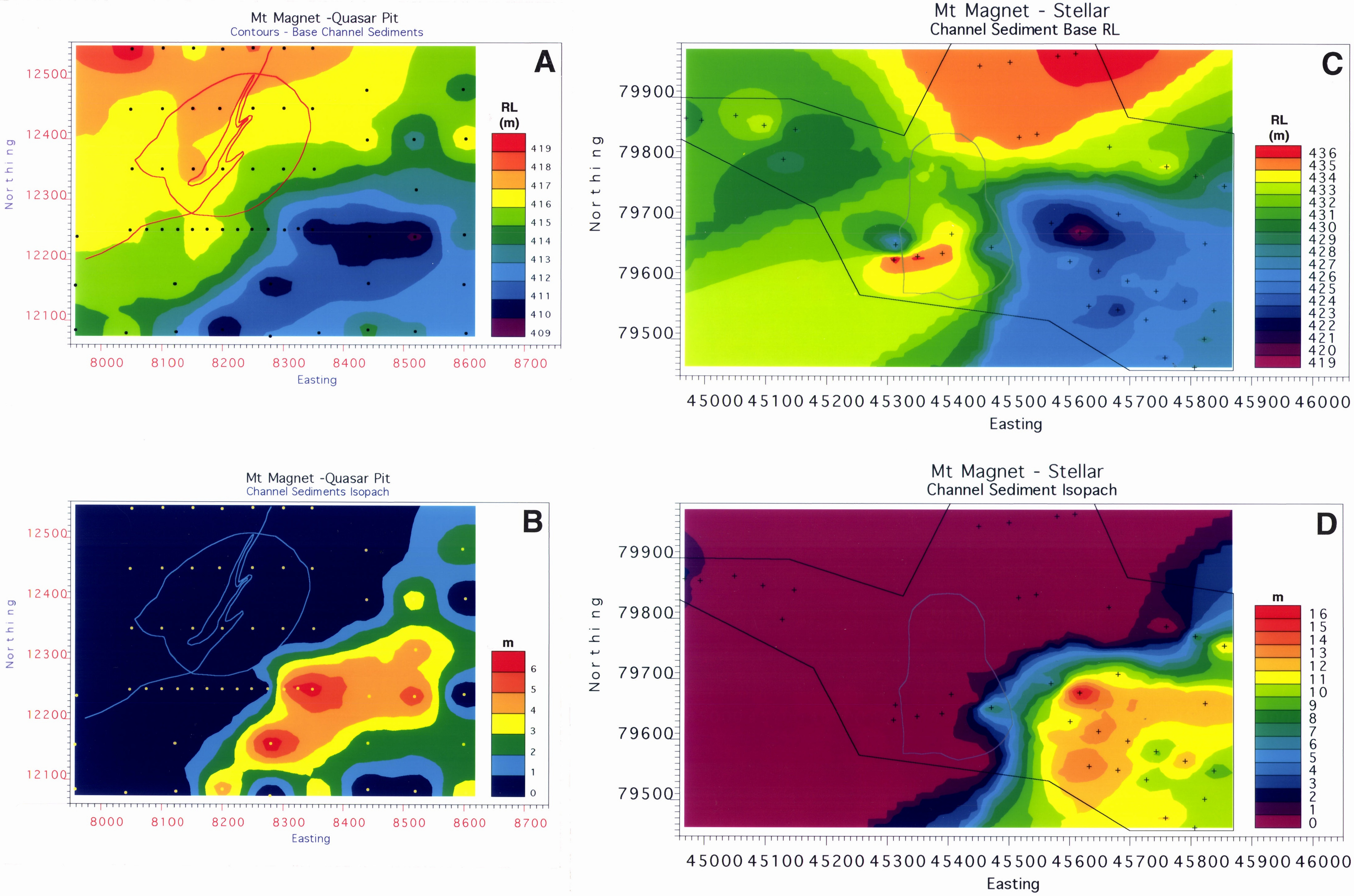


Figure 5 - Contours of the top of the residual profile and isopach maps of the palaeochannel sediments around the Quasar and Stellar pits.

The bedrock is overlain by about five metres of hardpanised colluvium-alluvium. A palaeochannel, predating the colluvial-alluvial sediments, lies to the east of the pit and consists of white kaolinitic clays with layers of lateritic nodules and pisoliths. The colluvial-alluvial and palaeochannel cover overlies weakly mottled, clay-rich saprolite which is silicified over some of the felsic-porphyry. The base of oxidation on the mafic-ultramafic rocks is around 35 m; on the felsic rocks the depth of weathering is variable, from a few metres to >40 m near the sheared contact.

Reconstruction of the original surface from drill collar information shows that the ground was nearly flat to the west with a very low, arcuate, approximately north-trending ridge in the centre and east. This surface was strewn with polymictic lag. The distribution of drilling was sufficient to give a relatively accurate picture of the palaeotopography.

4.2 Basement

The bedrock is overlain by about five metres of hardpanised colluvium-alluvium (Figure 4D) and consists of weakly mottled, clay-rich ultramafic saprolite, kaolinitic saprolite and silicified felsic-porphyry. Some weak mottling occurs in the clay-rich, felsic saprolite, where the base of oxidation deepens towards the structural contact. The base of oxidation on the ultramafic rocks is around 35 m; on the felsic rocks, the depth of weathering is variable, from a few metres to >40 m near the shear zone.

4.3 Palaeochannel sediment

The palaeochannel sediments are restricted to the south-west of the pit and were deposited in an arcuate channel (Figure 5A) eroded into the basement; the flow direction was possibly towards the south-west. As at Stellar (section 5), the channel has a steep gradient on its northern margin and a lesser gradient to the south. The palaeochannel isopachs (Figure 5B) indicate a general thickness of three metres with local maxima of six metres, hence it is shallower and smaller than the palaeochannel at Stellar. The sediments consist of white, kaolinitic clays with distinct layers of lateritic gravels (with cutans). There are no exposures of palaeochannel sediments in the pit.

4.4 Colluvium-alluvium

The basement, on which the hardpanised colluvium-alluvium was deposited, slopes downwards to the south, suggesting that either the depression in which the palaeochannel sediments were deposited was incompletely filled or this area was partly eroded after deposition of these sediments. The gradients, prior to deposition of the colluvium, were gentle (1:80) and the thickness of the colluvium is quite consistent (4-8 m), in contrast with Stellar. Mechanical dispersion of any palaeosol developed on the residual regolith, just prior to deposition of the colluvium, would generally have been to the south.

The colluvium-alluvium is composed largely of lateritic nodules and pisoliths, with and without cutans, and fragments of quartz and ferruginous saprolite, in a silty-clay matrix. Fragments of jaspilite, chert and BIF generally occur in the upper two metres of the profile, with lateritic debris dominant at lower levels. The upper part of this transported overburden consists of poorly-sorted gravels with coarse, angular fragments of quartz and lithic material, typical of colluvium. Towards its base, the transported cover becomes matrix dominated, with coarse, poorly sorted, gravelly lenses, consisting of rounded quartz pebbles and lateritic debris, indicating an alluvial environment. Manganese oxide staining is strongly associated with matrix-dominated horizons.

4.5 Geochemistry

Several media were investigated from 57 drill holes on a regular orientation grid. The top metre of the residual profile was compared to a one or two metre (combined) sample representing the interface between residual profile and colluvium. The colluvium and the ferruginous lag developed on the colluvium were also assessed.

4.5.1 Top of saprolite and the saprolite-colluvium interface

The weathered Archaean at Quasar was eroded, prior to deposition of colluvium-alluvium, with little preservation of sub-surface laterite, so anomalies in this stripped environment will present small targets. The only dispersion halos likely to be present will be those that may have been preserved or those developed since burial:-

1. 'Lateritic' halos in remnants of ferruginous saprolite, mottled zone and lateritic duricrust or gravels at the top of the weathered basement. Such material could be mechanically dispersed in the base of the colluvium-alluvium.

2. Halos formed in soils developed on the partly stripped profile, now possibly represented by or incorporated in, the base of the colluvium-alluvium.

3. Halos formed during or after deposition of the colluvium-alluvium, chemically dispersed into the sediments or along the unconformity. Such dispersion could still be active.

Accordingly, the most promising sample media were considered to be the upper metre of the residual regolith and the interface sample that includes the unconformity between weathered bedrock and the colluvium-alluvium. The latter would include contributions from each dispersion process. No drill holes intersected the mineralisation at the levels examined, which is a very typical exploration situation. Reliance must then be placed on intersecting very minor mineralisation and dispersion halos.

Gold, in the top of the residual profile (Figure 6A), gives a single point anomaly of 1460 ppb immediately south of the pit on the sheared contact. Adjacent drill holes have background abundances. There are no significant anomalies within the pit. In contrast, in the interface sample (Figure 6B), there is a much broader, but lower order, anomaly of ~100 ppb, locally reaching 250 ppb, which occupies much of the southern part of the Quasar pit.

Bismuth shows a localised concentration of >2.4 ppm to the east-southeast of the pit at the top of the residual profile (Figure 6C). Similar but wider anomalies are present in the interface samples from the western part of the pit (Figure 6D).

The *arsenic* and *antimony* contents of the primary mineralisation are very low and this is reflected by the absence of significant anomalies in either sample medium. However, much higher concentrations of As (>120 ppm) and Sb (>17 ppm) occur to the east, suggesting a source east of the study area. Arsenic and Sb are not effective in detecting Quasar-style mineralisation

Lead shows a single point anomaly of 200 ppm at the top of the residual profile at the western side of the pit, coinciding with the Bi anomaly (Figure 6E, compare Figure 6C). Again, the interface sampling has broadened the target to an anomaly of 35-40 ppm in a background of 10 ppm, which overlies most of the northern part of the pit (Figure 6F).

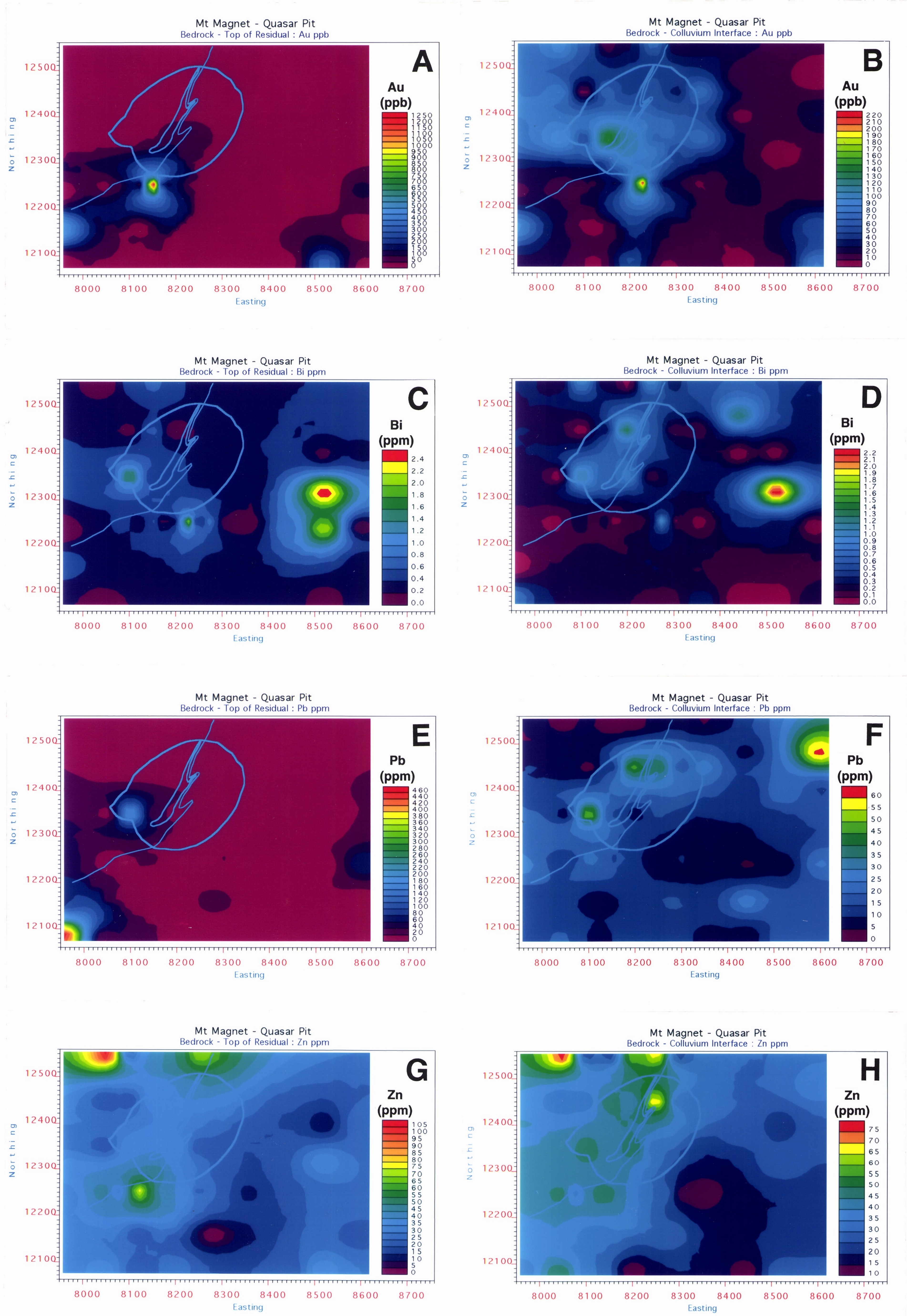


Figure 6 - Geochemical maps of the top metre of the residual profile and the bedrock-colluvium interface around the Quasar pit.

Mt. Magnet

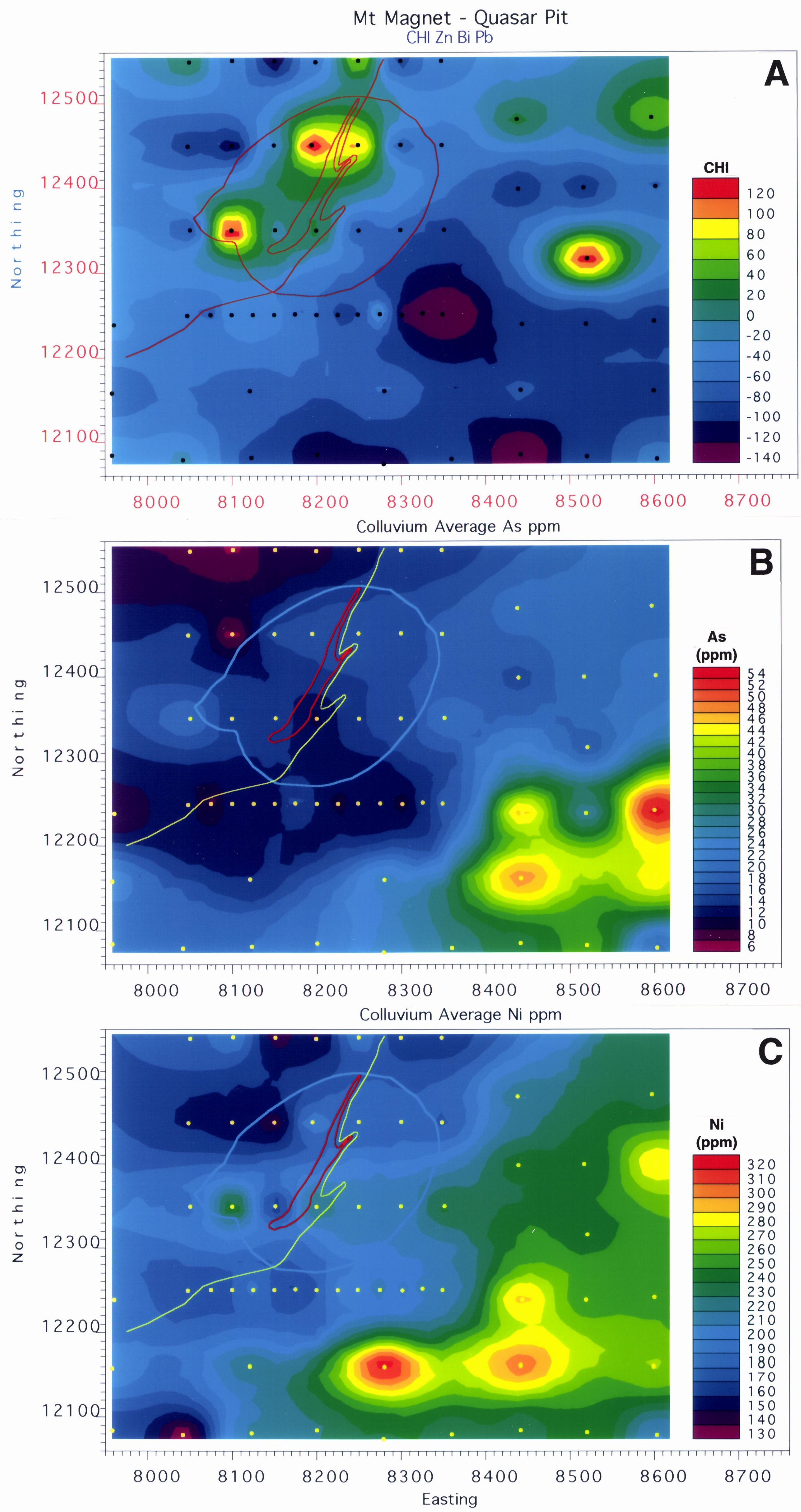


Figure 7 - Geochemical maps of a linear combination of Bi, Pb and Zn from the interface samples at Quasar (A), averaged data for colluvium intersections for As (B) and Ni (C).

Some elements are related to *lithology*. At the top of the residual profile, *chromium* shows increased abundances in the area of the pit and in the extreme north-west. It also shows a generally increased abundance in the north and north east of the area, corresponding with the subcrop of mafic-ultramafic rocks, with a decreased abundance in the area generally occupied by felsic rocks. Very similar distributions are shown by *nickel, copper, vanadium and zinc.* The interface samples have lower abundances of these elements but the dispersion patterns are more homogeneous and indicate the local lithological trend well.
Uranium and yttrium, particularly in the interface samples, depict a zone of higher abundances that approximately marks the sheared contact between the felsic and the mafic-ultramafic rocks. The abundances are very low and probably have little practical value.

A linear combination or *multi-element index*, of the form given below, of Bi, Pb and Zn interface sample data is shown in Figure 7A (compare Figures 6C-H).

$$CHI = 100(Bi-1) + 2(Pb-10) + 2.2(Zn-30)$$

A combination of these pathfinder elements improved the target size and accurately defined the mineralisation in the pit area. Apart from highlighting the multi-element nature of the geochemical halo, this additive technique allows neighbouring anomalies in different elements to reinforce one another, which is not achieved by processing single element data.

4.5.2 Palaeochannel sediments

The palaeochannel sediments would be expected to have a detrital geochemistry related to their source rocks. However, adsorptive properties of the abundant clays and Fe oxides in the sediments might retain post-depositional hydromorphic anomalies. Past groundwater flow directions (presumably dominantly along the palaeochannel) are critical to their interpretation.

The palaeochannel is restricted to the south-east of the study area; it is areally small and the data set comprises only 14 intersections incorporating 55 samples. Arsenic is strongly correlated with Fe, Sb and Cr, indicating probable adsorption of As and Sb by Fe-oxides, and suggests that the palaeochannel sediments, and particularly any authigenic ferruginous materials within them, may be useful regional prospecting media. The small area, small number of intersections and the very short course of the palaeochannel through the study area prevents anything but these preliminary observations.

4.5.3 Colluvium-alluvium and lag

The colluvial blanket, derived from the auriferous Boogardie Synform, has imported detritus with a high Au background (mean ~50 ppb). The distribution of Au in this material will depend upon the provenance of the detritus which may vary during deposition, the form of Au and any chemical dispersion from underlying mineralisation. Superimposed on this will be the practical effects and limitations of the sampling method, in this case aircore drilling.

The vertical relationships and consistency in Au content between different units of the colluvium-alluvium were investigated by contouring the data and comparing the distributions in the 1-2 m and 3-4 m intervals. Although there are some locally high Au abundances (150 ppb) in both intervals, there is no spatial correspondence in the Au distributions between these almost adjacent layers, with the basement and the overlying lag, indicating false or 'rootless' anomalies. For many elements (Au, Ba, Cu, Pb, Th, V), the inter-layer correlations were statistically less than the limit of 95% confidence and are most likely to be random. Those that exceeded this limit are either related to lithology of provenance (Co, Cr, Fe, Ga, Nb, Ni) or to hardpanisation (Mn). The only pathfinder elements for which there was any significant interlayer correlation within the colluvium-alluvium were As and Sb (Figure 7B and C), suggesting derivation from a dominantly mafic-ultramafic source in the south-east.

5. STELLAR DEPOSIT

5.1 Geological and geomorphological setting

Gold mineralisation is associated with quartz-tourmaline veining in a brittle, dilational zone and is hosted by dacitic quartz porphyry, near its structural contact with an ultramafic rock. The mineralisation is sulphide-poor. The felsic and mafic-ultramafic Archaean rocks, exposed in the pit, have been weathered to saprolites and, in part, to lateritic duricrust. The residual profile is partly truncated by a palaeochannel, filled with mottled, puggy clays and is overlain by colluvium-alluvium.

Prior to mining, the Stellar site had a lag-strewn surface, on colluvium-alluvium that sloped gently upwards to the north. The thicknesses and basal surfaces of each major regolith unit were contoured (e.g., Figures 5C, D). To the south-west, the ground has since been obscured by mine dumps; logging of drill cuttings in this vicinity was not possible. The stratigraphy of the Stellar Pit and details of the palaeochannel stratigraphy and its characteristics are shown in Figures 8 and 9.

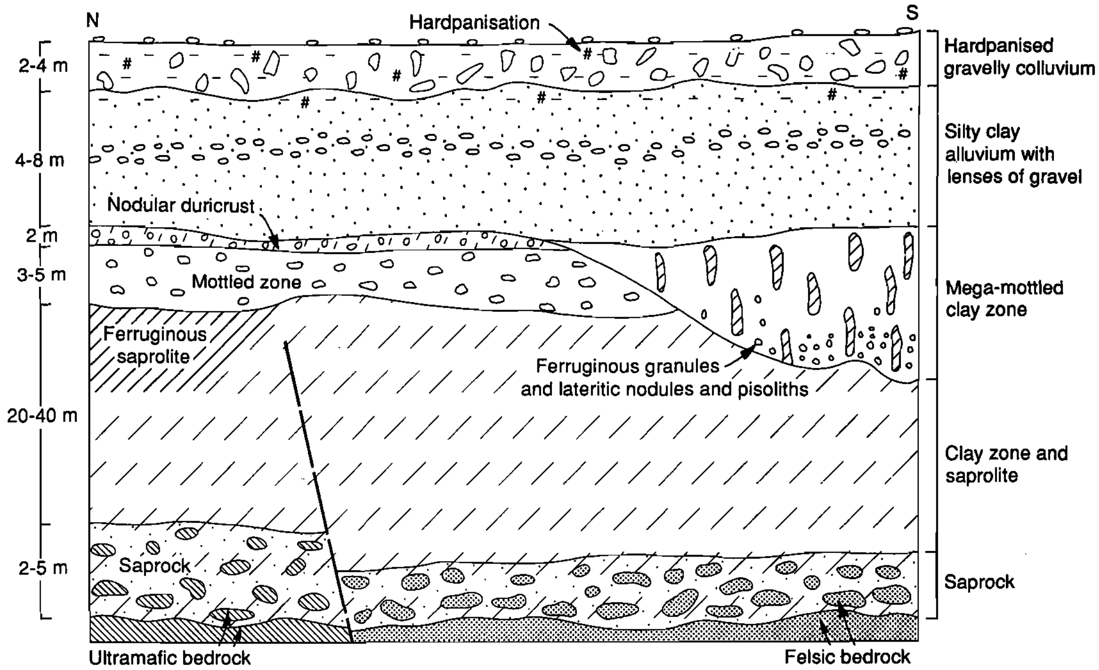


Figure 8 - Regolith stratigraphy, Stellar Pit.

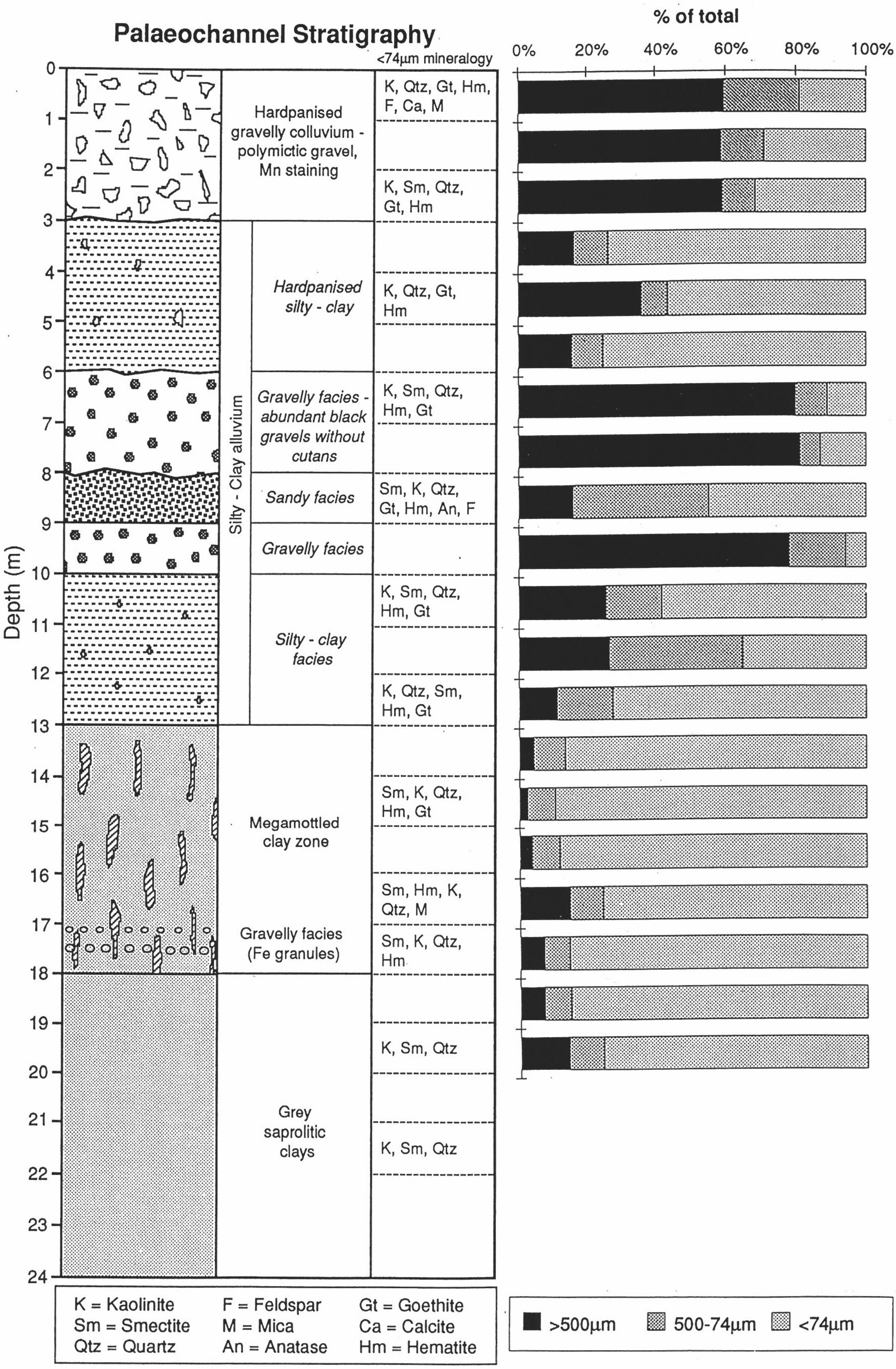


Figure 9 - Palaeochannel stratigraphy, mineralogy, distribution of size fractions and characteristics of regolith units, Stellar Pit.

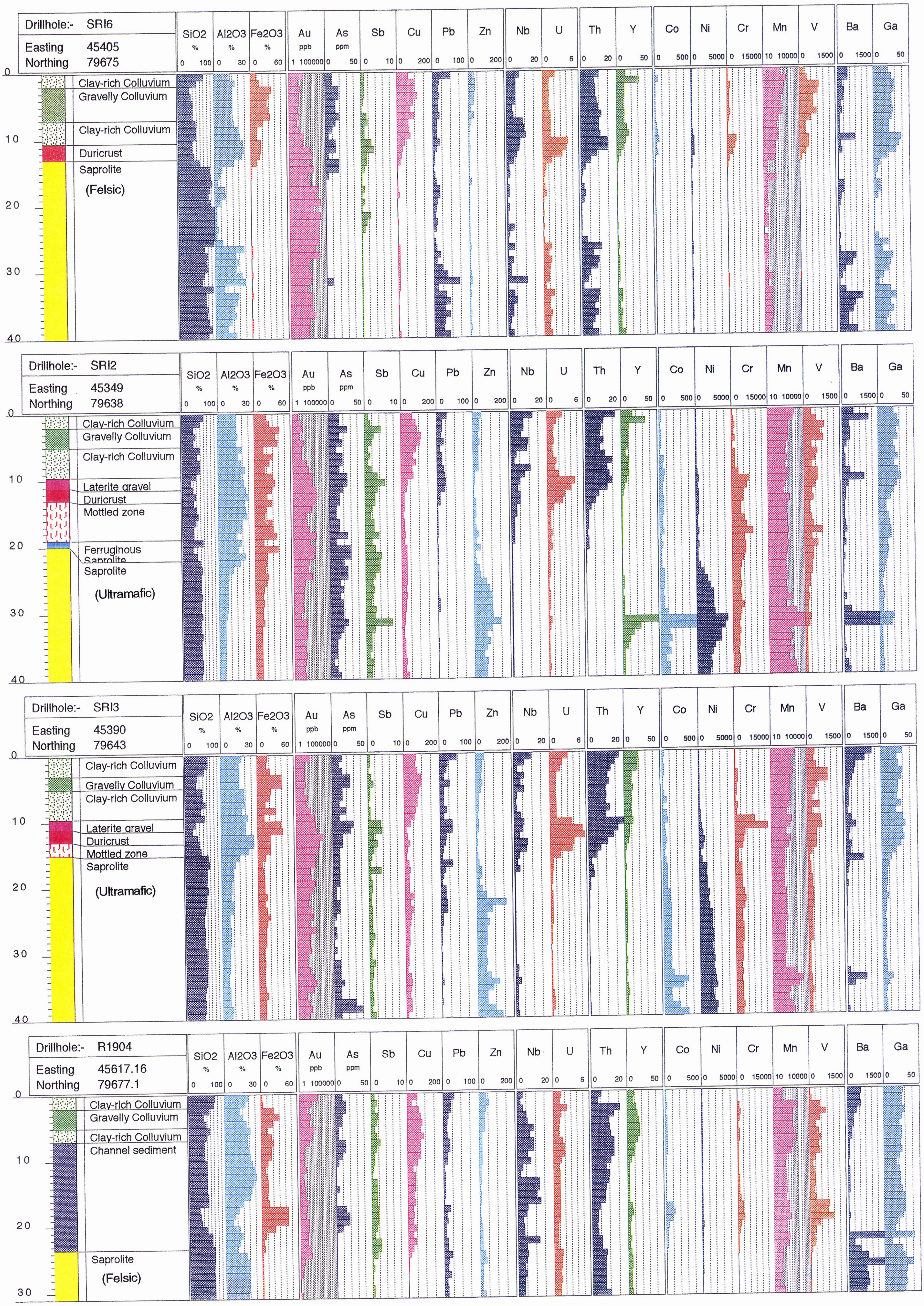


Figure 10 - Vertical distribution of elements in felsic and ultramafic profiles at Stellar Pit.

TABLE 1
CHEMICAL COMPOSITION AND MINERALOGY OF FERRUGINOUS MATERIALS -STELLAR

Sample	Type	Bedrock	SiO2 %	Al2O3 %	Fe2O3 %	CaO %	MgO %	K2O %	TiO2 %	Zr ppm	Cr ppm	Ni ppm	Mn ppm	As ppm	Sb ppm	Au ppb	Mineralogy in order of abundance
09-2000	ND	Ultramafic	20.06	16.15	46.34	0.06	0.14	0.03	0.35	80	11606	428	0.031	23	4.9	1300	Gt, K, Hm, Qtz, Sm
09-2001	ND	Ultramafic	17.20	10.38	56.17	0.08	0.24	0.02	0.26	73	8446	326	0.015	194	5.0	870	Gt, K, Qtz, Sm
09-2002	ND	Ultramafic	24.20	14.86	45.48	0.08	0.21	0.04	0.45	120	7940	342	0.018	127	4.2	1490	Gt, K, Qtz, Sm
09-2018	ND	Ultramafic	10.30	20.82	55.71	0.05	0.14	0.02	0.44	140	19018	643	0.024	31	5.8	349	Hm, Gt, K, Mgh, Sm, Qtz
09-2004	ND	Felsic	16.09	14.66	54.14	0.11	0.42	0.05	0.44	140	16391	327	0.021	26	6.3	1510	Hm, Mgh, Gt, K, Qtz, Sm
09-2005	ND	Felsic	25.21	18.29	41.92	0.08	0.23	0.15	0.35	243	7445	186	0.009	26	5.4	403	Gt, K, Qtz, Sm, Hm
09-2019	ND	Felsic	32.31	25.51	25.86	0.10	0.28	0.03	0.64	159	5767	666	0.005	14	2.8	4760	Gt, K, Qtz, Sm
09-2006	FeG	Palaeochannel	12.30	14.99	60.36	0.09	0.29	0.03	0.47	164	19832	405	0.058	42	7.5	25	Hm, Mgh, Gt, K, Qtz
09-2007	FeG	Palaeochannel	10.63	10.53	66.12	0.13	0.31	0.01	0.45	161	18465	301	0.077	46	9.1	<5	Hm, Mgh, Gt, K, Qtz
09-2008	FeG	Palaeochannel	11.41	10.13	65.95	0.12	0.25	0.01	0.44	158	18909	316	0.073	48	10.0	<5	Hm, Mgh, Gt, K, Qtz
09-2009	FeG	Palaeochannel	11.40	12.84	62.08	0.13	0.21	0.02	0.46	157	18792	347	0.050	43	8.2	12	Hm, Mgh, Gt, K, Qtz
09-2010	FeG	Palaeochannel	11.47	12.95	62.08	0.13	0.23	0.02	0.48	154	18822	350	0.051	40	7.6	<5	Hm, Mgh, Gt, K, Qtz
09-2011	FeG	Palaeochannel	12.09	12.47	62.88	0.12	0.20	0.02	0.45	145	17737	317	0.050	52	10.1	16	Hm, Mgh, Gt, K, Qtz
09-2012	FeG	Palaeochannel	13.58	7.38	65.91	0.10	0.30	0.01	1.00	101	4907	277	0.018	23	3.6	<5	Hm, Mgh, Gt, K, Qtz
09-2013	FeG	Palaeochannel	10.44	5.73	73.19	0.12	0.28	0.01	0.96	94	7219	201	0.029	23	4.8	26	Hm, Mgh, Gt, K, Qtz

Analyses by XRF and INAA

ND = Nodular Duricrust
FeG = Ferruginous Granules (2-4 mm)
Gt = Goethite
Hm = Hematite
Mgh = Maghemite
K = Kaolinite
Sm = Smectite
Qtz = Quartz

The regolith consists of a cover of colluvial-alluvial and palaeochannel sediments, thickening from 10-22 m from west to east, unconformably overlying Archaean bedrock weathered to 60 m. The following units are recognised:-

1. Hardpan, 0-3 m thick, developed in coarse gravel;

2. Red-brown, silty clays, with through-bedded lenses of coarse gravel, and containing rounded quartz pebbles (to 5 mm diameter) with low sphericity;

3. Laterally persistent, mega-mottled, puggy, smectitic-kaolinitic clays of the palaeochannel;

4. Residual, lateritically weathered Archaean bedrock.

The lateritic weathering profile appears to be essentially complete but the upper, ferruginous horizon transgresses the unconformity between bedrock and palaeochannel. There is a nodular, vermiform laterite over ultramafic rocks whereas the felsic rocks have an indurated mottled clay with abundant lateritic nodules.

5.2 Residual regolith

5.2.1 Distribution

A complete to partly truncated lateritic profile is buried beneath the colluvial and palaeochannel sediments. The base of oxidation is variable but tends to be very deep (generally >60 metres). There are two distinct relationships:-

1. Colluvium-alluvium overlies the mostly residual nodular duricrust (Figures 8, 4A). These duricrusts are sporadically developed in the pit, to the north-east and to the north-west. A mottled zone underlies the nodular duricrust and is transitional between saprolite and laterite. A zone of ferruginous saprolite is preferentially developed on ultramafic rocks.

2. The colluvium-alluvium is separated from felsic saprolite by intercalated palaeochannel sediment in the south-east of the pit and extends further to the south-east (Figures 5C, D).

Quartz-tourmaline veins in the basement have weathered *in situ* to coarse, rounded cobbles that trace the original projection of the veins well into the laterite horizon. However, similar cobbles are widely dispersed in the upper parts of this horizon, suggesting minor lateral transport, possibly by mass flow. The 'boulder bed' that hosted the supergene mineralisation, first mined at Stellar, may have developed by such mass flow, rather than representing a high energy fluvial deposit. However this material had been mined prior to the commencement of the research.

5.2.2 Stratigraphy and composition

In pit exposures, the laterite forms a semi-continuous horizon from 1.5-2.0 m thick. It merges downwards with a mottled zone, clay zone and saprolite which, in turn, passes into felsic or ultramafic bedrock.

The laterite is nodular to pisolitic and is either weakly-indurated or more strongly cemented as a nodular duricrust. It consists of yellowish brown to reddish brown, goethite-rich nodules, set in a pale to yellowish brown, sandy clay matrix. The nodular duricrust is dominated by goethite and kaolinite, with variable amounts of quartz, hematite, smectite and maghemite. The nodules (5-10 mm) are generally subrounded to irregular and are separated from the porous, kaolinite- and smectite-rich matrix by yellowish-brown cutans up to 0.5 mm thick. Between the nodules, a network of pale kaolinite and quartz patches occur. These have resulted from removal of Fe oxides from the matrix. Irregular to ellipsoidal voids also occur in the matrix, some of which have an earthy infill of kaolinite and quartz. There are no systematic differences in mineralogy between laterites over felsic and ultramafic rocks (Table 1).

In polished section, the matrix of the nodular duricrust and mottled zone from both felsic and ultramafic profiles have abundant, angular grains of detrital quartz. The quartz grains vary widely from 20-200 µm, with a predominance at 50-100 µm. Many quartz grains show corrosion, solution, partial replacement and impregnation by hematite and goethite. Cores and cutans of some nodules contain quartz but others are quartz free. The iron oxides are a mixture of goethite and hematite. Some cutans have abundant detrital quartz and retain the fabric of the matrix.

The geochemical data for felsic and ultramafic profiles are shown in Figure 10 and the compositions of laterite samples developed over the two lithologies are compared in Table 1. The compositions of the lower, weathered layers (upwards to mottled zone) are related to the compositions of their underlying parent rocks (Figure 10). The geochemical characteristics of the parent rock (e.g., Cr, Fe) diminishes from the bottom to the top of the profile but remains evident in the saprolite and mottled clay zones. However, in the lateritic duricrust, Al, Si, Fe, Mg, Zr, Cr and Ni contents are very similar over both felsic and ultramafic rocks (Table 1) and suggest that the laterite has developed in transported material.

There are significant concentrations of Au (350-1490 ppb) and As (14-195 ppm) in the lateritic duricrust over felsic and ultramafic rocks (Table 1). Free Au occurs in the nodules as irregular, subhedral to anhedral crystals and as delicate wire forms (20-100 µm) on the surfaces of goethite or hematite. In detail, the Au crystals show dissolution and surface pitting. The close association of Au and Fe oxides, and the morphology of the Au, indicates that the Au is dominantly secondary.

5.3 Palaeochannel sediment

5.3.1 Distribution

The sediments of the palaeochannel were well exposed in the south-east wall of the pit, prior to pit wall collapse. They are unconformable on the basement and extend to the east and south east (Figure 5D), reaching a maximum thickness around drill hole R1904 (Figure 5D) of 18 m. The residual regolith surface, onto which the palaeochannel sediments were deposited, probably had a palaeohigh to the north and a localised palaeohigh in, what is now, the south-west wall of the pit, although some modification of the landscape probably occurred prior to colluvium-alluvium deposition. The area east and south-east of the pit had been eroded into a curved channel, possibly with an entry point to the east and an exit to the south. The north and north-west wall of the channel was steep (1:10) but the south-east part sloped quite gently upward (1:75) to the south-east. The upper part of the residual regolith, along the steep flank of the channel, is formed by duricrust.

5.3.2 Stratigraphy and composition

The sediments of the palaeochannel, which are overlain unconformably by the colluvium-alluvium, consist of a grey, plastic clay and minor sandy clay (smectite and kaolinite) (Figures 4B, C). Hematitic brown and yellow mottles occur as vertically elongate aggregates up to 400 mm long (Figure 4C). Creamy, grey clays become more prominent with increasing depth and contain elongate, columnar cracking structures which expose roots, commonly sheathed in Fe-rich accumulations. This mega-mottled horizon is typical of palaeochannel environments in the Yilgarn (Anand *et al.*, 1993b; Singer, 1979; Kern and Commander, 1994).

An irregular horizon of sepiolite masses occurs towards the top of the palaeochannel. Sepiolite has been reported in both marine and lacustrine environments and is abundant in some valley calcretes in the Yilgarn (Butt *et al.,* 1977). It is generally associated with aquatic, alkaline conditions, with high activities of Si and Mg.

Two types of ferruginous materials occur towards the base of this unit; small, black granules (2-5 mm) and lateritic nodules and pisoliths (4-10 mm). The mottles contain abundant, angular to well-rounded, black, ferruginous granules, lateritic nodules and pisoliths, ferruginised lithic fragments and quartz grains. Lateritic nodules and pisoliths are also scattered throughout the clay. The cores of the granules have an earthy to silvery, metallic lustre and a few have a thin, earthy cutan; some are magnetic. The granules, nodules and pisoliths consist of hematite and maghemite, with small amounts of goethite, kaolinite and quartz. At present, their origin is unclear; it appears that, although many have been transported, some have developed ***in situ*** in the clays. Ferruginous granules in the mega-mottled clay contain mainly of Fe_2O_3 (>62%), SiO_2 (10-12%) and Al_2O_3 (5-15%) and are characterised by high concentrations of Cr, Ni and low concentrations of Au and As (Table 1). This contrasts with the lateritic duricrust, which has greater concentrations of Au.

5.4 Colluvium-alluvium

5.4.1 Distribution

The thickness of colluvium-alluvium increases to the north-west. The surface on which it was deposited was stepped and sloped downwards to the north-west. Prior to colluvium deposition, there was a palaeohigh to the east and south-east of the site of Stellar Pit, a steep gradient (1:35) close to the south-east pit wall, a relatively gentle slope (1:120) throughout the pit area and a further steep gradient (1:20) to the north-west, leading to a low point around drill hole R1649. This palaeotopography suggests reversal of gradients since the beginning of deposition of the palaeochannel sediments; it implies that palaeochannel sediments may have been more widespread, overlying the residual regolith throughout, and to the north-west of the Stellar Pit, but have since been eroded. Mechanical dispersion of any palaeosol developed on the residual regolith at this time would have been generally to the north-west.

5.4.2 Stratigraphy and composition

The colluvium-alluvium is composed of two sedimentary units: a lower, red-brown, silty clay with coarse, gravelly lenses, rounded quartz pebbles and remnant trough bedding and an upper hardpan from 0-3 m depth, in the coarse gravel. Each unit consists of several facies (see Figure 9). The colluvium-alluvium was separated into three size fractions; >500 μm, 74-500 μm and <74 μm. The <74 μm fraction was analysed mineralogically.

Hardpanised gravelly unit : the upper colluvium-alluvium is an approximately three metre thick, polymictic, gravel-dominated unit, composed of a variety of clasts, including fine- to medium-sized, lateritic nodules and pisoliths (4-15 mm) and fragments of BIF, vein quartz and ferruginous saprolite in a red brown, sandy-silt matrix. The sand is generally poorly sorted and the quartz grains are angular, suggesting a proximal source. The clasts in the gravel are both magnetic and non-magnetic, rounded to angular, unsorted and up to 40 mm in diameter. Their variety indicates diverse origins, including breakdown of lateritic duricrust, saprolite and BIF. The <75 μm fraction largely consists of kaolinite and quartz, with small amounts of goethite, hematite, feldspar, calcite and mica (Figure 9). Red-brown hardpan is strongly developed in this unit and is brittle, dull, porous, laminar and partly silicified. Concentrations of black Mn oxides are occur on subhorizontal partings and on vertical fracture-surfaces.

Hardpanised silty-clay unit: this underlies the gravelly unit and is only moderately indurated and weakly hardpanised. Its thickness varies from 4-8 m. In places, where erosion of laterite and mottled zone has occurred, and the clays of the palaeochannel are absent, it lies directly on saprolite. This unit appears conformable with the overlying hardpanised gravelly unit but it lies unconformably on underlying units. The latter relationships are exposed in the Stellar pit, where the hardpanised silty-clay unit overlies buried laterite and extends over, and partly erodes, a mega-mottled clay horizon. There are three facies, with each being laterally continuous across the pit face.

Facies 1 consists of red-brown silty-clay, up to three metres thick, and is dominated by kaolinite and quartz, with small amounts of goethite and hematite (Figure 9). It appears to be derived from erosion of saprolite.

Facies 2 is 1-2 m thick and occurs as lenses of well-rounded, reddish brown to black lateritic gravels (without cutans) and rounded pebbles of vein quartz within the silty-clay facies and represent transported lateritic debris. These lenses are generally thinner than those of the fine-grained, silty-clay, alluvial materials. A sharp boundary separates facies 1 and 2 and is marked by a difference in appearance in the gravels. Magnetic, lateritic gravels of hematite and maghemite dominate the gravel fraction. Beds of lithic fragments are rare. This material appears to have been derived from erosion of a laterite. The <75 μm fraction largely consists of kaolinite, smectite and quartz with small amounts of hematite and goethite.

Facies 3 comprises sand to sandy clay, up to one metre thick. Its <75 μm fraction consists largely of smectite, kaolinite and quartz with small amounts of goethite and hematite (Figure 9). It appears to have been derived from erosion of saprolite.

6. ACKNOWLEDGMENTS

Assistance at Mt. Magnet by J. Block, M. Doyle, E. Faust, A.P. Bristow, H. Warren, C. Wilkinson and B. Bradley, both in carrying out the research and in preparation for the field trip is acknowledged with appreciation.

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BAXTER

STOP 1

Manganese quarry 669431E 7166153N

This in a massive, Mn- and Fe-rich, vermiform duricrust, overlying Horseshoe Formation metasediments on the flanks of a low hill. The duricrust is variable in its Fe content which may reflect variations in the composition of the bedrocks. Duricrust flanks the sides of the hills; breakaways are very muted in this area.

The Peak Hill Mine is visible to the east, in the distance, where there are low rises and hills of ferruginous saprolite on metasediments of the Horseshoe Formation. This area forms an erosional regime.

To the west are low hills and ridges of Horseshoe Formation metasediments and ridges of BIF (Padbury Formation) in the far distance. To the south are low rises of variably complete laterite profiles very typical of the Narracoota Volcanics.

Sections 1.1-1.3 below refer.

STOP 2

Rise near turnoff to Harmony 665778E 7161385N

A low rise in ferruginous saprolite on Narracoota Volcanics is covered with a coarse, blocky lag of ferruginous saprolite with some quartz. Low hills of metasediments of the Horseshoe Formation lie to the north. About 100 m away, along the road, is a drillhole (PHR 043) which shows Narracoota Volcanics weathered to a depth of 41 m (to saprock).

STOP 3

Plain on approach to Harmony 665006E 7162298N

This illustrates a typical depositional plain characterised by a coarse, polymictic lag of ferruginous lithic fragments and quartz, with a very gentle slope (1:250) to the southwest. The lag overlies an acidic, red, loamy soil which, in turn, overlies hardpanised colluvium. The sub-surface geology around the Harmony pit will be discussed. Section 1.4 below refers.

STOP 4

Rab drilling south-west of Harmony pit. 662650E 7160960N

The spoil from a number of old drill holes may be inspected which show a progression from buried laterite, on the flanks of the palaeohigh, to a deep palaeochannel with two quite distinct parts, upper, greenish-grey mottled clays and lower sediments rich in opaline silica. This illustrates some of the difficulties and dilemmas in logging these materials from drill cuttings.

STOP 5

River colluvium 662129E 7160676N

Naturally eroded section in the colluvium showing some curious, basin-like structures possibly related to past biological activity. Probable lunch stop. The geochemistry of the top of the basement around the Harmony Pit will be discussed. Section 2 below refers.

STOP 6

Harmony Pit 663555E 7161615N

Information points shown by orange markers on the pit wall.

1. Surface silicification of ultramafic rocks (with preserved schistose rock fabric) of Narracoota Volcanics underlain by unsilicified saprolite and overlain, by about 2 m of colluvium with a very uneven base.

2. Ferruginous, hardpanized saprolite of the volcanic rocks, in which patches of white cryptocrystalline silica are developed near the upper surface. This is overlain by a very thin layer of colluvium. The colluvium over the pit at this point (Figure 4C) is extremely thin.

3. Gravelly material related to the duricrust and the top of the mottled zone. It is poorly consolidated and contains nodules and pisoliths with cutans (see Figure 4B). This is overlain by about 2 m of colluvium.

4. Mottled duricrust on the volcanics overlain by the south-east margin of the palaeochannel covered by about 2 m of colluvium (see Figure 4E)

5. Megamottled clays of the palaeochannel proper, overlain by about 2.5 m of hardpanised colluvium.

6. Fine, mottled, residual profile (top of mottled zone) on volcanics overlain by the coarsely mottled north-west margin of the palaeochannel. This is overlain by about 1 m of colluvium and 1.5 m of locally-derived alluvium which was probably too small to be recorded (or was not logged) in the drilling.

7. Mottled saprolite of metapelites of Thaduna metasediments, which are hardpanized towards their top, overlain by about 3 m of Mn-stained colluvium with lenticular structures.

STOP 7

Drill Core

An opportunity to examine the top portions of some diamond drilling, which was started from surface, showing the colluvium and its complex relationship to the underlying saprolites.

Those that may wish to may inspect the Peak Hill Pit from the nearby viewing point.

BAXTER

T.J. Munday, I.D.M. Robertson, C. Phang and D.J. Gray

1. HARMONY DEPOSIT

1.1 Introduction

The Harmony Deposit (previously known as the Contact Deposit), with a reserve of 2.148 Mt at 3.6 g/t Au, is located approximately 10 km west of Peak Hill and some 90 km north of Meekatharra. The region is arid, characterised by a low, irregular rainfall averaging 200 mm per annum. Vegetation cover is thin and consists largely of mulga and other drought-resistant shrubs and grasses. The deposit is located within a depositional plain bounded to the west by the westerly extent of the Robinson Ranges, to the north by the southerly extension of the Horseshoe Range and to the east and south by rises and low hills. The deposit was discovered in 1991 with mining commencing on 3rd July 1995.

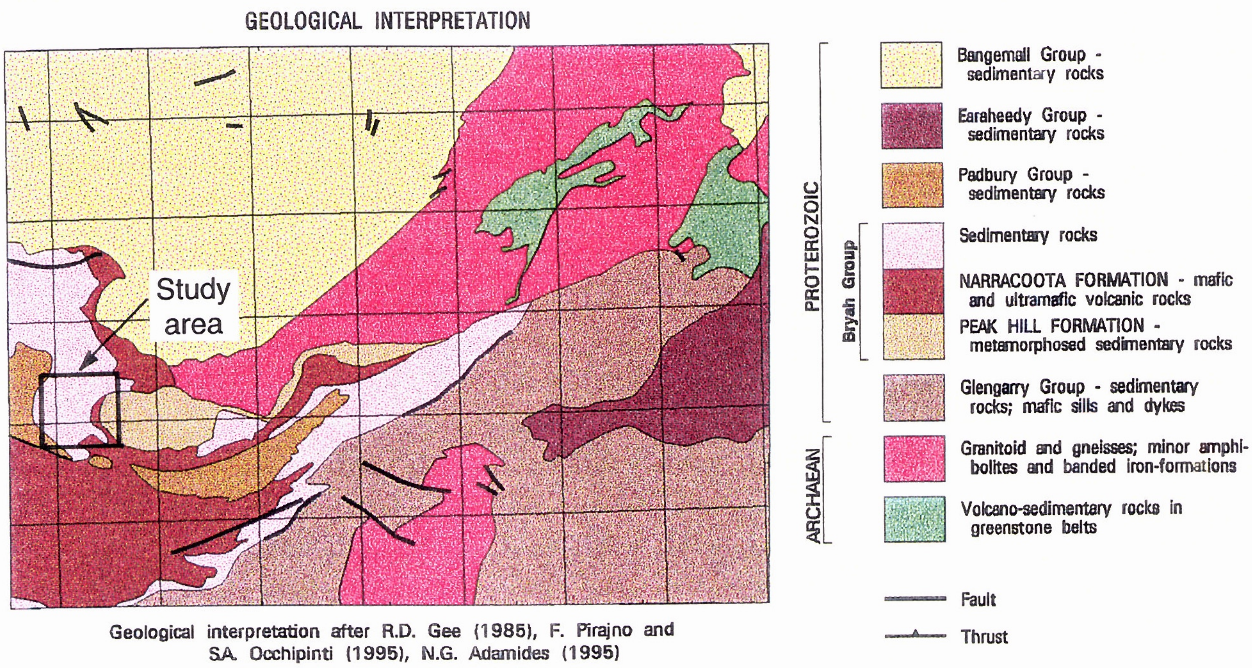

Figure 1 - Regional geological setting of the Baxter study area (source GSWA 1995).

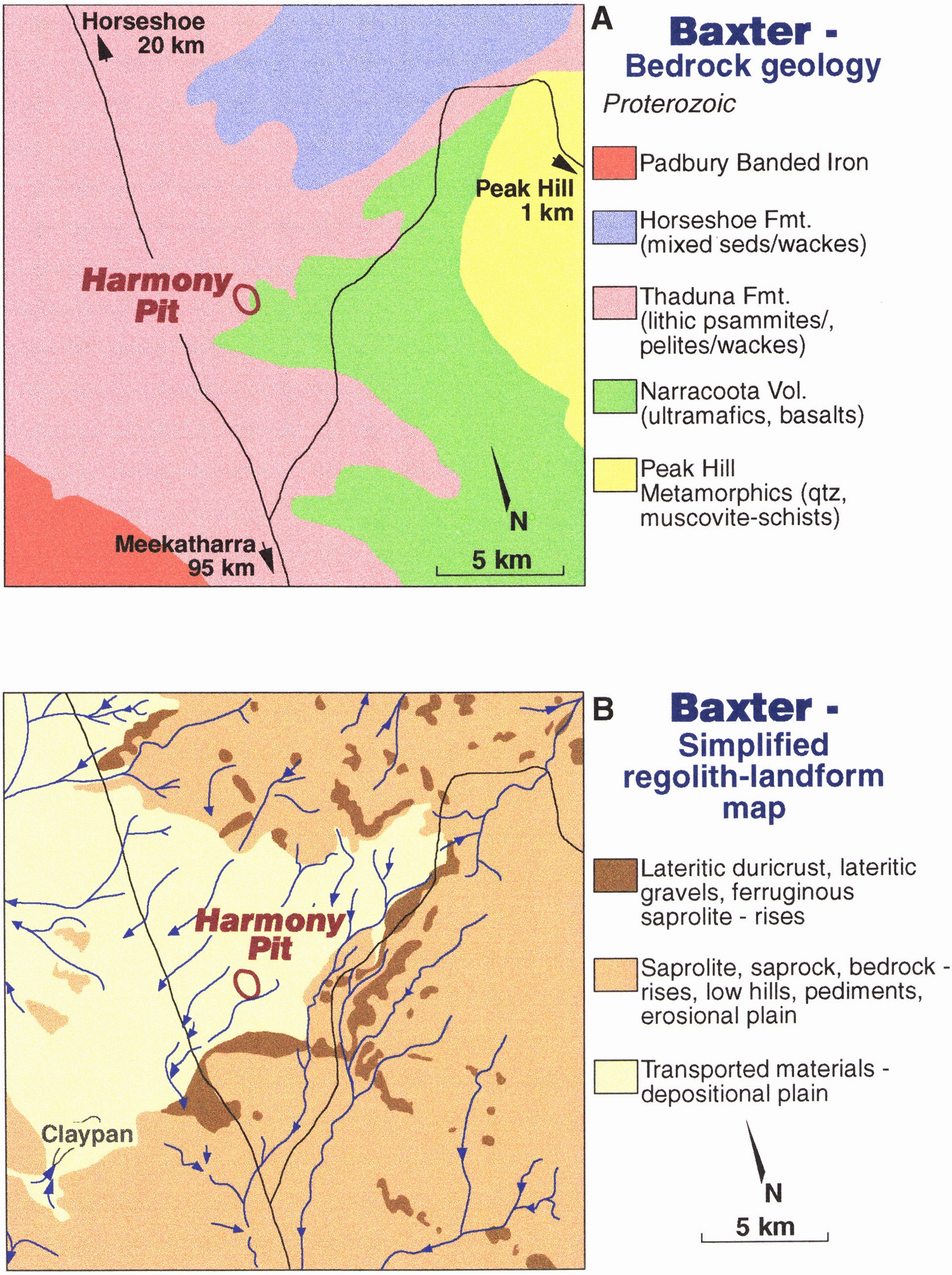

Figure 2 - A: Local bedrock geology map of the Harmony deposit and surrounding area.
B: Simplified regolith-landform map for the Harmony deposit and surrounding area.

Figure 3 - Landsat TM colour ratio composite for the region around the Harmony deposit. The image data have been spectrally processed to enhance differences between regolith materials.

1.2 Regional and Local Geological Setting

The Peak Hill District, within which the Harmony Deposit is located, comprises part of a major early Proterozoic orogenic belt, the Capricorn Orogen, that developed on the northern margins of the Yilgarn Craton around 1.8 Ga (Gee 1987). The District is interpreted to represent part of an early Proterozoic sequence containing thick trough and shelf sediments and mafic and ultramafic volcanics that have been subject to complex folding and thrusting, and moderate metamorphism (Figure 1). The sequence around Peak Hill is regarded as the western part of the Nabberu Basin, but is more properly thought of as a tectonic province rather than a sedimentary basin. The main tectonic features of the region are the fold belt associated with the Bryah, Glengarry and Padbury Groups, two basement highs - referred to as the Marymia and Goodin Domes - and the Bangemall Basin to the north.

The local geology about the deposit is summarised in Figure 2A. Harmony is located at the contact between the Narracoota Volcanics and the Thaduna Greywacke which form part of the Bryah Group. The Narracoota Volcanics comprise a folded sequence of mafic and ultramafic rocks. The Thaduna Greywacke is a thick, turbidite sequence of fine-grained lithic, feldspathic and mafic wacke with subordinate interbedded slaty mudstone (Gee 1987). To the north-west of the deposit, calcareous, manganiferous shales and subgreywackes of the Horseshoe formation outcrop. BIF's of the Padbury Group form prominent ridges south-east of the area.

1.3 Mineralisation

Primary gold mineralisation, associated with quartz veining, is stratabound, hosted within a mafic sequence (albitised dolerite and basalt) at the top of the Narracoota Volcanics, close to the contact with the overlying Thaduna Greywacke. The deposit is low in sulphides with pyrite >> pyrrhotite. The primary orientation of the mineralisation appears to be sub-parallel to the hanging wall contact of the sediments and volcanics associated with sub-vertical structures trending north-south. The detailed structural setting of the deposit is currently under investigation. Mineralisation also occurs as a relatively flat-lying supergene deposit close to the surface. This occurs largely within the saprolite of the volcanics but extends into the overlying colluvial material. The depth of oxidation over the deposit is variable, averaging approximately 80 m, with a water-table at 30 m.

The deposit was found through a shallow RAB drilling program sampling buried "lateritic" material. Anomalous Au levels were detected in the vacinity of Harmony and a follow-up drill program located mineralisation in what is now the southern part of the Harmony Pit.

1.4 Regolith Geology

The deposit is located in a broad depositional plain, surrounded by low hills and ridges (Figure 2B). The area is aggraded by infrequent active sheet flow and channelled stream flow, with subordinate wind erosion. To the south of the pit, the colluvium mantles the backslope of a bevelled breakaway (shown as a linear orange feature trending east-west on the Landsat image - Figure 3). The area south of the breakaway is an erosional plain developed in Thaduna metasediments. The regolith is characterised by a coarse, blocky, quartz-rich polymictic lag developed over ferruginous saprolite. Low rises characterise the landscape to the east and south-east of the deposit. The regolith comprises variably preserved lateritic profiles developed over Narracoota Volcanics, consisting of Fe-rich duricrust, lateritic gravels and ferruginous saprolites (oranges and reds in the Landsat image of Figure 3). Further east, the regolith is largely composed of saprolite, subcrop and outcrop related to the Peak Hill metamorphics and the Narracoota Volcanics (greens and purples on Figure 3). To the north-east of Harmony, the landscape becomes dominated by low hills developed in the mixed sediments of the Horseshoe Formation. Thick, massive-vermiform, manganiferous duricrusts have developed in places.

In the immediate vicinity of the deposit, the regolith is characterised by a variably thick, hardpanised, red-brown, colluvial-alluvial blanket (blues-browns on Figure 3), beneath which the degree of complexity varies considerably. In places, particularly close to the Harmony Deposit, the colluvium directly overlies a basement of ferruginous saprolite, saprolite and saprock. Elsewhere, notably to the southwest and northeast of Harmony, the colluvium is underlain by various mottled clay sediments which appear to infill palaeochannels cut into the basement. Parts of the basement (residual saprolitic material) are mantled by buried duricrust, complete with nodules and pisoliths, coated with pale brown, clay-rich cutans.

Intercalated within the palaeochannel-fill sediments there are horizons containing lateritic nodules and pisoliths with cutans. There are two possible explanations. Firstly, there has been an intermittent depositional history for the channel sediments with periods of exposure and further weathering of lower units and the development of a lateritic duricrust, followed by the continued deposition of transported materials. Secondly, and a more likely explanation, is that these horizons may relate to local erosion, transport and deposition of *in-situ* lateritic debris from adjacent slopes of a palaeo-valley, which was being progressively infilled with finer sediments.

1.4.1 Regolith stratigraphy

Because of the complexity of the sub-surface regolith and the very extensive drilling around the Harmony deposit, an overview of the regolith was undertaken to develop a 3-D regolith model of regolith stratigraphy for the site. A total of 708 drill holes were logged, noting only the major regolith units, colluvium, duricrust, palaeochannel-fill sediment and basement (interpreted as top of residual saprolite). A detailed lithological log was not attempted, as this had already been completed by AFMECO Pty Ltd. Each log was corrected for hole inclination and collar elevation and a database assembled. Contour and isopach maps of the various surfaces and regolith units were produced to provide some indication of palaeotopography and the spatial disposition of regolith materials in three dimensions (Figures 4A-E).

The contour map of the top of the residual profile on the basement, that is the top of the saprolite on metasediments and metavolcanics and their associated mottled zones and duricrusts, shows the Harmony Deposit lying on a palaeohigh which trends in a north-westerly direction. Cut into the basement are two palaeochannels. A major, deep palaeochannel, which appears to parallel the trend of the palaeohigh, lies to the west of Harmony. A flow direction to the north-west (from the volcanics into the metasediments) is postulated from a study of the basement topography (Figure 4A). A smaller, shallower palaeochannel drains north-east from the margins of the Harmony deposit. The regolith of the palaeohigh largely consists of ferruginous saprolite. Thick, mottled zones and clay-rich saprolites underlie the palaeochannels. A comparison of the basement contours (Figure 4A) with those detailing the thickness of the duricrust, interpreted as *in-situ* (Figure 4B), indicates the duricrust to be confined to the flanks of the palaeohigh. Duricrust thus occurs neither on the palaeohigh, possibly because of stripping, nor in the palaeochannels, possibly because of erosion.

Extensive colluvial deposits have infilled many of the palaeovalleys, with the thickest colluvium (Figure 4C) developed over the palaeochannels. The topography, prior to the deposition of the colluvium, is shown in Figure 4D. The upper part of the colluvium is hardpanised. An isopach map of the palaeochannel sediments (Figure 4E) fits the palaeochannels cut in the basement (Figure 4A). Some of these sediments may be subdivided into an upper unit of dark, puggy clays and a lower unit of pallid clays with silica.

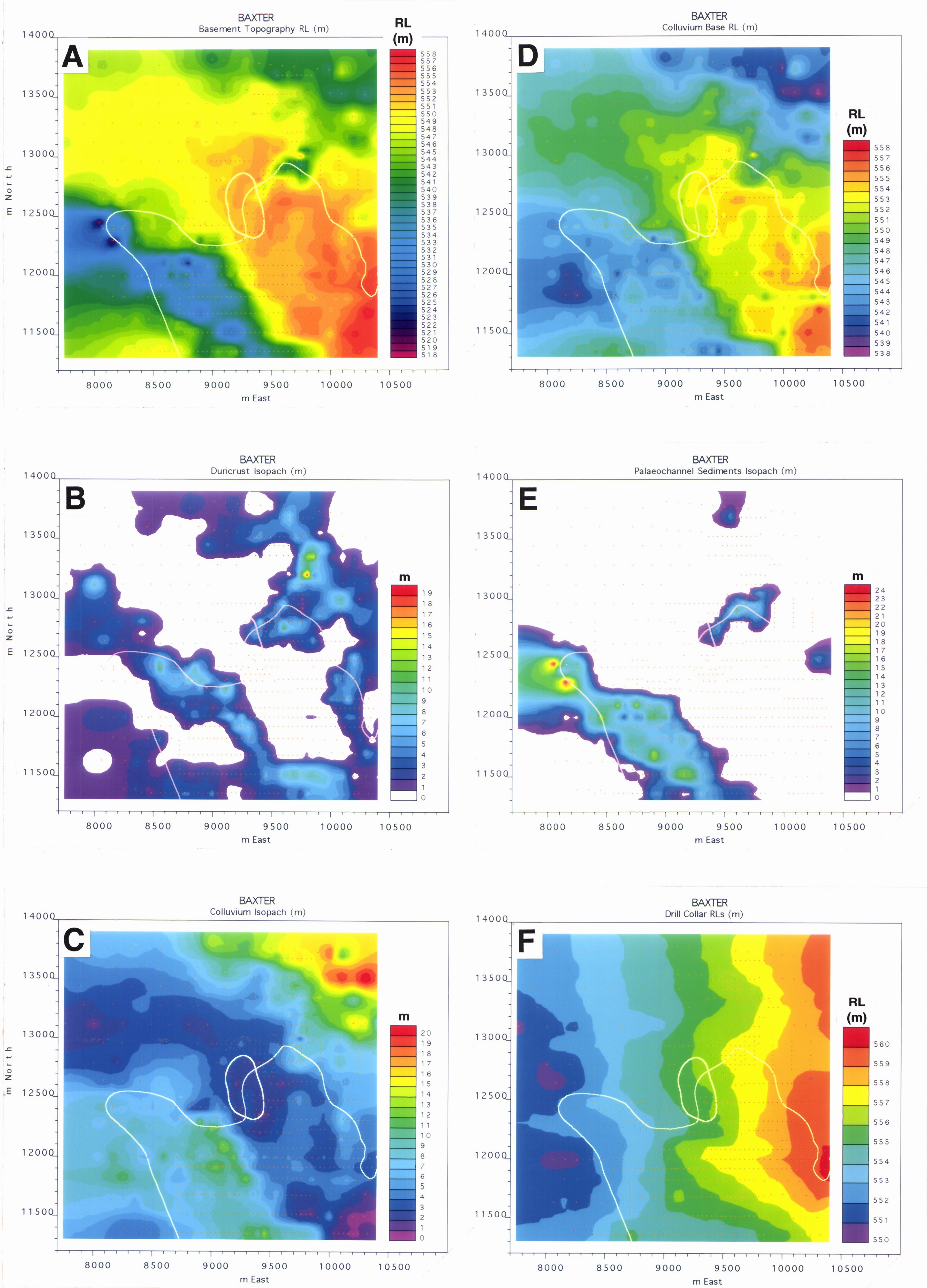

Figure 4 - Contours of the palaeotopography and isopach maps some regolith units around the Harmony Deposit.

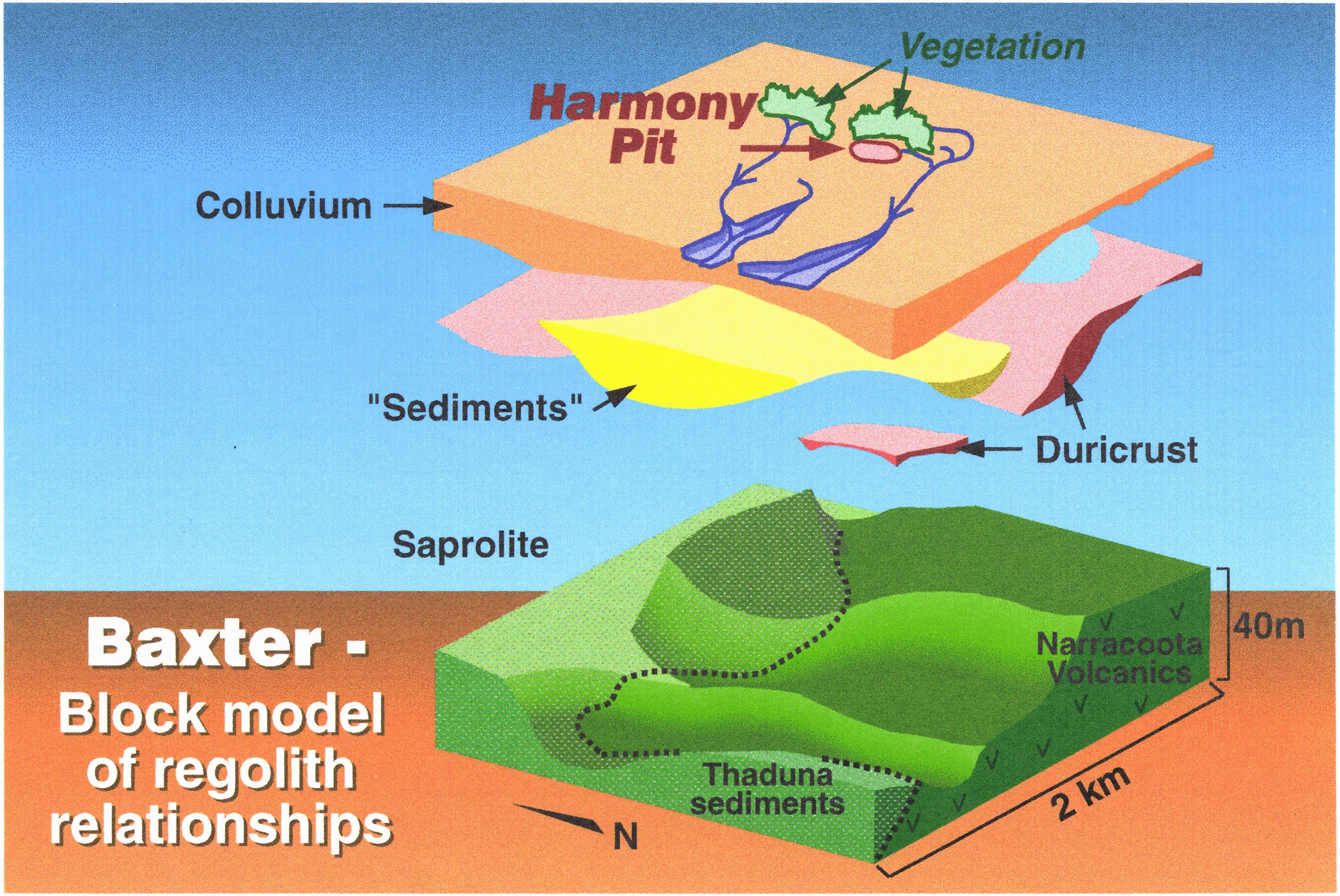

Figure 5 - 3-D model of regolith units at Baxter.

The present topography consists of a gently inclined surface which is being incised by a southwest-flowing drainage system (Figure 4F). A schematic representation of the regolith about the deposit is shown in Figure 5 as a cut-away 3D model.

2. REGOLITH GEOCHEMISTRY

2.1 Introduction

Geochemical haloes in the weathered basement are being delineated before investigating the geochemistry of the overburden, palaeochannel sediments or colluvium. A broad suite of elements have been determined by XRF and INAA, including a range of alkalis, alkaline earths, transition elements, some chalcophile elements, metalloids and a suite of lanthanides and actinides.

2.2 Sampling of ferruginous basement materials

A reconnaissance survey of the top of the basement was undertaken by collecting ferruginous samples on a 0.5 km triangular grid. Most samples were of buried duricrust. Where duricrust was missing, mottled zone was sampled and where neither were present, ferruginous saprolite was taken. All samples were washed, on a coarse nylon screen, to remove clays and to produce a ferruginous concentrate.

Initial investigation has shown that Au (50-100 ppb) and W (5-16 ppm) indicate the mineralisation at Harmony but the metalloids, As (20-50 ppm), Sb (5-12 ppm) and Se (4-7 ppm), indicate a narrow, separate zone or corridor to the southeast.

The distribution of a number of elements is influenced by lithology. High Cu (>40 ppm) is restricted to the volcanics. Conversely, elevated Th (>10 ppm) and Pb (>15 ppm) seems restricted to the sediments. The Ti/Zr ratio clearly separates the mafic volcanics from the sediments, which are more felsic. The eastern part of the volcanics are rich in Cr and Ni, apparently reflecting a sliver of ultramafic rocks here. This remains apparent, despite intense weathering to duricrust and ferruginous saprolite. The sediments and the remainder of these volcanics are relatively poor in Cr (<1000 ppm) and Ni (<200 ppm).

The alkalis (Na, K, Rb, Cs) are concentrated in the north-east parts of the sediments probably related to concentrations of resistant muscovite and paragonite.

The rare earth elements showed a number of particularly interesting patterns. Cerium and Y form a north-northwest trend through the deposit, and La, Eu and Sm accurately target the deposit. The heavy rare earths, including Lu and Yb, define a ridge between Harmony and Enigma North. This close targeting of the environs of Harmony by the rare earths is unexpected. Examination of fresh rock samples is critical before a proper interpretation can be given. Phosphorus provides very similar pattern to those of the rare earths and it is possible that the REE may be hosted by phosphate minerals as, for example, florencite, an analogue of alunite.

So far, a dataset of 25 samples has been investigated as a pilot study, which has shown some encouraging trends. Fill-in sampling has been completed, quadrupling the data set, and a suite of fresh rock samples collected within and outside the mineralised zone.

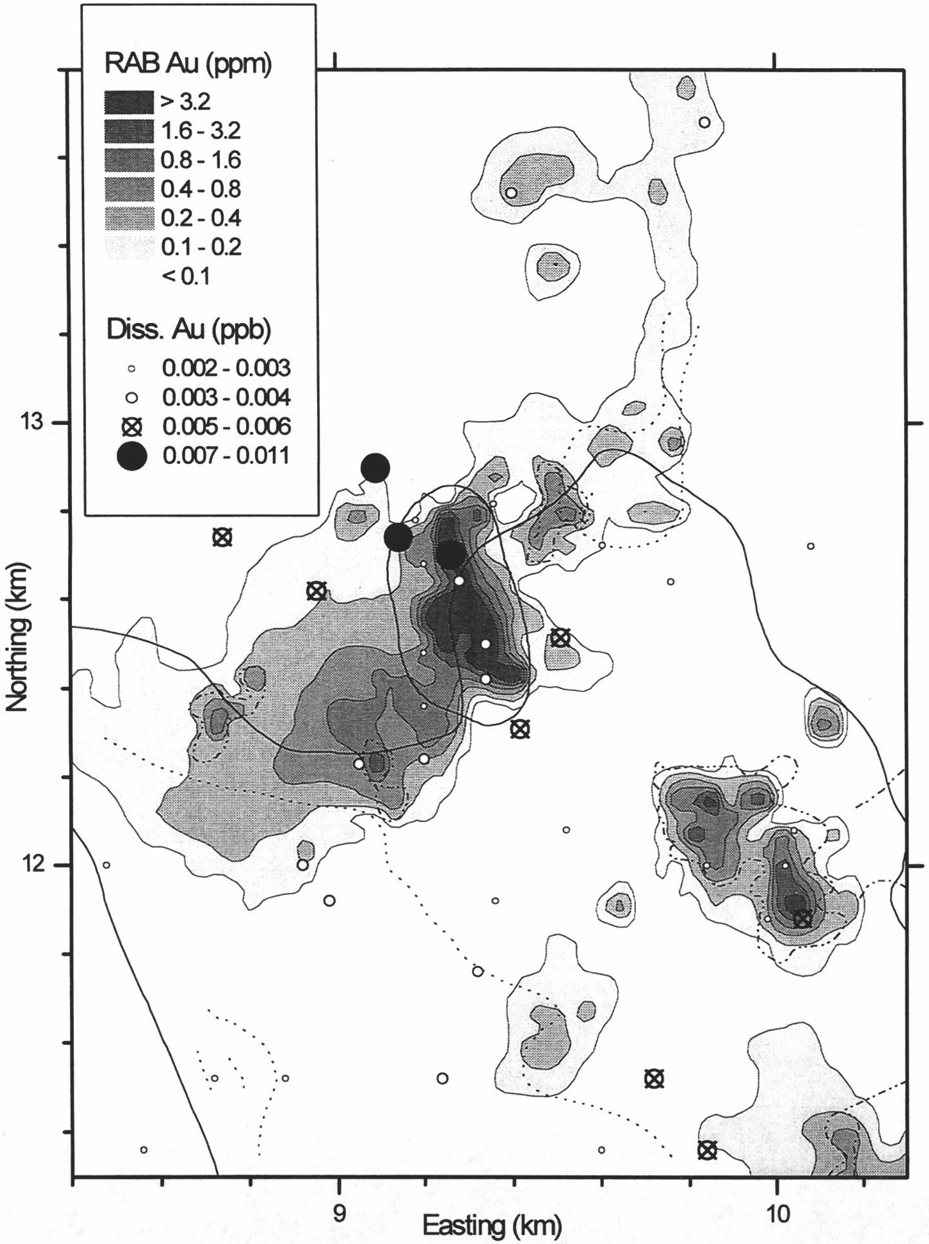

Figure 6: Dissolved Au concentration (dots) superimposed on contours of maximum Au in RAB drill cuttings

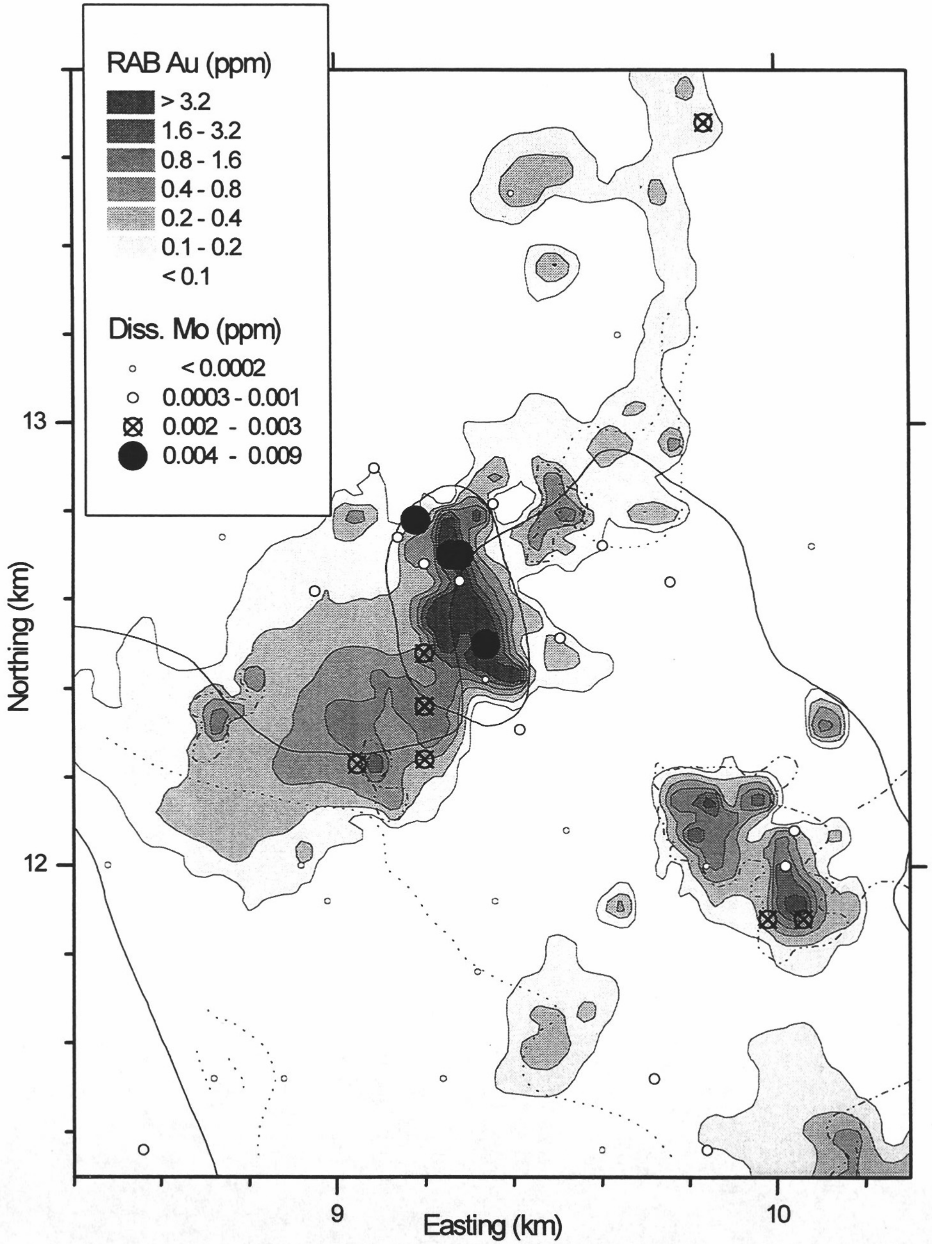

Figure 7: Dissolved Mo concentration (dots) superimposed on contours of maximum Au in RAB drill cuttings

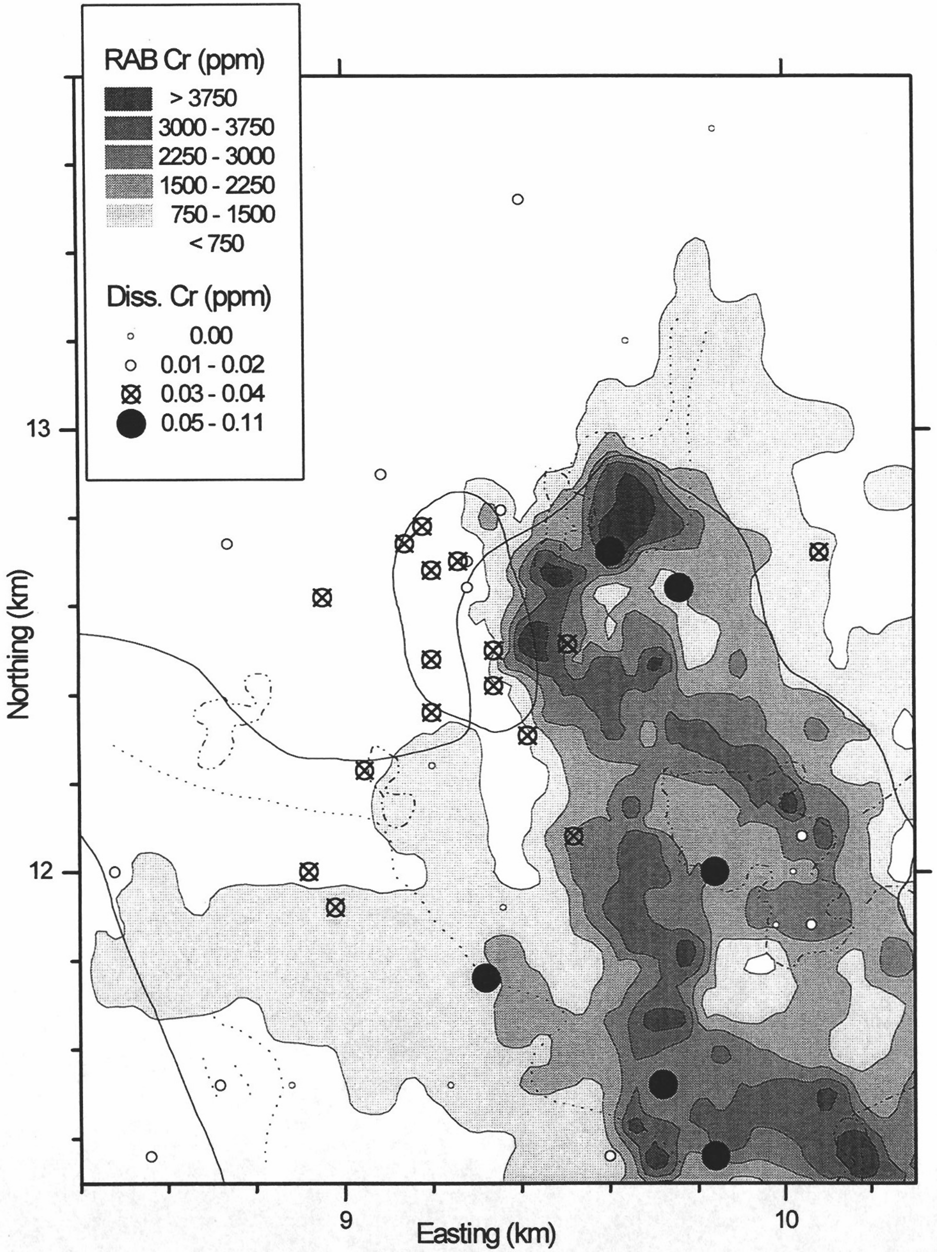

Figure 8: Dissolved Cr concentration (dots) superimposed on contours of maximum Cr in RAB drill cuttings

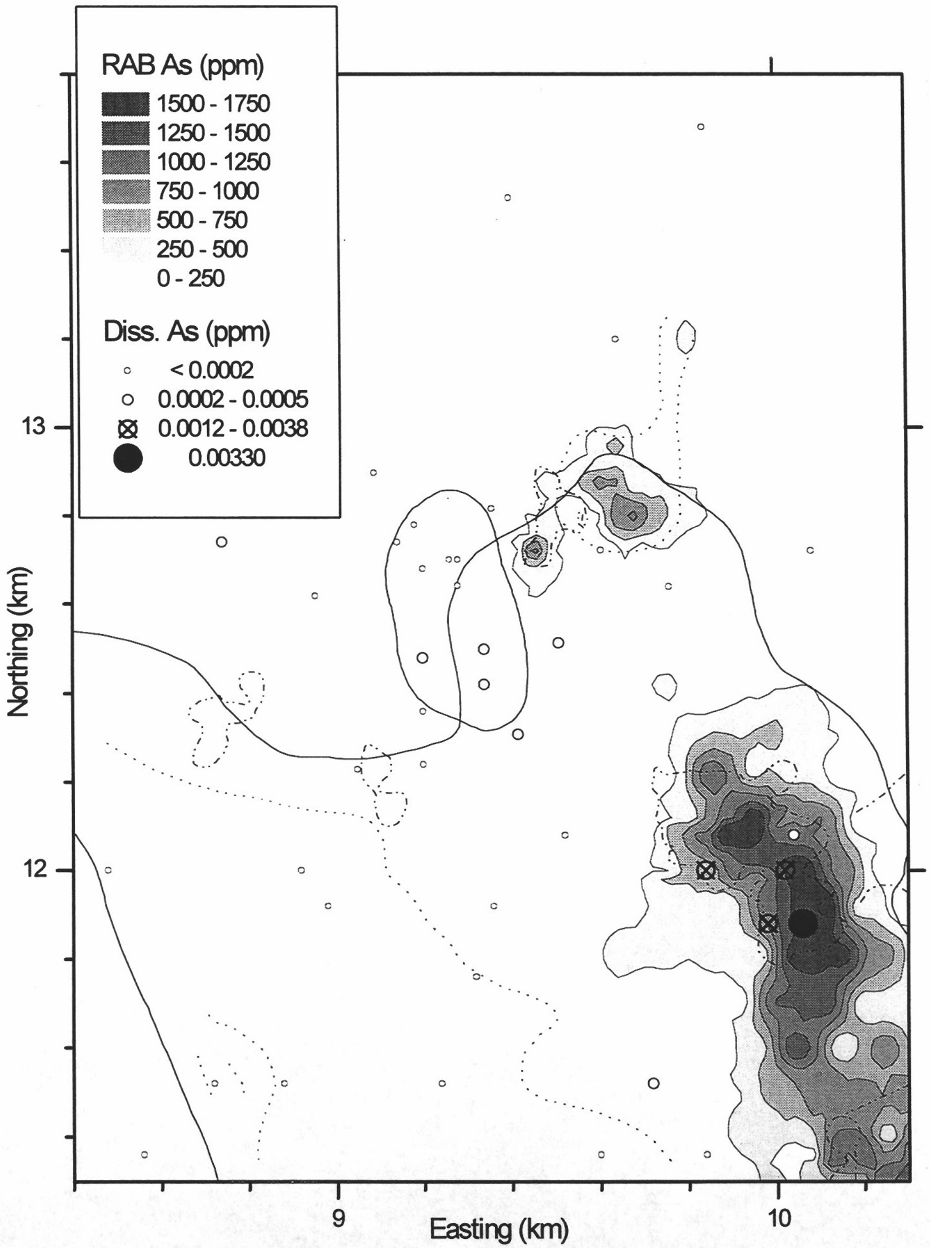

Figure 9: Dissolved As concentration (dots) superimposed on contours of maximum As in RAB drill cuttings

3. HYDROGEOCHEMISTRY

3.1 Objectives

The objectives of investigating the hydrogeochemistry of mineralised areas are to advance knowledge of groundwater characteristics, particularly with reference to geochemical dispersions in the regolith, and to determine the potential for groundwater sampling as an exploration technique. Results at Baxter indicated that groundwater characteristics, though very different from sites south of the Menzies, nevertheless showed distinct influences from the underlying mineralisation and lithological factors.

3.2 Gold mineralisation pathfinders

Groundwaters around the Harmony deposit are neutral with low salinity, consistent with trends observed on the Yilgarn (*i.e.*, groundwaters tend to be acid and saline south of the Menzies line, and neutral tending to fresher waters to the north). Thus, the dominant mechanism for the mobilisation of Au in the southern Yilgarn, namely as the chloride complex ($AuCl_2^-$):

$$2Au_{(S)} + 4Cl^- + \frac{1}{2}O_2 + 2H^+ \rightleftharpoons 2AuCl_2^- + H_2O \qquad (1)$$

is not expected to be significant at Baxter. Two other mechanisms for Au solubilisation are as an organic complex, which is not expected to be important in low organic content groundwaters occurring at this site and as the thiosulphate complex $[Au(S_2O_3)_2^{3-}]$. Generation of this later complex is controlled by the production of thiosulphate:

$$FeS_2 + 3O_2 \Rightarrow Fe^{2+} + S_2O_3^{2-} \qquad (2)$$

which primarily occurs during oxidation of sulphides, when acid production is buffered by other minerals such as carbonates. Previous investigations (Butt *et al.*, 1993) have indicated that this is only significant for groundwaters sampled at the weathering interface, and will have little effect on Au solubility for shallower groundwaters such as those analysed at Baxter. Therefore, dissolved Au concentration is expected to be very low and of little direct exploration significance, as is observed (Figure 6). However, other elements can be associated with Au mineralisation and at this site may be better pathfinders in groundwater than Au itself. At Harmony, potential pathfinder elements include Mo (Figure 7), W, Sc and possibly Rb.

3.3 Lithological and geochemical discrimination

In addition to direct pathfinders for Au mineralisation, other elements can be use in groundwaters to indicate underlying lithology or other geochemical factors. Thus dissolved Cr concentration correlates well with the presence of ultramafic rocks (Figure 8), even though the groundwaters are contacting highly weathered lithologies. This discrimination occurs at Harmony and elsewhere, though interestingly does not occur for Ni, presumably because more severe (*i.e.* acidic) conditions are required to dissolve Ni from the solids than to dissolve Cr (Butt *et al.*, 1993). The other major correlation observed at Harmony is between dissolved As and the "As corridor", a band of As-rich rocks to the south-east of the study area (Figure 9).

4. ACKNOWLEDGEMENTS

Assistance was provided at Peak Hill during the early days by Rhod Grivas (AFMECO Pty Ltd). Later, Martin Hills (Plutonic Resources), Greg Chessell, Marshall Harper and Derek Lenartowics (Mine manager) of Peak Hill Resources assisted in planning the field visit.

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FENDER DEPOSIT, CUE

C.R.M. Butt

1. LOCATION AND GEOLOGICAL SETTING

The Fender deposit is approximately 2 km south of Big Bell, about 28 km WNW of Cue. The site is on the margin of a colluvial-alluvial plain which slopes gently to the north and east. The deposit itself is overlain by a thin cover of transported overburden and there is no outcrop in the immediate vicinity, although residual regolith is exposed within 200 m to the west. The stratigraphy and mineralization are known only from exploration drilling, but appear to be essentially the same as at Big Bell.

Big Bell and Fender are hosted by a regional volcanic and sedimentary sequence within the Murchison Province of the Archaean Yilgarn Craton (Handley and Cary, 1990). At Big Bell, the greenstone belt is narrow, steeply-dipping, strongly attenuated and overturned. It forms the west limb of a north-plunging regional anticlinal structure, which closes 14 km north of Big Bell. Deformation increases to the south and the whole belt, which is only about 1500 m wide at Big Bell, narrows to about 830 m at Fender, between confining granitic rocks to both east and west (Figure 1). The regional metamorphic grade is lower to middle greenschist. The stratigraphic sequence at the mine is summarized in Table 1. Precise identification of the individual units is not yet possible at Fender, although amphibolitic, porphyritic and schistose rocks are present, equivalent to those of the lower mafic (Hangingwall) and felsic volcanic (Host) sequences. The lithological contacts dip at about 75° east at Big Bell and a similar dip is assumed at Fender. Primary mineralization at Big Bell is confined largely to quartz-muscovite-potassium feldspar schists in the felsic volcanic (Host) sequence and is associated with similar rocks at Fender. Exploitable mineralization at Fender appears to be confined to the weathered zone. There are two styles, namely a small 'laterite' resource, in the southern part of the deposit, and weathered primary mineralization in the saprolite. In addition to Au, the mineralization in the saprolite is enriched in a range of pathfinder elements including As, Sb, W and, in places, Mo, a similar suite to that present at Big Bell.

REGIONAL SEQUENCE	LOCAL STRATIGRAPHY	PRECURSOR
Upper mafic sequence *(Footwall amphibolite)*	Chlorite schist	Pillow basalt
Felsic volcanic sequence	Felsic volcanic unit	Rhyolite (in part tuffaceous)
(Host sequence)	Cordierite schist	Aluminous mafic tuff
Lode	Potassium feldspar schist	Altered tuff (sinter)
Lode	Altered schist	Altered mafic tuff (Fe-rich)
	Biotite (garnet- magnetite) schist	Mafic tuff (Fe-rich)
	Intermediate schist	Intermediate tuffaceous volcanics
	Porphyroblastic garnet schist	Iron formation
Lower mafic sequence	Quartz-feldspar porphyry	Porphyritic rhyolite
(Hangingwall amphibolites)	Amphibole schist	Mafic flows

Table 1 - Principal lithologies in the Big Bell sequence (after Handley and Cary, 1990).

2. REGOLITH GEOLOGY

The Fender deposit is entirely concealed by a shallow cover of transported overburden. Outcropping residuum occurs about 150-200 m west of the mineralized unit and the sediments thicken to over 13 m about 200 m to the east.

In the vicinity of the deposit, the transported overburden consists of 1-5 m of fine- to medium-grained sand and sandy clays, overlying silty clays. Both the sands and the silty clays locally contain detrital lateritic gravels. The sands are weakly cemented in the top metre to form hardpan and some deeper sediments are mottled; there is no pedogenic carbonate. The sediments, which contain a few crystals of feldspar (0.5-1.0 cm), are probably derived from the granites to the west.

There are two principal regolith situations beneath the overburden (Figure 2):

1. Lateritic profile apparently complete: in the southern part of the deposit, a small laterite resource is contained in lateritic residuum and ferruginous saprolite. The ferruginous unit consists of pisoliths and nodules in a clay-rich matrix.

2. Lateritic profile truncated: in the northern part of the deposit, sediments are deposited on saprolite which, in some places, is leached and mostly depleted in Au but, in others, Au is at ore-grade concentrations immediately beneath the unconformity.

These two situations are also evident in the west, where lateritic residuum and saprolite outcrop.

The depth of weathering exceeds 50 m over the mineralized felsic sequence but the amphibolites of the hanging-wall in the east are almost fresh at the unconformity (12-14 m depth). The unconformity between the sediments (generally the silty clays) and saprolite is recognisable by changes in fabric, the presence of muscovite in drill cuttings and/or the presence of rock fragments having lithic fabrics. The unconformity is less easy to identify in the south, where the material underlying the sands and silty clays is highly ferruginous, because muscovite (if originally present) and lithic fabrics have been destroyed by weathering. This unit is interpreted as being residual because of the monomictic composition of the coarse fraction and the presence of cutans on the nodules and pisoliths that comprise this fraction.

3. GEOCHEMICAL EXPRESSION OF MINERALIZATION

Exploration data suggest that there is no geochemical expression of the deposit in the transported material, even though the total depth is less than 6 m over the subcropping mineralization (Figure 3). This lack of expression has been the focus of research at this site which has, as its objective, a close investigation of the geochemistry of the overburden, including study of possible use of partial extraction analyses for gold and appropriate pathfinder elements. Because of probable cross-hole contamination of existing samples, the overburden and uppermost residuum have been resampled. Holes were drilled on three traverses across the subcrop of the deposit, investigating both regolith situations. Prior to drilling each hole, a pilot hole was drilled to purge the rods and cyclone of cuttings remaining from the previous hole, to minimize contamination. The sections illustrated in Figure 2 are based on this drilling. They exemplify where the sediments overlie:

1. ore-grade lateritic mineralization (2000-6600 ppb Au, section 240N);

2. ore-grade saprolite mineralization (2000 ppb Au, section 400N);

3. leached saprolite mineralization (100 ppb Au, section 340N). High concentrations of pathfinder elements suggest this material was originally Au-rich and is now depleted.

Samples were collected at 1 m intervals and initial results, based on analyses of these samples, confirm the exploration results which, for the most part, were based on 4 m composites.

4. ACKNOWLEDGEMENTS

The interest and cooperation of Nigel Radford (Normandy Exploration) and Graham Rankine (Posgold (Big Bell) Pty. Ltd.) for encouraging research at this site are gratefully acknowledged. Shanta Dries (Posgold (Big Bell) Pty. Ltd.) has provided invaluable assistance in sampling and data collection.

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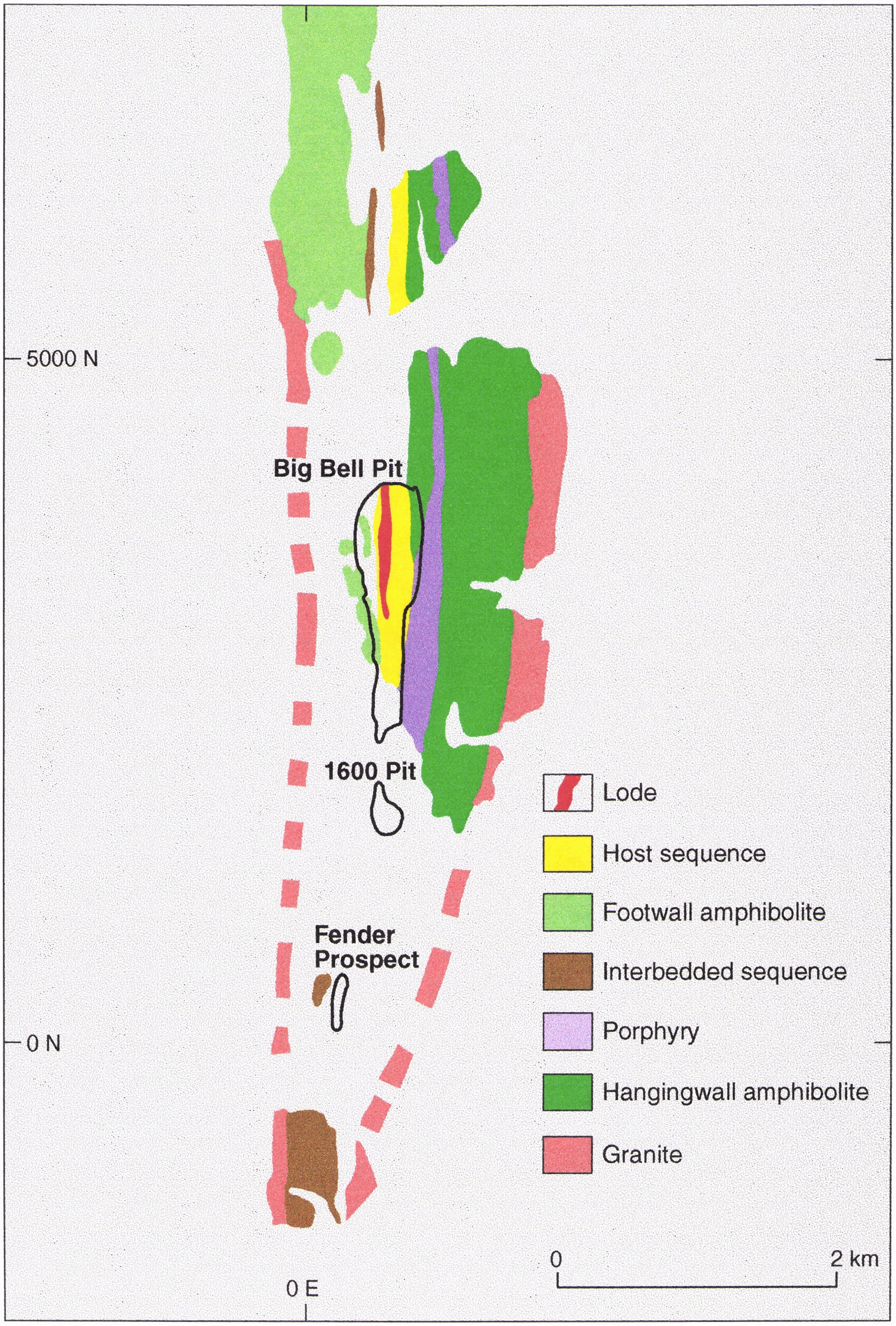

Figure 1 - Outcrop geology, Big Bell area (from data supplied by PosGold Pty Ltd).

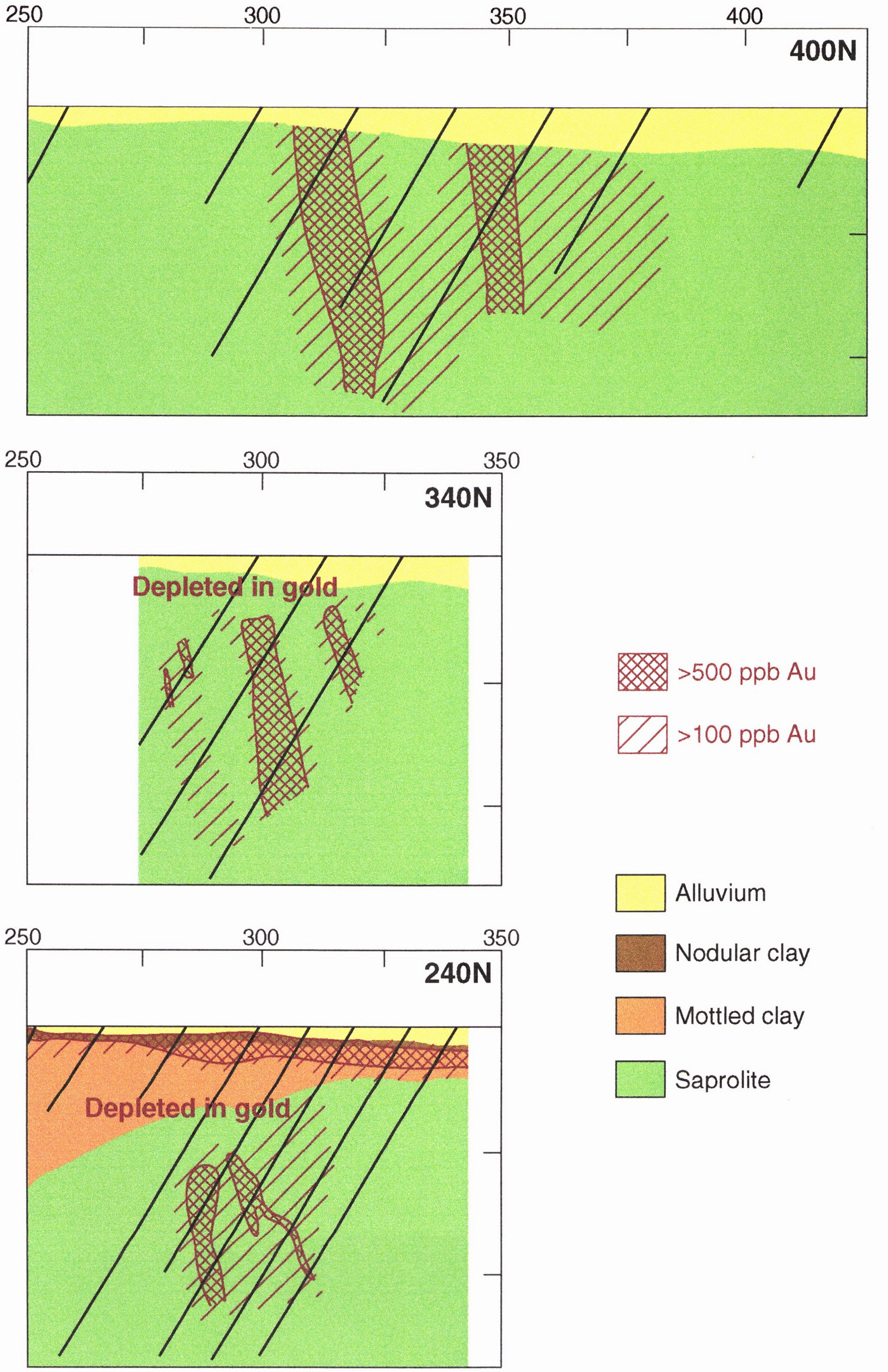

Figure 2 - Drill sections, Fender deposit. Regolith geology and gold distributions (from data supplied by PosGold Pty Ltd).

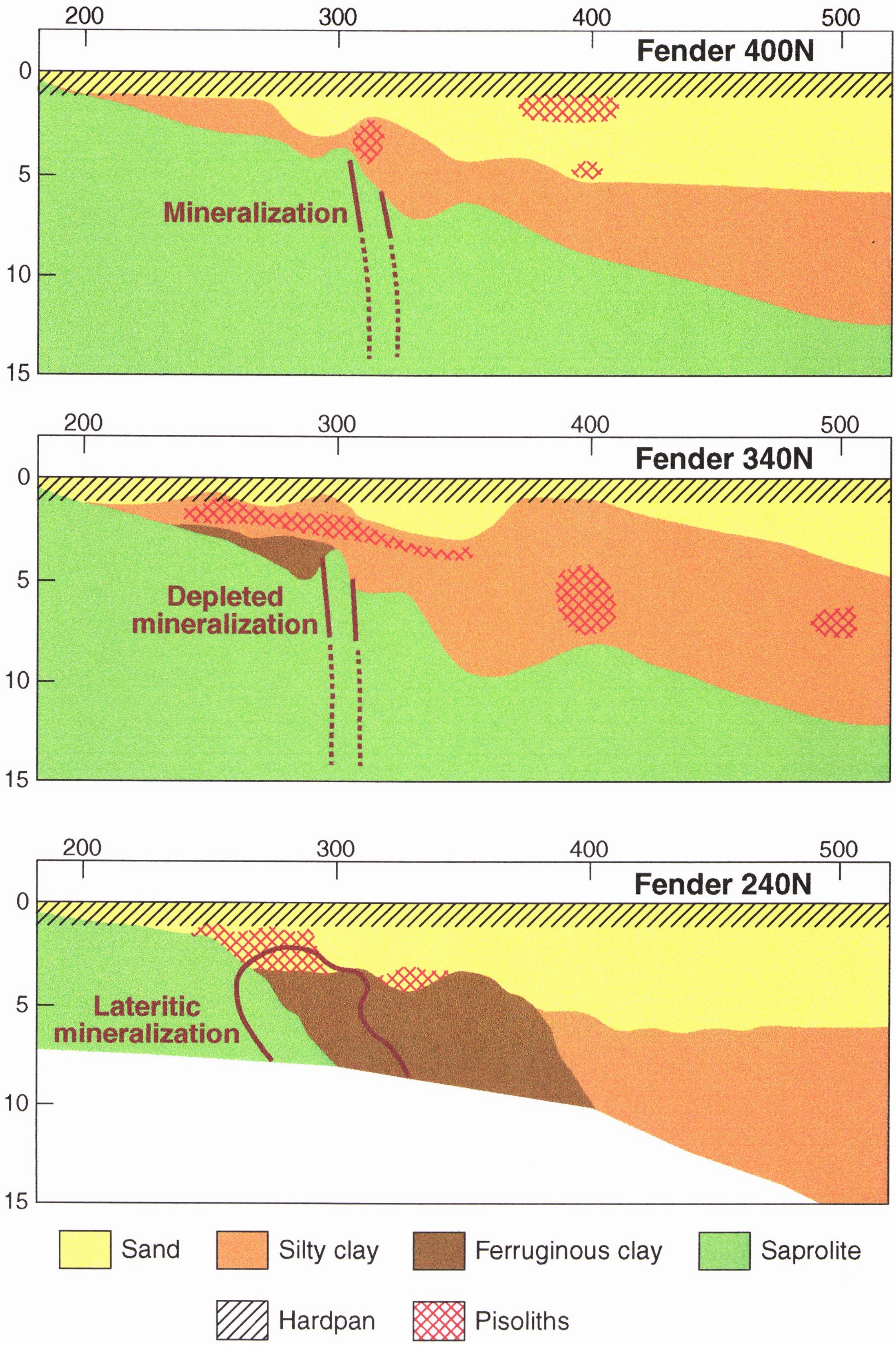

Figure 3 - Regolith geology, Fender deposit, derived from new shallow drilling.