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# CHARTERS TOWERS - NORTH DRUMMOND BASIN FIELD EXCURSION

# FIELD GUIDE

*K. Scott, Li Shu, S. Fraser, I.D. Campbell, R.R. Anand and I.D.M. Robertson*

**CRC LEME OPEN FILE REPORT 122**

**February 2002**

(CSIRO Exploration and Mining Report 286R/CRC LEME Report 11R, 1996. Second impression 2002)

CRC LEME is an unincorporated joint venture between CSIRO-Exploration & Mining, and Land & Water, The Australian National University, Curtin University of Technology, University of Adelaide, University of Canberra, Geoscience Australia, Bureau of Rural Sciences, Primary Industries and Resources SA, NSW Department of Mineral Resources-Geological Survey and Minerals Council of Australia, 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, PO Box 1130, Bentley WA 6102, Australia

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## CSIRO/CRC LEME/AMIRA PROJECT P417
## GEOCHEMICAL EXPLORATION IN REGOLITH-DOMINATED TERRAIN, NORTH QUEENSLAND 1994-1997

In 1994, CSIRO commenced a multi-client research project in regolith geology and geochemistry in North Queensland, supported by 11 mining companies, through the Australian Mineral Industries Research Association Limited (AMIRA). This research project, "Geochemical Exploration in Regolith-Dominated Terrain, North Queensland" had the aim of substantially improving geochemical methods of exploring for base metals and gold deposits under cover or obscured by deep weathering in selected areas within (a) the Mt Isa region and (b) the Charters Towers - North Drummond Basin region.

In July 1995, this project was incorporated into the research programs of CRC LEME, which provided an expanded staffing, not only from CSIRO but also from the Australian Geological Survey Organisation, University of Queensland and the Queensland Department of Minerals and Energy. The project, operated from nodes in Perth, Brisbane, Canberra and Sydney, was led by Dr R.R. Anand. It was commenced on 1st April 1994 and concluded in December 1997. The project involved regional mapping (three areas), district scale mapping (seven areas), local scale mapping (six areas), geochemical dispersion studies (fifteen sites) and geochronological studies (eleven sites). It carried the experience gained from the Yilgarn (see CRC LEME Open File Reports 1-75 and 86-112) across the continent and expanded upon it.

Although the confidentiality period of Project P417 expired in mid 2000, 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 122) is a second impression (second printing) of CSIRO, Division of Exploration and Mining Restricted Report 286R, first issued in 1996, which formed part of the CSIRO/AMIRA Project P417.

**Copies of this publication can be obtained from:**
The Publication Officer, c/- CRC LEME, CSIRO Exploration and Mining, P.O. Box 1130, Bentley, WA 6102, Australia.. Information on other publications in this series may be obtained from the above or from http://leme.anu.edu.au/
**Cataloguing-in-Publication:**

Charters Towers - North Drummond Basin Field Excursion, Field Guide.
ISBN 0 643 06782 5
1. Geochemistry - North Queensland 2. Regolith - North Queensland 3. Landforms - North Queensland
I. Scott, K.M. II. Title
CRC LEME Open File Report 122.
ISSN 1329-4768

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## PREFACE

The principal objective of the P417 Project is to improve substantially geochemical methods of exploration for base metals and Au in areas obscured by weathering or under younger cover. The research includes geochemical dispersion studies, regolith mapping, regolith characterisation, dating of profiles and investigation of regolith evolution. The project has sites in both the Mt Isa Region and in the Charters Towers-North Drummond Basin.

Essential to this project is translation of research findings into practical exploration outcomes. Field excursions are an essential link in this technology transfer. The last excursion was in July 1995 and covered the Eastern and Western Successions of the Mt Isa Region, where research sites have deeply weathered profiles on Proterozoic and Mesozoic bedrocks and are partly overlain by variable thickness of recent sediments. This second excursion provides opportunities to examine the weathering of younger Palaezoic rocks and their Tertiary cover sequences (Suttor, Southern Cross and Campaspe Formations) and the geomorphology of the region, all of which are important to geochemical exploration of the region.

The excursion includes visits to mineral deposits, prospects and field sites. On the first day the excursion visits Red Falls, where the Campaspe Formation can be demonstrated to overlie the Southern Cross Formation, the Featherby Walls, where the sandstones of Southern Cross Formation unconformably overlie the Ravenswood Granodiorite. At both these sites, mottling and nodules are common. In the Waterloo Area a ferruginous profile is developed in the top of the Campaspe Formation. The Waterloo Deposit has been quoted as occurring below 60 m of Campaspe Formation, however, work done in this Project indicates that the thickness of the cover has been overestimated in places and a Pb mechanical dispersion train occurs at the base of the Campaspe Formation.

The second day covers Scott Lode, the Cindy Deposit and the Wahines Prospect. Here, weathered profiles are developed on cover sequences and on the basement. Weathered components of earlier sequences have been included as detritus in later materials, implying a complex and continued weathering history. Concentrations of Fe have developed both at surface and at depth in the cover sequences which have adsorbed pathfinder elements related to mineralisation in the basement.

The Police Creek and Wirralie prospects and profiles through the Suttor Formation are visited on the third day. Ferruginous duricrusts and silcretes are developed on the Suttor Formation.

At the Police Creek Prospect, the transported cover is generally less than 6 m thick and mottles have developed both in it and in the underlying bedrock. There appears to be both hydromorphic and mechanical dispersion in the cover. The <75 µm fraction of the soil has a more intense Au anomaly than the <180 µm fraction. Although As and Sb occur in the fine fraction, these elements are concentrated with Fe oxides of the coarse fraction with Mo.

At the Wirralie Deposit, the Au anomalies in the Suttor Formation reflect mechanical transport from the basement. Arsenic and Sb contents are generally low in the Suttor Formation, except where ferruginous sediments occur.

### ACKNOWLEDGMENTS

Assistance was provided by RGC Exploration Pty Ltd, Normandy Exploration Ltd, Ross Mining NL, Battle Mountain Australia Inc and Mt Leyshon Gold Mines in allowing access to their ground, providing data and logistical support. Sample preparation was by W. Maxwell, K. Lim and J. Crabb at Floreat Park and by J. Davies, G. Hansen. M. Kassis and N. Haylen did the sectioning at North Ryde. Thin and polished sections were prepared by R. Bilz. X-Ray Diffraction and XRF analysis was by M.K.W. Hart and K. Kinealy. INAA analysis was by Becquerel Laboratories at Lucas Heights. Preparation of artwork was by A. Vartesi, C.R. Steel, E. Mylka, J. Michie, C. Taylor and P. Phillips. Document formatting and compilation was by P. Phillips, J. Porter and D. Bridgewater. Travel arrangements and correspondence were organised by G. Ashton. All this is acknowledged with appreciation.

**R.R. ANAND**
*Project Leader*

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*Deputy Leader*

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# 1.0 REGIONAL OVERVIEW - CHARTERS TOWERS-NORTH DRUMMOND BASIN; GEOMORPHIC PROVINCE

*S.J. Fraser*

## 1.1 Introduction

This regional study provides a framework, so that mapped geomorphic landform units can be associated with particular regolith[1] attributes that occur in the landscape. The map provides a framework so that it is possible to 'plug-in' various observations, allow cautious extrapolation of these specific observations to other areas, and help develop an understanding of regolith issues over the region.

The map was derived using a mosaic of four Landsat TM scenes and traditional photo-geological methods (*i.e.*, photoform, drainage, and cover type information), which allowed the subdivision the area into a number of geomorphic provinces based on landform units.

The Charters Towers - North Drummond Basin area has a history of mining activity and it is considered to be highly prospective. The main styles of mineralisation noted to date include:-
*Volcanogenic Cu-Pb-Zn-Ag-Au-Ba mineralisation* within the Mt Windsor Volcanics of the Seventy Mile Range Group (*e.g.*, Thalanga Mine, Liontown, Highway, Reward);

*Mesothermal Au mineralisation* consisting of narrow veins associated with quartz-carbonate alteration and base-metal sulphides (*e.g.*, Charters Towers, Rishton, Hadleigh Castle);

*Permo-Carboniferous Porphyry-related Au mineralisation* related to intrusive complexes associated with Permian rhyolitic to trachytic plugs and dykes (Mt Leyshon); and,

*Epithermal Au mineralisation,* some examples of which are localised within the sediments and volcanics of the Drummond Basin, and commonly spatially associated with porphyry systems (*e.g.*, Pajingo, Wirralie, Mt Coolon, Yandan).

## 1.2 Location, Climate and Vegetation

The study area extends from latitudes 20° 04' 30" - 21° 36' 30" S and longitudes 145° 57' 30" to 147° 40' 30" E, and covers parts of the Charters Towers, Townsville, Mt Coolon and Buchan 1:250 000 scale map sheets (Figure 1).

Charters Towers, the principal population centre within the area, is situated on the Flinders Highway some 135 km southwest of Townsville. A network of station tracks and three major roads allow access throughout the study area. The Gregory Developmental Road (sealed to Belyando Crossing), which connects Charters Towers with Clermont (some 380 km south) is located within the western half of the area. The Collinsville - Mt Coolon - Belyando Road (unsealed) allows east-west access across the southern section of the area. The Mingela - Ravenswood - Burdekin Dam Road (sealed), allows north-south access east of the Burdekin River, and an unsealed track to the south (road passes under the dam spillway) joins tracks that lead to Mt Coolon and Collinsville.

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[1] "Regolith" is used here as a general term for the entire cover, cemented or unconsolidated, that overlies unweathered bedrock and which is formed by weathering, erosion, and sedimentary or chemical deposition.

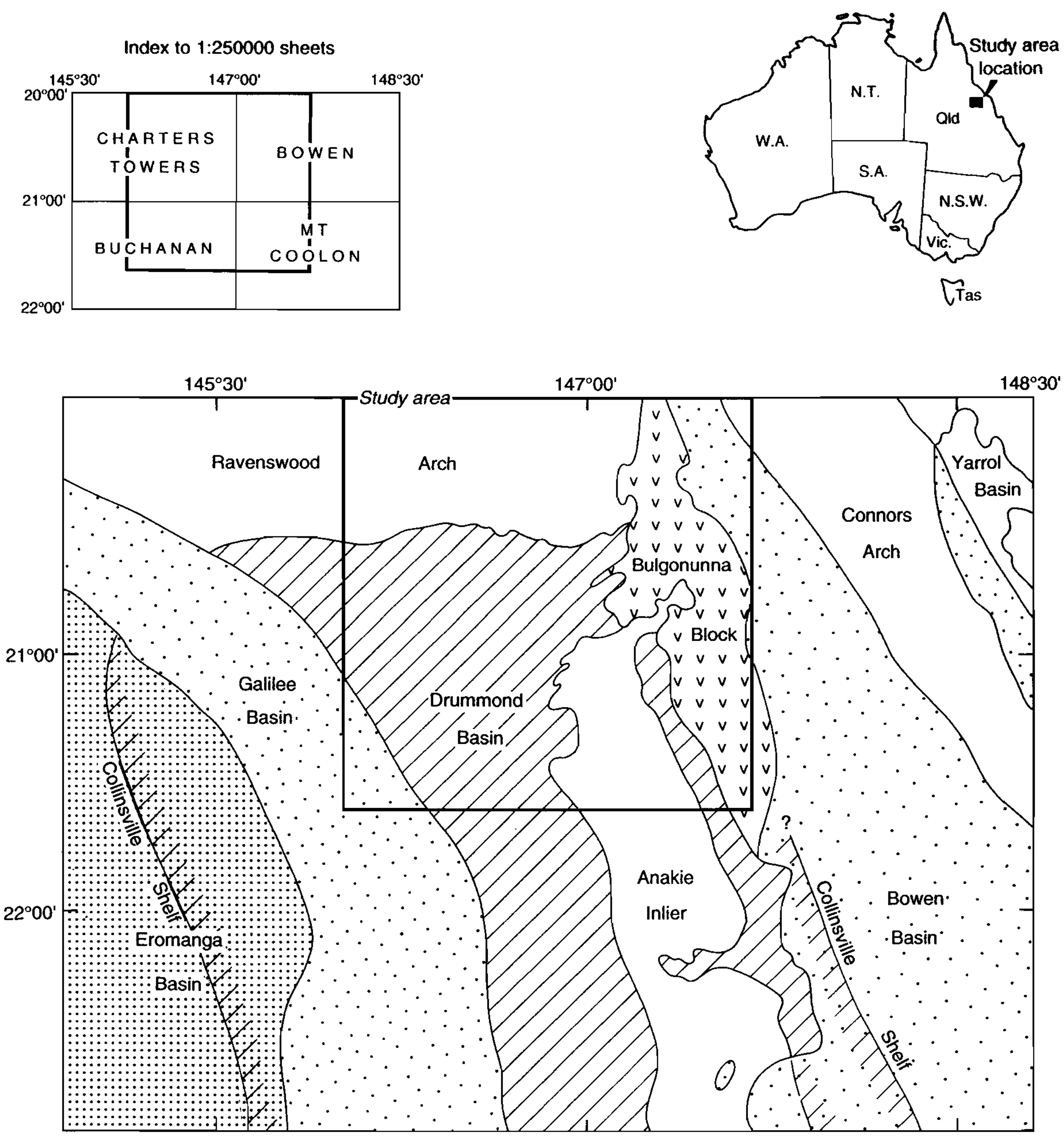



**Figure 1. Location of the study area and structural setting, Charters Towers-North Drummond Basin.**

The climate of the area is tropical semi-arid. Annual rainfall is 550-750 mm; however, falls over the past ten years have been substantially less than normal. Most rain falls in the summer months, and is typically associated with coastal cyclonic disturbances. Daily temperatures range from 21° - 35° C in December, to 7° - 26° C in July.

The vegetation over the area consists predominantly of open woodland and grassland savannah, dominated by eucalyptus, acacia and spear grass.

### 1.3 Generalised Geology

The bedrock (Pre-Tertiary) geology of the study area can be sub-divided into the following structural units: Ravenswood Arch, Anakie Inlier, Drummond Basin, Bulgonunna Block and the Galilee Basin (Figure 1; after Olgers, 1972). The rocks of the Anakie Inlier and Ravenswood Arch are essentially basement to the sediments of the Drummond Basin, which are in turn overlain by volcanics (Bulgonunna Block) and younger sediments (Galilee Basin).

The Anakie Inlier is a north-trending ridge of early-to-mid Palaeozoic rocks surrounded by younger strata of the Drummond and Bowen Basins. The Pre-Devonian Anakie Metamorphics (quartz-mica schists, phyllite, slate, limestone and volcanics), Mid-Devonian volcanics and sediments and Upper-Devonian intrusive granite are the main lithologies of the Inlier (Day *et al.*, 1983).

The Ravenswood Arch (Lolworth-Ravenswood Block) is an east-trending basement ridge at the northern limit of the Drummond Basin. This block consists of early Palaeozoic metamorphics, sediments and volcanics (Seventy Mile Range and Charters Towers Groups - see Hartley *et al.*, 1989), which have been extensively intruded by Mid-to-Lower Ordovician granitoid plutons. Post-granitoid igneous activity in the Carboniferous resulted in extrusion of rhyolitic lavas and pyroclastics associated with porphyry and high-level intrusive complexes (*e.g.*, Mt Leyshon Complex).

The Drummond Basin contains Late Devonian to Early Carboniferous sediments deposited in a structural remnant of a large intermontane basin (Olgers 1972). These sediments were deposited both on the west (mainly) and east of the Anakie Inlier on a basement of early-to-mid Palaeozoic metamorphics and granite (Day *et al.*, 1983). Olgers (1972) recognised three cycles of sedimentation separated by periods of volcanism. Sedimentation ceased at the onset of the Kanimblan Orogeny, during which the sequence was folded and uplifted to form a structural high shedding material into the Bowen and Galilee Basins.

The Bulgonunna Block consists of Bulgonunna Volcanics, which unconformably overlie the Drummond Basin, east of the Anakie Inlier. The Volcanics have a regional dip to the east and consist of porphyritic rhyolitic-to-dacitic flows with pyroclastics, minor andesite, lithic siltstones and sandstone. The Volcanics are attributed a Late Carboniferous to Early Permian age.

The Late Carboniferous to Mid Triassic Galilee Basin formed as a large, shallow intracratonic basin to the west (and south) of the Drummond Basin. The Basin received mainly fluviatile sediments; however they are now mostly covered by later sediments of the Eromanga Basin, with only the northeastern margin (against the Drummond Basin) exposed.

Two Cainozoic sediment systems are developed within the study area; an older system represented by the Southern Cross Formation and its southern correlative, the Suttor Formation; and, a younger system represented by the Campaspe Formation.

The Southern Cross and Suttor formations generally occur as flat-lying caps to mesa and upland areas. These units consist predominantly of fluviatile and lacustrine sandstones and siltstones. Henderson (1996) suggests that the provenance for the sequence was a well-weathered landscape, based on the quartz-rich nature of the sandstones and the presence of kaolinitic clays. Henderson (*ibid.*) also suggests a Palaeocene age for the system, based on a 53 Ma basalt that overlies Suttor Formation at Mt Dalrymple.

The Campaspe Formation consists of poorly sorted, clay cemented sandstones and siltstones with minor conglomerate. Henderson (1996) notes that the general coincidence of the top of the Campaspe Formation with the contemporary landscape leads to the conclusion that the unit essentially has been unmodified since its deposition. Henderson (*ibid.*) also suggests a Pliocene age for the Campaspe Formation based on its stratigraphic relationship between two basalt flows with isotopic ages of 3.8 and 1.35 Ma .

At least one period of extensive weathering has occurred in the Tertiary with evidence of formation of ferruginous duricrust and weathering profiles on both Southern Cross (Suttor) and Campaspe Formation sediments. There is also evidence of a post-Campaspe weathering event as suggested by development of ferruginous nodules and pisoliths on the Campaspe Formation.

## 1.4 Geomorphic Provinces

A preliminary map of geomorphic provinces has been compiled for the Charters Towers - North Drummond Basin area (Figure 2). The base Landsat mosaic is shown in Figure 3. The units have been defined primarily on the basis of drainage texture and photo-form which, when combined, represent landform. The map presented here is preliminary, refinements are expected as field work continues.

Table 1 gives a brief description of the interpreted geomorphic units and associated regolith characteristics. There is no formality in the various unit names, nor is there any convention in the labels. It is anticipated that the terminology and unit definition criteria will evolve.

There are several major catchments that dominate the landscape of the study area, all of which belong to the Burdekin River system. The Burdekin and Campaspe Rivers are in the north; the Cape and Belyando Rivers are in the west; and the Suttor River is in the south. These rivers have given the area dominant erosional characteristics, with a progressive lowering of base-level towards the east and north-east.

### *1.4.1 Eastern Margin of the Study Area*

A zone of moderate-to-high relief, with rugged terrain (unit MRR), occurs along the eastern side of the area, and it is suggested that most previous weathering profiles and materials have been stripped away from this unit (assuming they were developed there in the first place). Field work, however, has indicated that silcretes are preserved over some of the granitic lithologies, and further work is needed to determine their extent.

### *1.4.2 Central Zone of the Study Area*

A zone of complex landforms occurs in the central portion of the study area. This zone has been subdivided into a number of geomorphic units, based on landform and interpreted erosional activity. There are extensive areas of basement lithologies (pre-Tertiary) along with a variable distribution of Tertiary sediments (units UPS, RSm, RSc). It is generally difficult to assign these sediments specifically to one of the Tertiary sediment systems (either Campaspe or Southern Cross Formations). However, as a general statement, most mesas (unit UPS) appear to be part of the Southern Cross Formation.

In the north-central region of the area, there has been extensive stripping of materials, including weathering profiles, from the general region of the Ravenswood Complex (unit UCLG), with preservation of some Tertiary sedimentary outliers (some possibly Quaternary) as mesas (unit UPS - Featherby Wall Stop; Section 2.2). Weathered granitic material (saprolite) is also preserved.

The Rolleston River Catchment (unit CDA) is a particularly active drainage system (possibly reactivated through base level lowering), which is actively encroaching (through headwater retreat) into less active (base level more stable) terrain to the west of it. It should be noted that some remnant mesas in this vicinity could well belong to the Campaspe Formation (unit UFP). The Rolleston Catchment appears to be almost choked, leading to a complex, mixed landscape of eroded basement, eroded Tertiary sediments and Quaternary alluvial and colluvial material.

# LEGEND

**A_F**
Alluvial plains associated with present day drainages; some sediment re-working in stream valleys.

**SW_SS**
Moderate-to-steep terrain with colluvium

**CDA**
Rolleston River drainage catchment: a particularly active catchment that contains sediments derived from erosion of Tertiary formations.

**FUC**
Relatively flat undulating areas with low rises /hills, predominately transported surficial material, which is relict and currently being eroded (i.e., reworked)

**EUP**
Elevated undulating plains, commonly bounded by scarps.

**UFP**
Undulating flat plains of sediments (Tertiary?), now re-worked by cross-cutting streams and encroaching aggressive catchment expansion of other drainage systems; sheetwash and bedload re-working of pre-existing sediments

**RSc**
Remanant sedimentary cover, level or sloping with low mesas and /or their dissected remains

**RSm**
Remanant sedimentary mesa, typically with undulating plateau tops, bounded by steep scarps.

**UPS**
Undulating plateau surfaces, with moderate elevation, commonly bounded by scarps; these areas generally appear old.

**SEDS**
Slightly elevated dissected sediments with trellis drainage pattern; flat-lying but old

**SUH**
Strongly undulating, rounded hilly terrain, low-to-moderate relief with exposed basement rocks

**TSBS**
Thin soils on basement sediments; low-to-moderate relief, dissected terrain

**UCLG**
Strongly dissected (eroded) granitic terrain; low undulating hills, bare eroding ridges with sediment-filled valleys - consisting of thin lithosols

**FeI**
Strongly dissected terrain with iron-staining, probable association with mafic intrusives (?)

**MRR**
Rugged terrain, moderate-to-high elevation, sediments moved through system with minor temporary accumulation

# TRIP STOP LOCATIONS

| | |
|---|---|
| Red Falls | Stop 1 |
| Featherby Walls | Stop 2 |
| Waterloo Area | Stop 3, 4, 5 |
| Pajingo Area | Stop 6, 7, 8 |
| Marandoo T'Off | Stop 9 |
| Police Creek Area | Stop 10, 11, 12, 13, 14 |

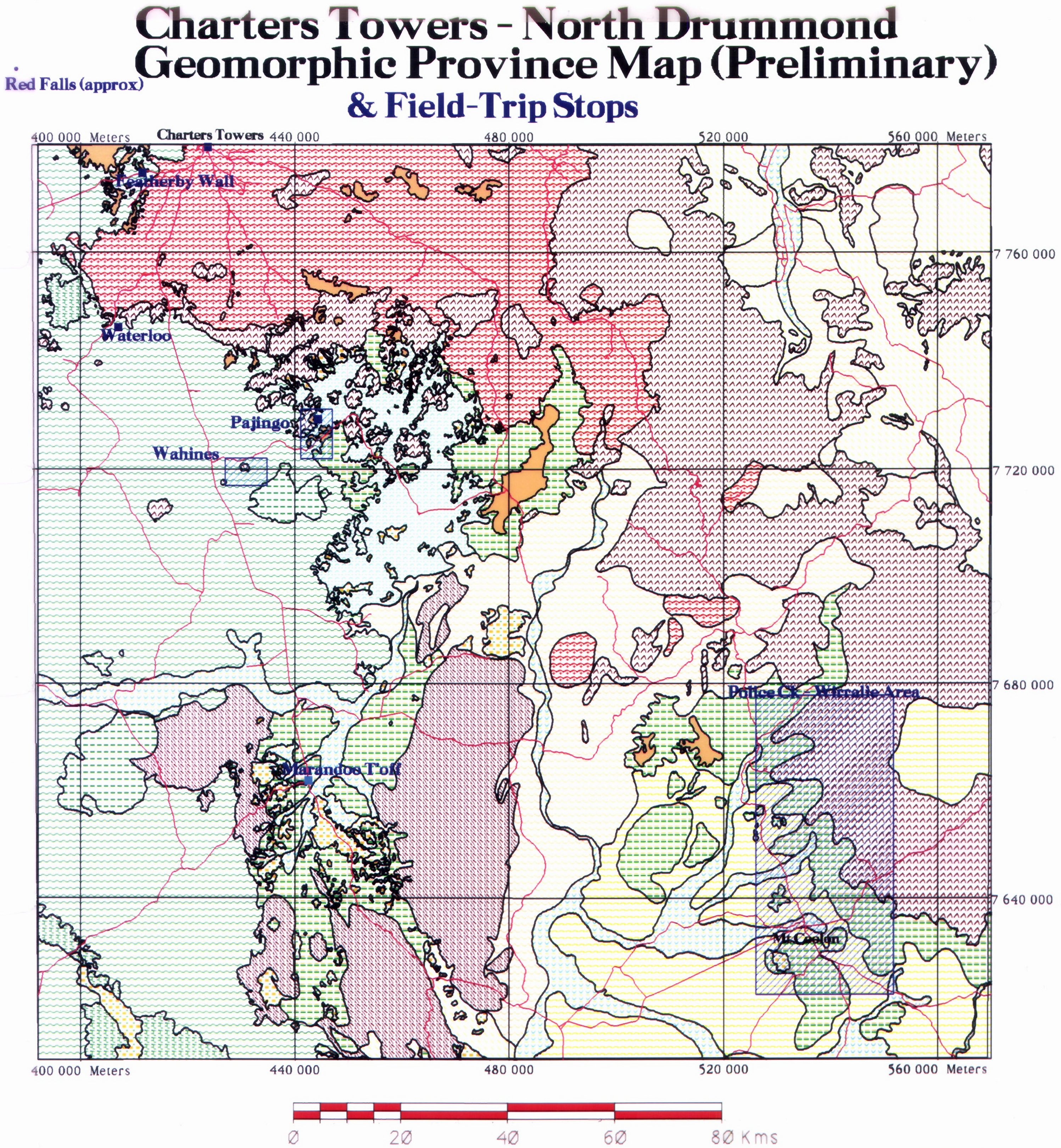



Figure 2. Preliminary map of geomorphic provinces - Charters Towers-North Drummond Basin area (and Field Trip Stops).

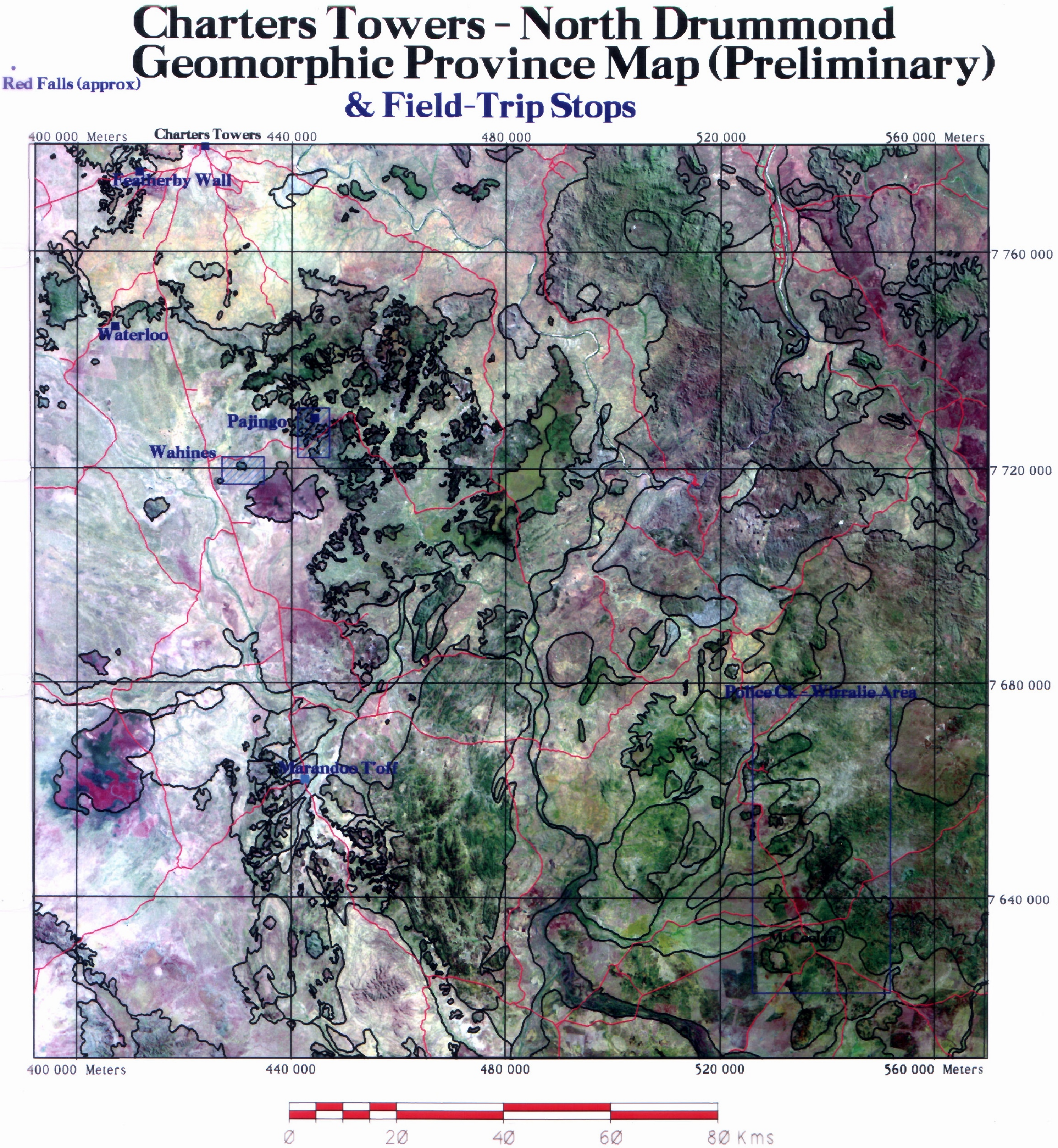



Figure 3. A Landsat mosaic - Charters Towers-North Drummond Area.

**Table 1 :** Table Relating the Geomorphic Descriptions to Regolith Characteristics for the Mapped Geomorphic Units

| Map Unit | Geomorphic Description | Regolith Observations |
|---|---|---|
| A/F | Alluvial plains associated with present-day drainages; some sediment re-working | Detritus derived from erosion of Palaeozoic, Mesozoic and Cainozoic lithologies |
| SW/SS | Moderate-to-steep terrain; sheet wash areas; | Areas with fairly active erosion and detritus through put; unlikely that weathered profile materials have survived |
| CDA | Rolleston River Catchment : an active, almost choked catchment with sediments derived from erosion of Tertiary sediments | Recent alluvial and colluvial material; sediment production exceeds rate of removal; complex landscape. |
| FUC | Relatively flat, undulating areas with low rises/hills, predominantly transported surficial material, which is relict and currently being reworked. | Predominantly recent alluvium and colluvium covering basement and overlying sedimentary units ( *i.e.,* Suttor/ Southern Cross/Campaspe Fms) |
| EUP | Slightly elevated, undulating plains, commonly bounded by scarps, possibly with gilgai development | Areas of black soil, - possibly remnant lake deposits, (apparently caused by ponding within drainages). |
| UFP | Undulating flat plains of sediments (perhaps Tertiary Campaspe Fm); now being re-worked by cross-cutting streams and encroaching catchment expansion; sheetwash and bedload re-working of pre-existing sediments | Extensive plains, with surficial sheetwash and soil development. Field work has shown that, at a number of places, these deposits include a layer of ferruginous nodules that overlie a buried, weathed profile. The extent of this layer needs to be evaluated further. (Campaspe Fm) |
| RSc | Remnant sedimentary cover, level or sloping with low mesas and/or their dissected remains | Dissected sedimentary cover, may contain partially preserved weathering profiles; (may be related to either Campaspe or Southern Cross Fm lithologies) |
| RSm | Remnant sedimentary mesas, typically with plateau tops, bounded by steep scarps unless they abut higher ground | Mesas commonly with preserved weathering profiles, but not everywhere; (may be related to either Campaspe or Southern Cross fm lithologies) |
| UPS | Undulating plateau surfaces, with moderate elevation, commonly bounded by scarps | Ferruginous duricrust present; some residual sand developed on mesas, plateaus, backslopes. (Southern Cross Fm or equivalent) |
| SEDS | Slightly elevated, dissected sediments with trellis drainage patterns; flat-lying (inlier within UFP unit) | Lithosols and colluvium on slopes, alluvial material in valleys; rate of sediment production approximately equals rate of removal |
| SUH | Strongly undulating, rounded, hilly terrain, low-to-moderate relief with exposed basement | Lithosols and colluvium on slopes, alluvial material in valleys; rate of sediment production exceeds rate of removal. Remnant outliers of weathered basement |
| TSBS | Thin soils on basement sediments; low-to-moderate relief | Lithosols and colluvium on slopes, alluvium in valleys. Moderate to thin cover as basement structural trends show through. Remnant outliers of weathered basement |
| UCLG | Undulating country, consisting of thin lithosols over strongly dissected (eroded) granitic terrain | Some preservation of saprolite on hills and topographically higher areas |
| FeI | Strongly dissected low terrain with iron staining, possibly associated with mafic intrusives | Strongly weathered mafic intrusives, ferruginous soils and ferruginous saprolite probably preserved |
| MRR | Moderate-to-high relief, rugged terrain; bedrock characteristics evident. | Minor lithosols and colluvium on slopes, alluvium in valleys is removed with little accumulation, rate of sediment production approx equals rate of sediment removal |

In the south-central part of the study area (Blowhard Creek - *not marked on map*), the complexities of the Rolleston River Catchment are repeated on a broader-scale. Areas of outcropping basement (folded sediments and volcanics) are covered by partially eroded Tertiary sequences in various states of truncation and preservation.

In the south-eastern-central part of the study area (the Suttor River Catchment including both Police and Rosetta creeks), Tertiary sediments (units RSc and RSm) on the western flanks of the MRR unit have been described as part of the Suttor Formation (*i.e.,* the Southern Cross Formation). These sediments have been eroded, in part, to form extensive areas of flat, undulating terrain (unit FUC).

### *1.4.3 The Western Zone of the Study Area*

The western part of the study area appears to be a more mature landscape, which is now being encroached by drainage catchments of the central part of the study area. In this western region there is an extensive plain (units EUP and UFP) which is considered to consist of Tertiary sediments of the Campaspe Formation, with smaller elevated inliers of flat-lying 'older' Gaililee Basin sediments (unit SEDS) forming basement-highs and ridges.

## 1.5 Implications for Exploration

Some preliminary implications for exploration can be inferred from the map with the following caveat: The landscape geomorphic units, defined herein, are not homogenous regolith units; some regolith variability is expected which is dependent on the scale of the observations. Therefore, the validity of the following statements for particular areas needs to be established.

1) In those areas with moderate-to-steep terrain, both with and without colluvium cover (units MRR and SW-SS), traditional geochemical prospecting techniques (stream sediment, soil and rock chip sampling) should be adequate to detect concealed mineralisation (providing there is a geochemical halo);

2) In the central part of the area, the exposed bedrock landforms (units TSBS, SUH, UCLG, & FeI) may contain saprolitic material. Care may be needed to determine the nature of the materials sampled and their geochemical significance. Optimal sampling strategies for this landscape are yet to be determined for this environment.

3) Areas covered by more recent alluvium, derived from erosion of Tertiary and older materials (units, A/F, CDA) may require more extensive investigation. The nature and thickness of these Quaternary materials needs to be determined, as they are likely to mask the geochemistry beneath and sub-surface sampling is likely to be necessary.

4) In those areas covered by ferruginous sediments of the Southern Cross Formation (units RSc, RSm and UPS) geochemical dispersion from underlying mineralisation may be evident in particular regolith materials (ferruginous nodules and pisoliths). Further investigations are needed.

5) Initial results suggest that there is a non-continuous, but widespread occurrence of a ferruginous nodular layer within the UFP unit (presumed Campaspe Formation). The significance of this layer for exploration geochemistry depends on a large number of factors, and it could easily be argued that this is not a particularly favourable sampling medium (*e.g.,* it is, itself, derived from the Southern Cross Formation). However, it is also highly likely that the Campaspe Formation can occur both marginally to and at lower topographic elevations than the Southern Cross Formation, so it could, very possibly, directly overlie basement, without the Southern Cross Formation being present. Hence, dispersion from underlying mineralisation may be evident. Further work is needed here.

## 2.0 RED FALLS

*K.M. Scott and Li Shu*

### 2.1 STOP 1

*Location:* *367751E 7795918N*
*Geology:* *Campaspe Formation, Southern Cross Formation*
*Landform:* *Knick Point*
*Regolith:* *Ferruginous profile on southern and Campaspe Formations, mottled and ferruginous duricrust, nodular calcrete.*

The profile exposed in the creek is the type section for the Campaspe Formation (Wyatt *et al*., 1970) and is one of the few places in the region where Campaspe Formation can be seen overlying Southern Cross Formation (Figure 4 and 5A). In this location the Campaspe Formation consists of 14 m of coarse quartz-rich sands within a more clay-rich matrix. These sands unconformably overlie the Southern Cross Formation and may show cross-bedding and other bedding features (Figure 5B). At 1.8 m from the top of the section, nodular calcrete in a matrix of quartz and feldspar occurs (Nind, 1988). Weak ferruginisation, resulting in the cementing of quartz-rich grains by iron oxides, may occur at the top of the profile (Wyatt *et al*., 1970). This ferruginous horizon breaks down to form a lag composed mainly of 2-25 mm buckshot gravel, mainly Fe-stained and cemented sandstone with some large angular quartz fragments and occasional pisoliths and nodules (Figure 5C). The coarse gravels (samples 129986A and B, especially the hand picked Fe-rich material) have As, Cr, Cu, Pb and V preferentially concentrated within them. The fine material is richer in Al, Mg, Ca, Na, K, Ti, Ba, Cl, Co, La, Nb, Rb, Sr, Th, Y, Zn and Zr (Table 2). The bulk of the Campaspe Formation here consists of white to buff argillaceous sandstone (Figure 5D).

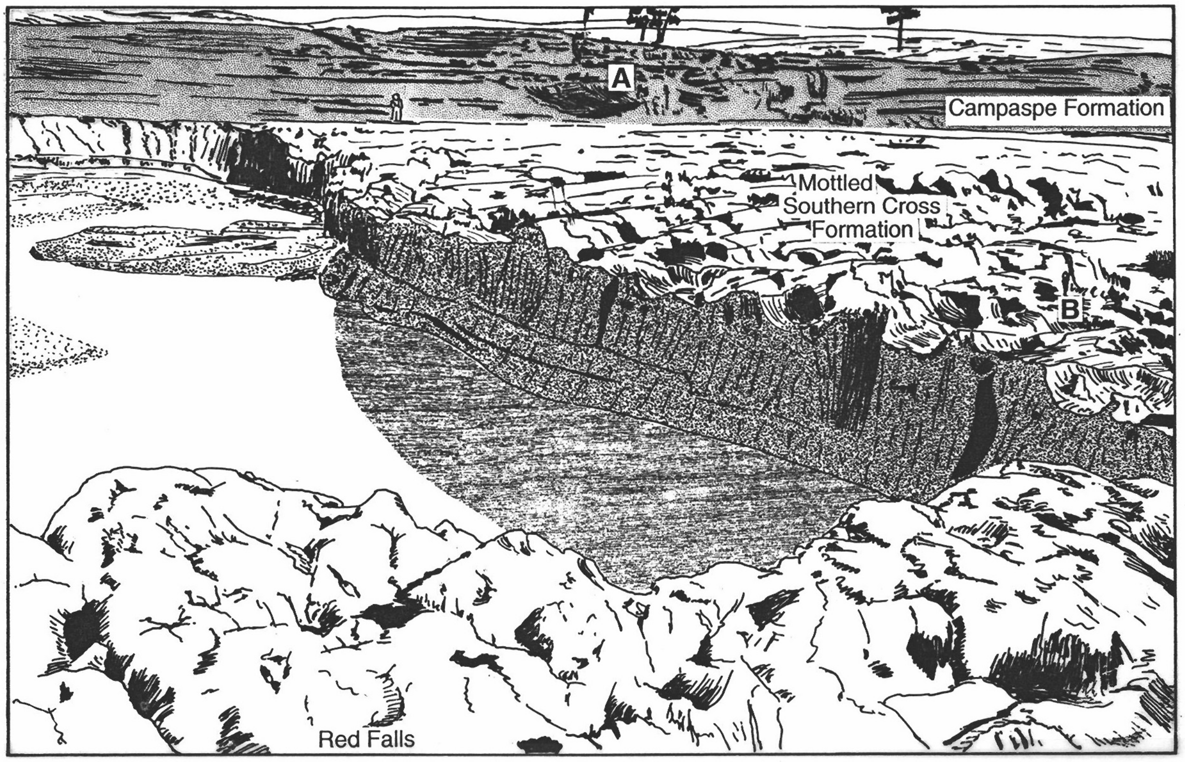



Figure 4. Red Falls on Lolworth Creek, northwest of Charters Towers. The Southern Cross Formation has been deeply weathered and ferruginised, forming the channel bed and the waterfall. The Campaspe Formation is exposed in the valley wall.

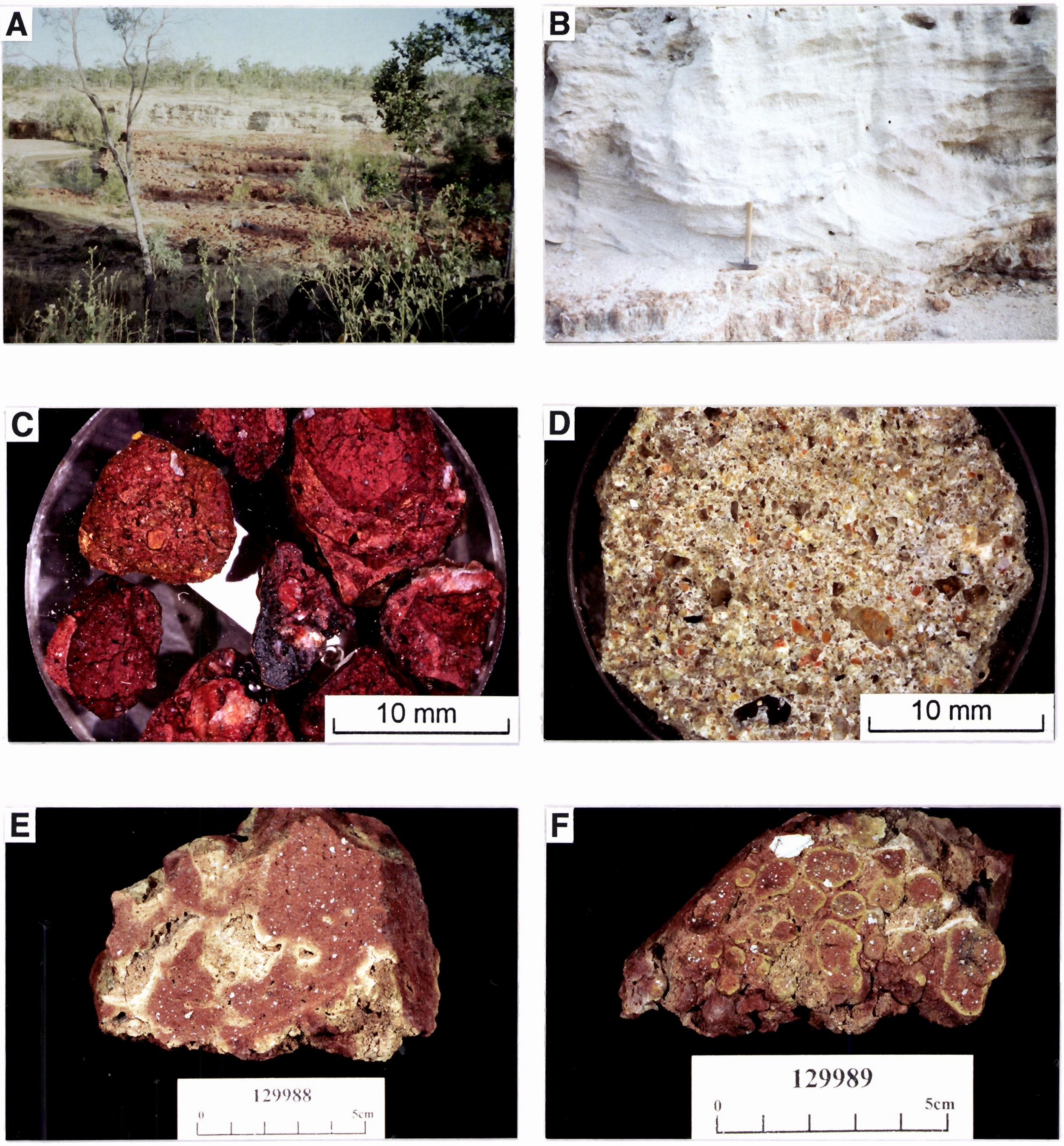



Figure 5A. Campaspe Formation (white) unconformably overlying Southern Cross Formation (red) at Red Falls.

Figure 5B. Cross-bedding at base of Campaspe Formation, Red Falls.

Figure 5C. Hand picked Fe-rich lag, derived from duricrust at top of Campaspe Formation, showing incorporation of pisoliths and quartz grains into fragments. (Sample 129986A, Red Falls).

Figure 5D. Argillaceous gritty Campaspe Formation. (Sample 129987, Red Falls).

Figure 5E. Mottled Southern Cross Formation, showing its gritty nature and irregular bleaching about root casts. (Sample 129988, Red Falls).

Figure 5F. Cemented pisoliths with more goethitic cutans in Southern Cross Formation (white - quartz grains). (Sample 129989 Red Falls).

The Southern Cross Formation consists of gritty sandstone which has been ferruginized and forms an incomplete lateritic weathering profile at this location. Mottled material with voids within less Fe-rich areas (which reflect root casts) and bands of cemented pisoliths with more goethitic cutans occur in the profile exposed in the creek bank and floor (Figures 5E-F). The pisolitic sample is more Fe rich than the mottled material and tends to have slightly higher chalcophile element contents (As, Cr, Cu, Pb and V; Table 2). These samples have a Ti/Zr ratio = 21 which is slightly higher than that for the Campaspe Formation duricrust-derived soil samples (Table 2).

**Table 2. Compositions of samples, Red Falls**
(major components, wt%; minors, ppm)

| | Campaspe Derived Soil | | | Southern Cross Formation | |
|---|---|---|---|---|---|
| **Sample type** | **Fe rich** | **Coarse +2 mm** | **Fine -75 μm** | | |
| **Sample No.** | **129986A** | **129986B** | **129986F** | **129988** | **129989** |
| **Depth (m)** | **0** | **0** | **0** | **15** | **17** |
| $SiO_2$ | 57.2 | 69.0 | 67.5 | 58.0 | 52.2 |
| $Al_2O_3$ | 9.46 | 6.65 | 15.0 | 19.6 | 18.6 |
| $Fe_2O_3$ | 25.5 | 18.1 | 3.79 | 8.93 | 17.1 |
| MgO | 0.10 | 0.07 | 0.32 | 0.57 | 0.26 |
| CaO | 0.04 | 0.03 | 0.26 | 0.20 | 0.15 |
| $Na_2O$ | 0.01 | 0.01 | 0.24 | 0.08 | 0.07 |
| $K_2O$ | 0.34 | 0.27 | 1.29 | 0.38 | 0.33 |
| $TiO_2$ | 0.40 | 0.29 | 1.17 | 0.88 | 0.79 |
| MnO | 0.16 | 0.10 | 0.16 | 0.04 | 0.10 |
| $P_2O_5$ | 0.07 | 0.06 | 0.08 | 0.06 | 0.10 |
| $SO_3$ | 0.01 | 0.01 | 0.03 | 0.01 | 0.02 |
| As | 33 | 25 | 2 | 4 | 9 |
| Au (ppb) | <5 | <5 | <5 | <5 | <5 |
| Ba | 180 | 95 | 240 | 140 | 240 |
| Br | <2 | <2 | 5 | <2 | <2 |
| Ce | 170 | 110 | 110 | 91 | 94 |
| Cl | <10 | <10 | 740 | <10 | <10 |
| Co | 9 | 5 | 27 | 1 | 3 |
| Cr | 200 | 160 | 32 | 35 | 110 |
| Cs | <1 | <1 | 4 | 2 | 2 |
| Cu | 16 | 17 | 5 | 23 | 32 |
| Ga | 12 | 9 | 18 | 25 | 22 |
| La | 11 | 11 | 71 | 20 | 18 |
| Nb | 8 | 5 | 23 | 12 | 10 |
| Ni | 26 | 22 | 22 | 12 | 14 |
| Pb | 120 | 74 | 44 | 22 | 51 |
| Rb | 27 | 19 | 100 | 25 | 26 |
| Sb | 1 | 1 | <1 | <1 | 1 |
| Sr | 13 | 11 | 48 | 38 | 39 |
| Th | 12 | 10 | 24 | 16 | 18 |
| W | 3 | 2 | <2 | <2 | <2 |
| U | 4 | 3 | 3 | 2 | 3 |
| V | 450 | 330 | 70 | 150 | 300 |
| Y | 17 | 19 | 75 | 19 | 11 |
| Zn | 8 | 10 | 24 | 38 | 49 |
| Zr | 200 | 150 | 840 | 240 | 220 |
| Ti/Zr | 12 | 12 | 12 | 22 | 21 |

## 2.2 STOP 2: Featherby Walls

*Location:* *411579E 7774720N*
*Geology:* *Southern Cross Formation, Ravenswood Granodiorite*
*Landform:* *Mesa*
*Regolith:* *Megamottles, lateritic pisoliths and nodules*

The Featherby Walls form an elongate mesa, rising 25 m above the surrounding pediment (Figure 6). It consists of sandstones of the Southern Cross Formation unconformably overlying Ravenswood Granodiorite. At the base of the mesa in the area of the "car park", flat-lying siltstones-mudstones with graded-bedding and pebbles up to 7-8 mm in size overlie weathered granitic material. Above this minor mottling and ferruginous pisoliths and nodules (<2 mm up to 15 mm) occur (Figure 7A). The mesa slope directly above the "car park" is covered with ferruginous scree materials; however some outcrop of clayey-mudstone and grits can be found. Towards the mesa top there is a zone of ferruginous concentration (top 3 m) with development of megamottles. Evidence of bedding becomes less obvious, but still there is a gross sense of layering. There is a tendency for these

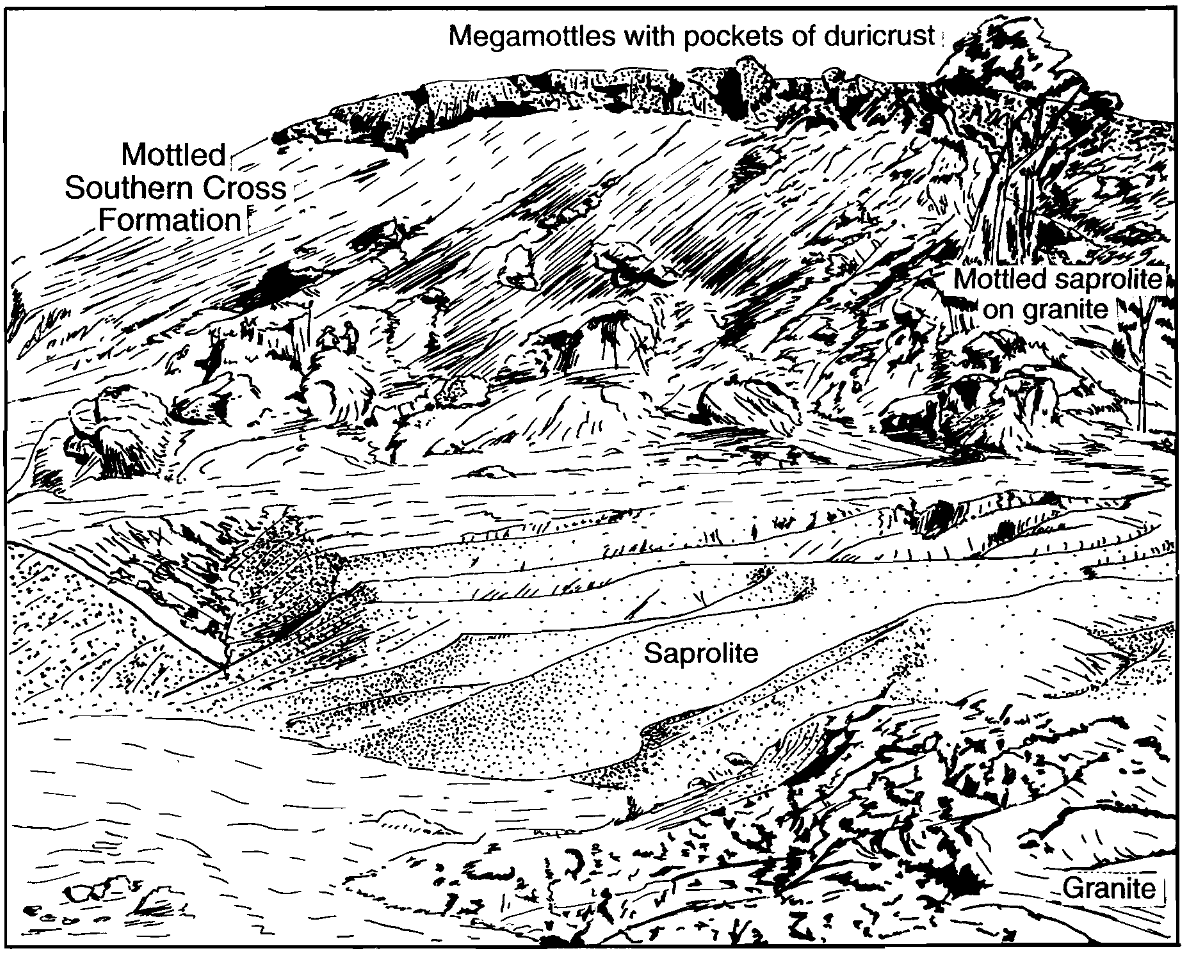



Figure 6. General view of a small mesa forming a part of the Featherby Wall, west of Charters Towers, showing fresh bedrock of granite, saprolite, mottled saprolite, mottled Southern Cross Formation and a duricrust cap.

sediments to appear more quartz-rich than elsewhere, an observation possibly explained by profile collapse following the removal of clay material (eluviation?). (Such mottles form by segregation of clay and Fe oxides probably controlled by sub-vertical cleavage in the saprolite). The top of the megamottled zone forms a pock-marked surface ("jacuzzi" landscape) due to removal of the soft clay material between the more Fe-rich areas (Figure 7B). Some ferruginous gravel derived from the breakdown of the more resistant material can be accumulated in such depressions.

On the eastern side of the mesa, megamottling can be seen developed on granitic material, and this gives rise to a "mini-tower" landscape. The actual contact between the sediments and the granitic material is not obvious.

A

B

Figure 7A. Mottling in saprolite, Featherby Walls.

Figure 7B. Pock-marked ("jacuzzi") surface on top of megamottled zone, Southern Cross Formation, Featherby Walls.

## 3.0 WATERLOO AREA

*K.M. Scott*

### 3.1 STOP 3: Waterloo Erosion Gully

***Location:*** *405400E 7746516N*
***Geology:*** *Mount Windsor Volcanics/Trooper Creek Formation?*
***Landform:*** *Gently sloping plain*
***Regolith:*** *Greg brown soil, weakly cemented pisoliths and gravels*

Grey-brown soil (0.3 m thick) overlies 0.5 m of weakly cemented pisoliths and gravels which in turn overlie a conglomeratic greywacke (with angular and sub-rounded quartz clasts and grains) cemented by drusy silica in the floor of the gully (Figures 8 and 9A-C). The soil has 30% of its weight as fine material <75 μm and 14% coarser than 2 mm. The coarse material consists of Fe-stained quartz and lithic fragments. Some quartz grains are sub-rounded. Comparison of the chemistry of the coarse and fine fractions reveals that the coarser fraction is more Fe-rich and has higher As, Cr, Cu, Ga, Ni, Pb and V contents. The finer fraction is particularly Si rich but also contains elevated Ca, Na, K, Ti, Ba, Br, Cl, Co, La, Nb, Rb, Sr, Th, Y and Zr relative to the coarser material. Au is also concentrated in the fine fraction (Table 3).

Pisolitic and gravelly material from between 0.3 and 0.8 m is cemented by Fe and Mn oxide (Figures 9D-F). These samples have somewhat similar levels of the economically significant trace elements (As, Cu and Pb) as the coarse surficial material but Ba, Ce, Co and Sr are greatly elevated, reflecting their association with Mn, and Cr and V are depleted relative to the surficial material (Table 3). Au is also present in one sample.

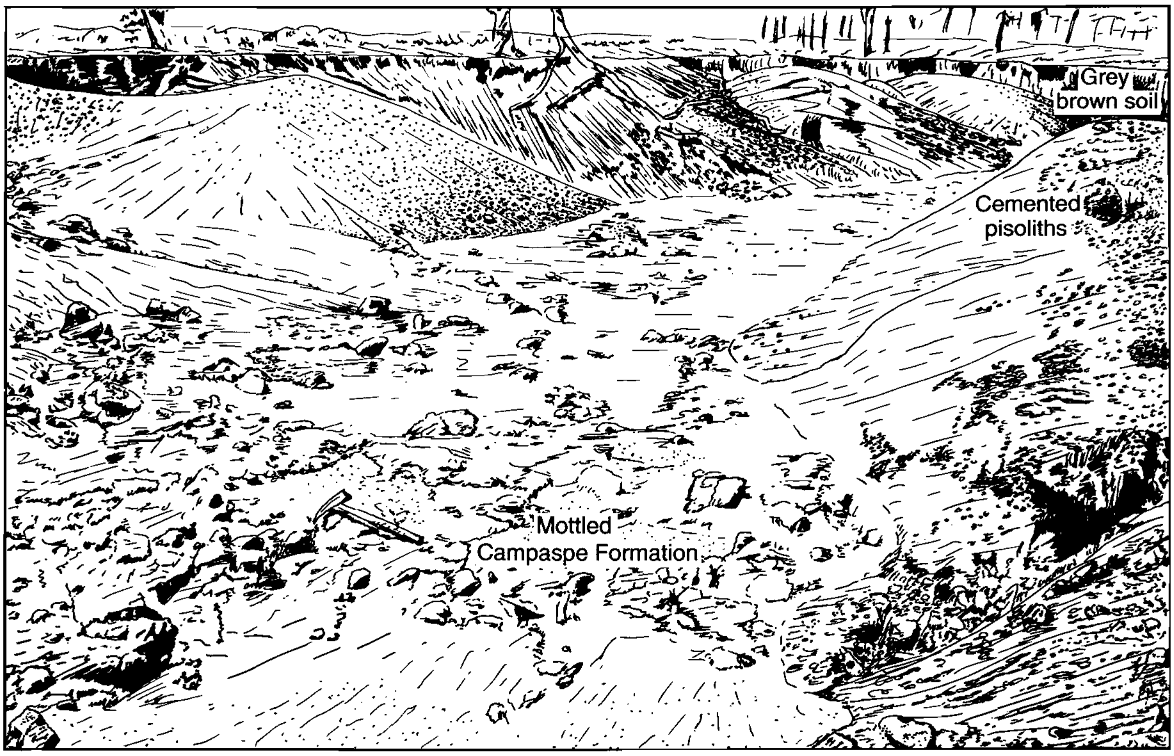



Figure 8. Erosion gully at the Waterloo Prospect. The sketch shows soil, pisoliths, cemented pisoliths and mottled Campaspe Formation.

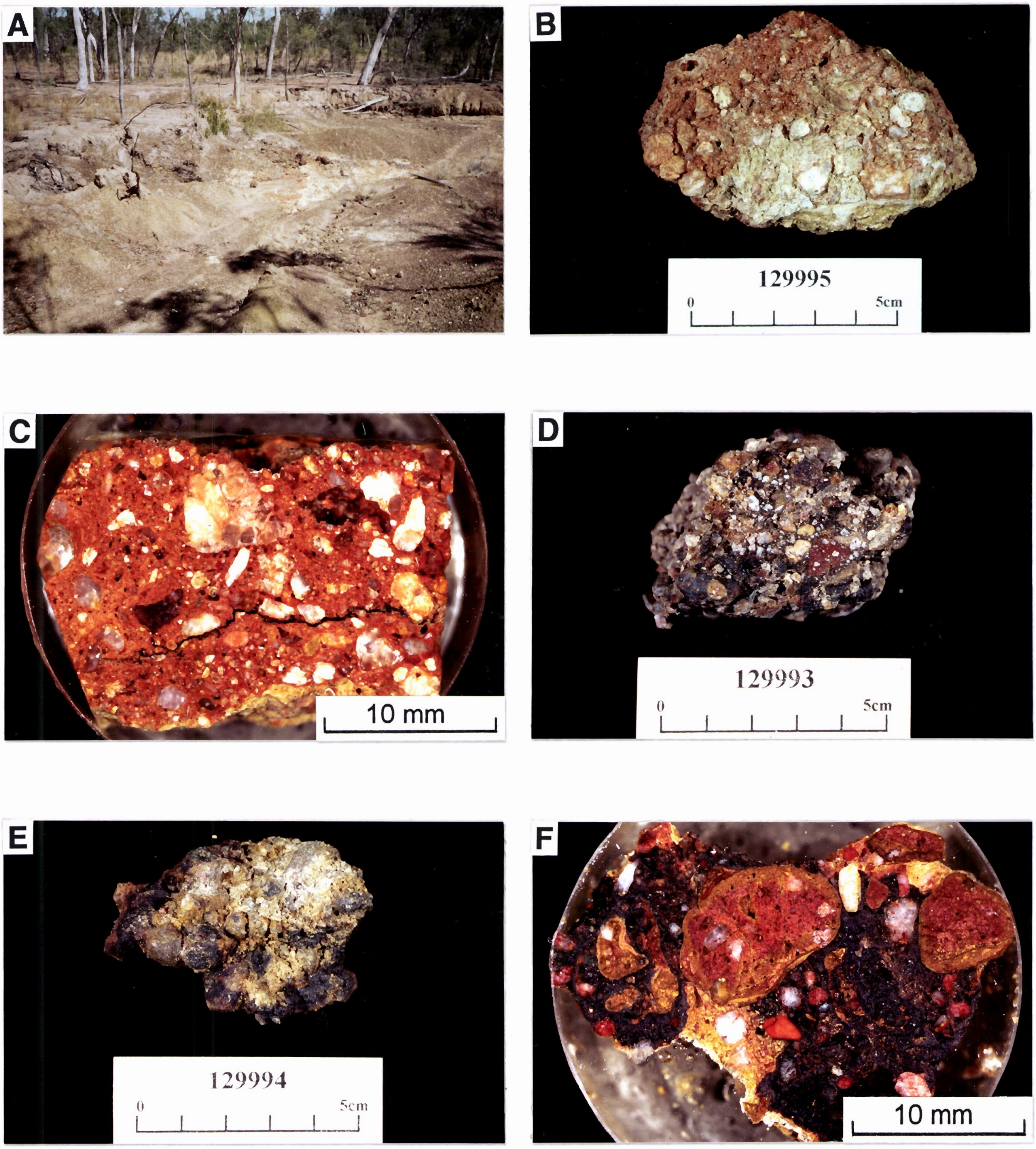



Figure 9A. Erosion gully, Waterloo area, showing soil overlying weakly cemented pisoliths.

Figure 9B. Conglomeratic greywacke (saprolitic Campaspe Formation) forming floor of Waterloo Erosion Gully. (Sample 129995).

Figure 9C. Detail of sample 129995.

Figures 9D-E. Fe- and Mn-cemented gravels from Waterloo Erosion Gully. (Samples 129993, 129994).

Figure 9F. Fe- and Mn-cemented pisoliths and quartz grains. (Sample 129994, Waterloo Erosion Gully).

Well indurated Campaspe Formation material from the floor of the gully contains only low Fe and hence has low chalcophile element contents. However it does contain significant Na (reflecting its plagioclase content) and Ba, Sr and S (possibly reflecting Sr-barite). Although still low, Zn is higher in this sample than in others of the profile (Table 3). The presence of the barite and elevated Zn may imply the incorporation of material derived from weathered mineralisation.

The Ti/Zr ratios of all samples (Table 3) reflect derivation of parent material from felsic rocks.

**Table 3. Composition of samples, Waterloo Erosion Gully**
(major components, wt%, minors, ppm)

| | Soil | | | | Mottled Campaspe Formation |
|---|---|---|---|---|---|
| **Sample type** | **Coarse +2 mm** | **Fine -75μm** | **Cemented** | **Gravels** | |
| **Sample No.** | **29992A** | **129992F** | **129993** | **129994** | **129995** |
| **Depth (m)** | **0** | **0** | **0.3** | **0.8** | **1.0** |
| $SiO_2$ | 55.9 | 81.9 | 68.6 | 62.8 | 70.1 |
| $Al_2O_3$ | 9.52 | 7.88 | 8.25 | 9.70 | 13.0 |
| $Fe_2O_3$ | 27.8 | 1.76 | 15.9 | 18.3 | 3.95 |
| MgO | 0.10 | 0.16 | 0.14 | 0.13 | 0.69 |
| CaO | 0.04 | 0.20 | 0.09 | 0.06 | 0.56 |
| $Na_2O$ | 0.05 | 0.54 | 0.68 | 0.21 | 2.24 |
| $K_2O$ | 0.17 | 0.40 | 0.29 | 0.26 | 0.58 |
| $TiO_2$ | 0.41 | 1.09 | 0.42 | 0.50 | 0.41 |
| MnO | 0.07 | 0.06 | 0.36 | 0.54 | 0.03 |
| $P_2O_5$ | 0.08 | 0.03 | 0.08 | 0.07 | 0.02 |
| $SO_3$ | 0.02 | 0.02 | 0.01 | 0.01 | 0.07 |
| As | 35 | <1 | 22 | 24 | 2 |
| Au (ppb) | <5 | 7 | 12 | <5 | <5 |
| Ba | 51 | 120 | 210 | 380 | 1600 |
| Br | <2 | 3 | <2 | <2 | <2 |
| Ce | 140 | 75 | 330 | 480 | 47 |
| Cl | <10 | 150 | <10 | 100 | 10 |
| Co | <1 | 17 | 150 | 170 | 13 |
| Cr | 170 | 12 | 78 | 80 | 3 |
| Cs | 2 | 2 | 1 | 1 | <1 |
| Cu | 25 | 8 | 24 | 33 | 8 |
| Ga | 18 | 7 | 13 | 15 | 16 |
| La | 16 | 59 | 24 | 31 | 73 |
| Nb | 1 | 17 | 4 | 9 | 4 |
| Ni | 22 | 7 | 25 | 30 | 9 |
| Pb | 62 | 30 | 61 | 70 | 13 |
| Rb | 14 | 38 | 14 | 17 | 24 |
| Sb | 2 | <1 | 1 | 1 | <1 |
| Sr | 9 | 32 | 20 | 14 | 110 |
| Th | 10 | 18 | 9 | 10 | 7 |
| W | 3 | <2 | 3 | 2 | <2 |
| U | 2 | <2 | <2 | <2 | <2 |
| V | 450 | 54 | 290 | 290 | 58 |
| Y | 16 | 65 | 25 | 29 | 55 |
| Zn | 7 | 17 | 12 | 11 | 27 |
| Zr | 160 | 660 | 160 | 180 | 100 |
| Ti/Zr | 15 | 10 | 16 | 17 | 24 |

### 3.2 STOP 4: Waterloo Case Study

In the Mount Windsor Subprovince, polymetallic mineralisation occurs within the andesites and felsic volcanics of the Trooper Creek Formation (Reward, Highway, Handcuff, Liontown, Magpie Waterloo, Agincourt and Warrawee) or in the stratigraphically lower rhyolites of the Mt Windsor Volcanics (Thalanga; Berry *et al.*, 1992; Figure 10). However much of the prospective volcanic terrain is covered by sandstones of the Tertiary Campaspe Formation. Although many of these deposits crop out and were found by prospectors (Liontown and Highway), the discoveries after 1972 were geochemical exploration successes, resulting from gossan recognition or stream/soil geochemistry surveys (Berry *et al.*, 1992). However, in 1981 the East Thalanga deposit was found below 20-80 m of Campaspe Formation (Hartley and Alston, 1995). At this deposit a dispersion train for Cu, Pb and Zn was found within the Campaspe Formation (Garnier *et al.*, 1989). These authors argue that, at least, part of the geochemical halo is the result of chemical dispersion and recommended that systematic analysis of Campaspe Formation material be undertaken because the position within the cover sequence could not be predicted *a priori*. A similar dispersion halo has also been identified at Waterloo (Hartley and Alston, 1995).

The significance of weathered footwall pyritic schist in a creek adjacent to the Waterloo deposit was recognised by Peter Gregory (now BHP) in 1985. Subsequent RAB drilling through soil and Campaspe Formation of the pediment of the area ultimately led to the definition of a resource of 372,000 tonnes at 3.8% Cu, 19.7% Zn, 2.8% Pb, 94 g/t Ag and 2 g/t Au (inferred) in the central Trooper Creek Formation, *i.e.* at the same level as most other deposits in the Mt Windsor Subprovince (Berry *et al.*, 1992). The deposit has been quoted as occurring below up to 60 m of Campaspe Formation (Berry *et al.*, 1992). However, work done during this project (Scott, 1995b) suggests that the thicknesses of cover may be over estimated in some cases and the dispersion train at Waterloo occurs at the base of the Campaspe Formation. Thus dispersion occurs in an identifiable location and is postulated to be entirely of mechanical origin at least for Pb. The change from Campaspe Formation into weathered bedrock is marked by the sudden cessation of feldspar- and smectite-bearing assemblages and the start of kaolinite-dominant assemblages. Bands of dolomite and Fe oxides also occur immediately beneath the feldspar-bearing rocks and are suggested to represent the Fe rich surface and pedogenic dolomite formation prior to deposition of the Campaspe Formation. Chemical criteria, *e.g.* Ti/Zr ratios are also suggested to readily differentiate the felsic-derived sandstones from weathered andesitic volcanics (Figures 11-18).

NOTE: The thickness of alluvial soil in the creek bank adjacent to the "discovery footwall schist" in the creek indicates that bedrock occurs within 10 m of the current surface in the orebody area.

***THIS SITE IS REGARDED AS A SIGNIFICANT GEOLOGICAL SITE - NO SAMPLING/HAMMERING ALLOWED.***

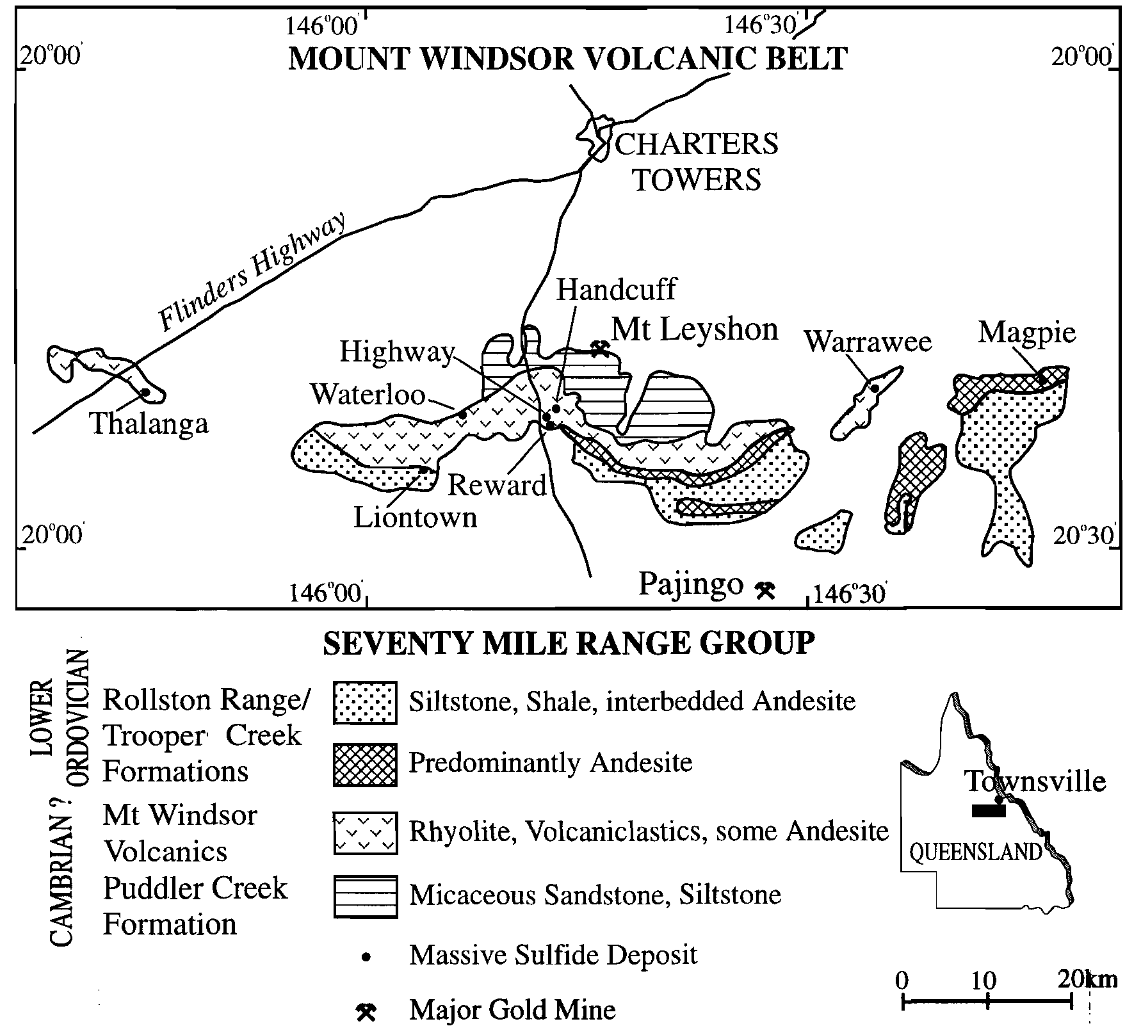



**Figure 10.** Location map of Mt Windsor Sub-province volcanics and mineral deposits of the region (after Hartley and Alston, 1995).

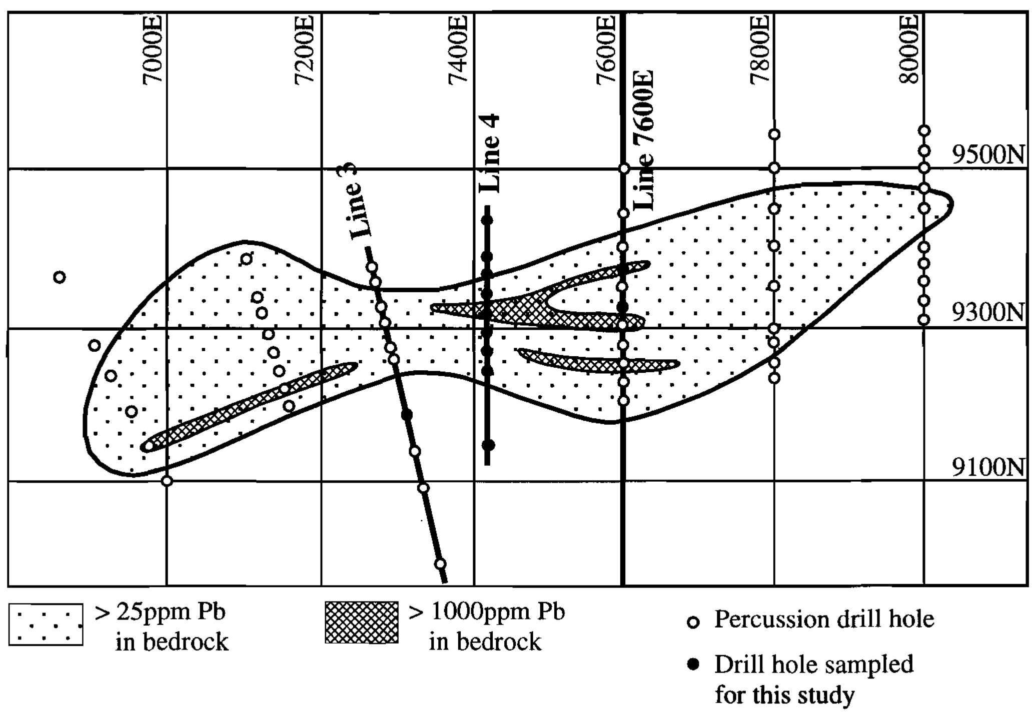



**Figure 11.** Plan of the Waterloo deposit, showing bedrock Pb contents and location of drill holes (based on the Penarroya (Aust) Pty Ltd grid).

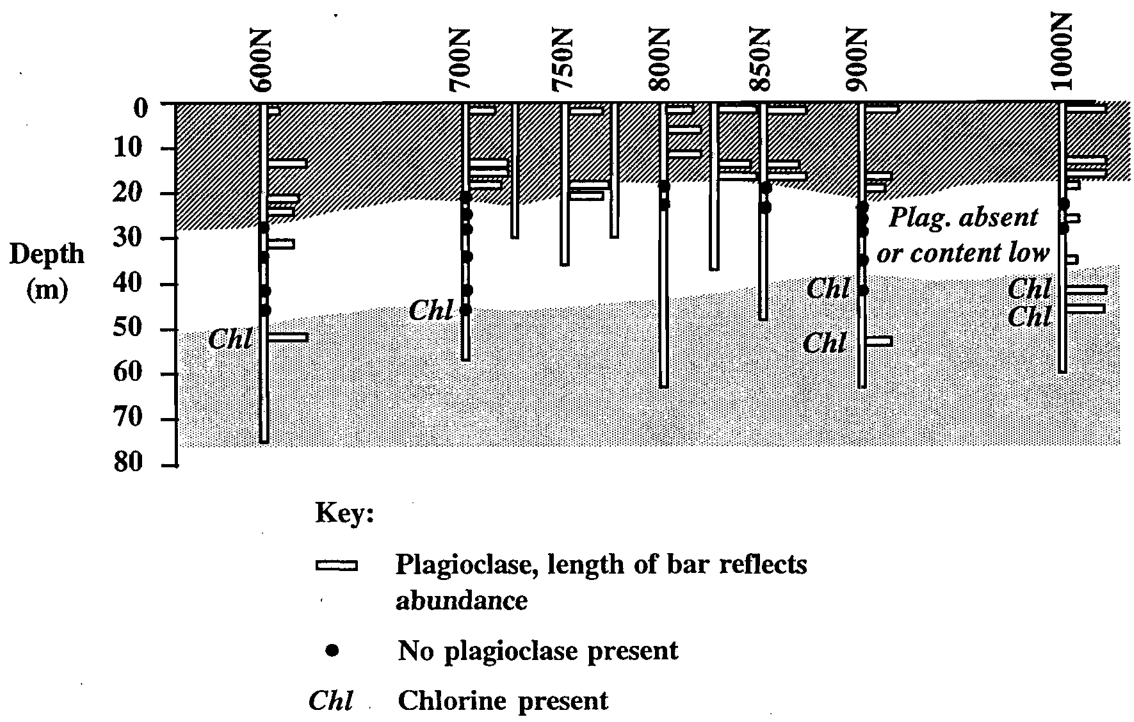



Figure 12. Plagioclase distribution, Line 4, Waterloo, showing upper (regolith) plagioclase zone and lower (fresh rock) plagioclase zones separated by zone with little or no plagioclase.

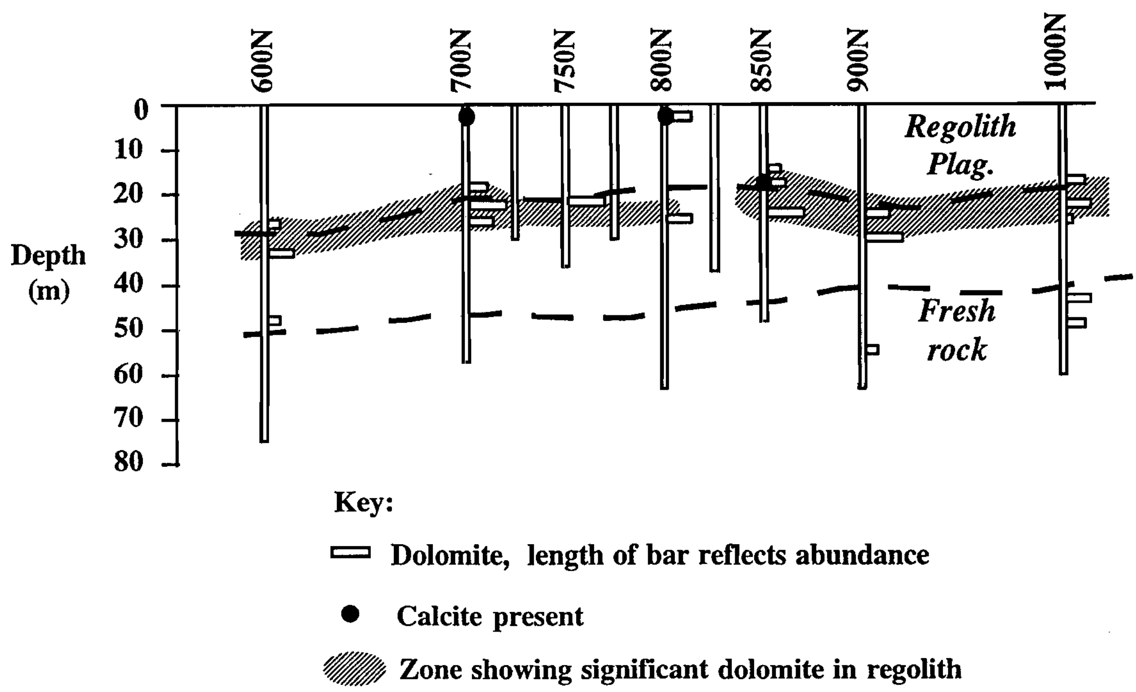



Figure 13. Carbonate distribution, Line 4, Waterloo, relative to plagioclase zones.

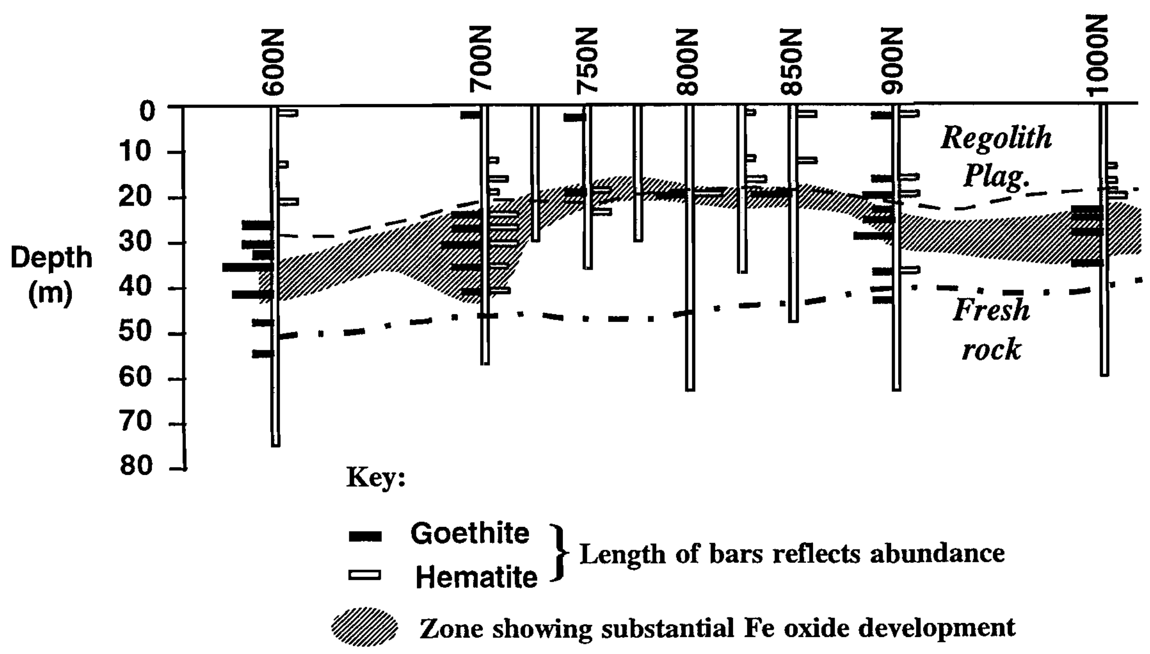



Figure 14. Goethite and hematite distributions, Line 4, Waterloo, relative to plagioclase zones.

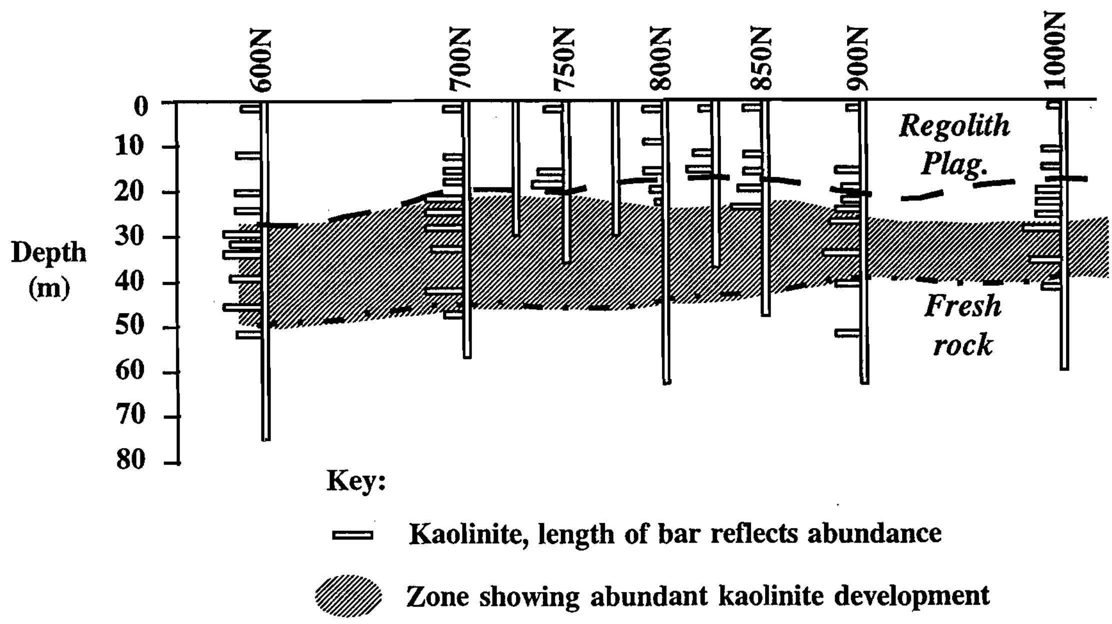



Figure 15. Kaolinite distribution, Line 4, Waterloo, relative to plagioclase zones.

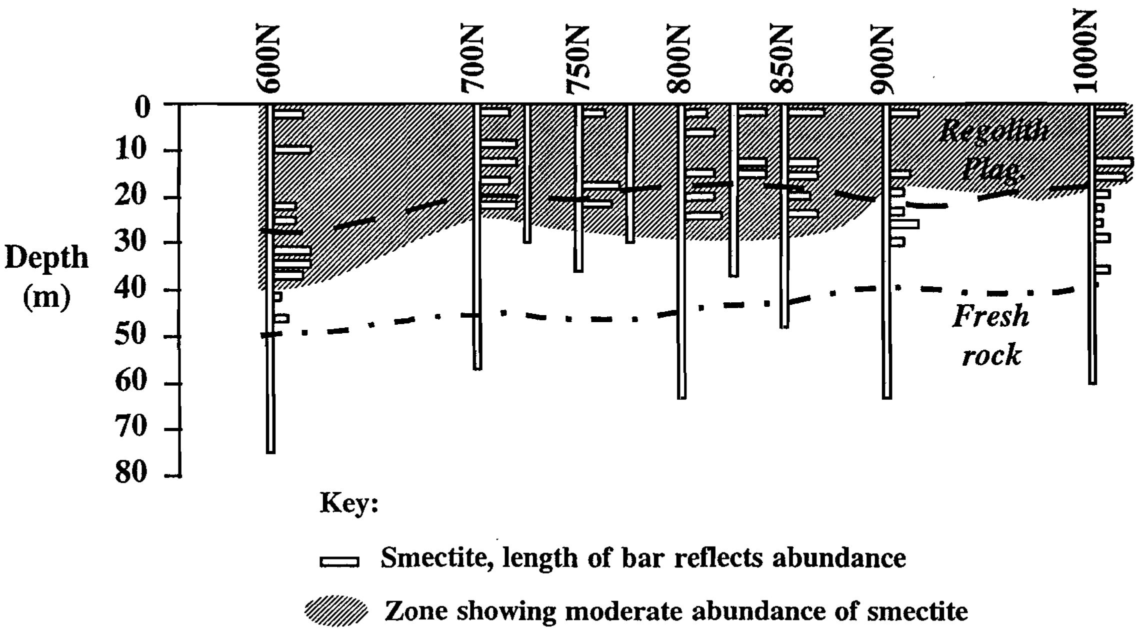



Figure 16. Smectite distribution, Line 4, Waterloo, relative to plagioclase zones.

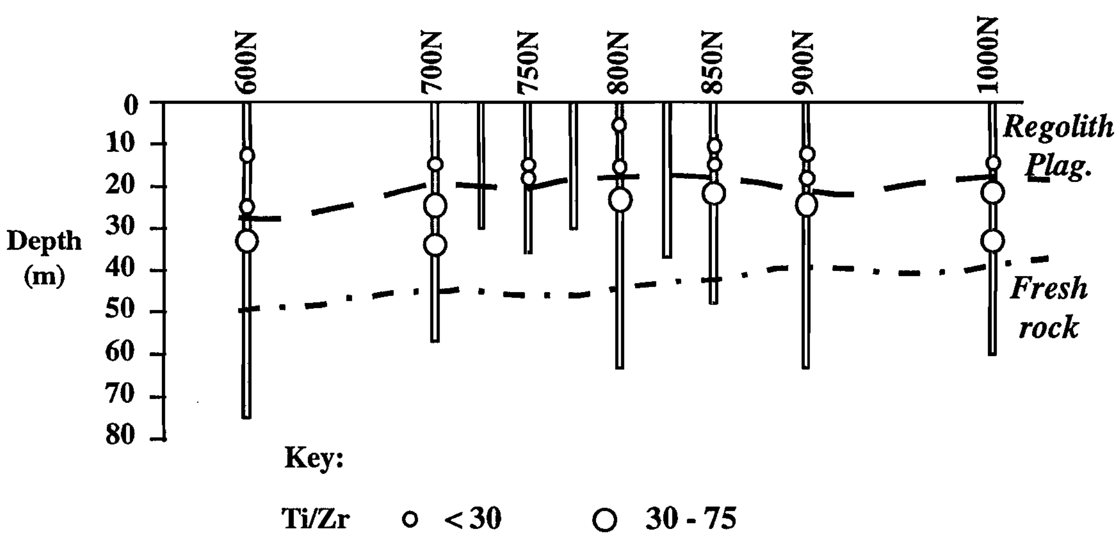



Figure 17. Ti/Zr ratios, Line 4, Waterloo, relative to plagioclase zones.

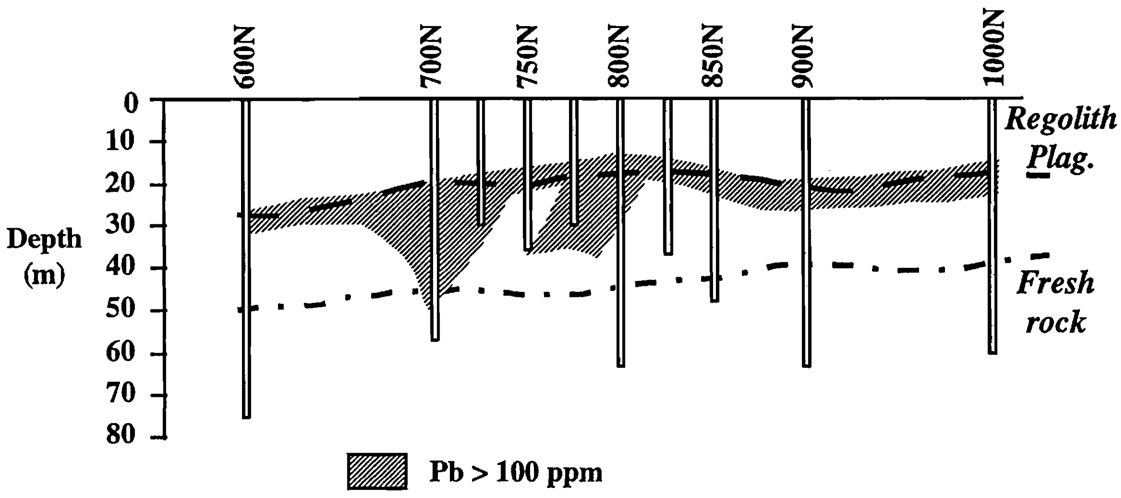



**Figure 18. Lead distribution, Line 4, Waterloo, relative to plagioclase zones.**

3.3 STOP 5: TW 29 Area

*Geology:* *Campaspe Formation*
*Landform:* *Plain*
*Regolith:* *Grey-brown soil, carbonates*

Polymictic float occurs with red-brown to grey brown soils of the pediment of this area (Figure 19A). Sample 129990 consists of brown soil with angular quartz, granitic and felsic volcanic fragments and some polished Fe concretions (Figures 19B-C). Twenty one per cent of the sample is coarser than 2 mm. Sample 12991 is a grey-brown soil with 58% of its weight coarser than 2 mm. The coarse material consists of Fe-stained fragments of sandstone (with quartz clasts to 5 mm), pisoliths and granitic fragments (Figures 19D-E).

The fine fraction of the soils is enriched in lithophile elements Al, Mg, Ca, Na, K, Ti, Br, Cl, Nb, Rb, Sr, Y, Zr plus Au and Zn relative to the coarser fractions (Table 4). The coarser material is enriched in Fe, Mn, As, Ba, Ce, (Co), Cr, Pb (Sb) and V relative to the finer fraction. Relatively high Mn contents in the coarser material from 129991 suggests that an association of Ba, Ce, Co (and perhaps Cr and Pb) with Mn occurs (as in the Waterloo Erosion Gully profile, Stop 3).

Logging of the fragments from RC hole TW29 reveals that the quartz grains in the top 17 m are clear and rounded whereas the quartz grains below that level are less abundant, angular and milky in appearance (Figures 19F-G). Rounded pebbles with a thin white bleached rim about a brown core (a found elsewhere in the Campaspe Formation) are also present in some samples, *e.g.* Figure 19H. Carbonate is present as discrete white chips between 16-22 m (Figure 20).

X-ray diffractometry of samples between 14 and 27 m reveals that material above 17 m contains abundant plagioclase, has montmorillonite > kaolinite and bears only minor mica and hematite. Below 17 m, plagioclase is absent and mica and kaolinite are quite abundant (kaolinite becoming the major clay below 22 m). The carbonate between 16-22 m is identified as dolomite. Alunite-type minerals ± barite are recognised below 18 m and the Fe oxide is goethite rather than hematite (Figure 20).

Figure 19A. Polymictic float over the Waterloo deposit, TW29 area. (Samples 129990 and 129991 collected here).

Figure 19B. Coarse ferruginous fragments. (Sample 129990A, TW29 area, Waterloo).

Figure 19C. Coarse lithic fragments. (Sample 129990B, TW29 area, Waterloo).

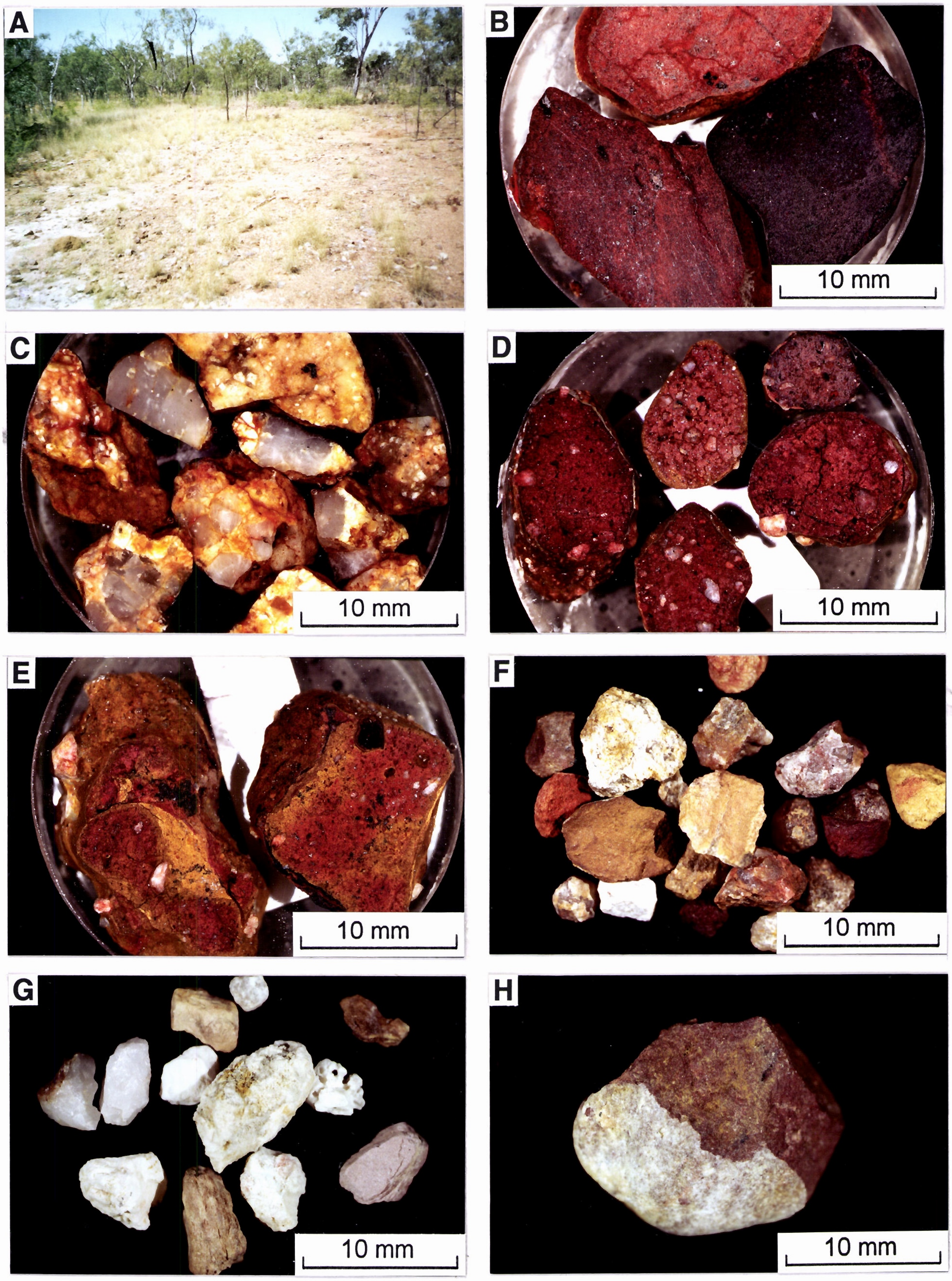
Figure 19D. Coarse ferruginous fragments. (Sample 129991A, TW29 area, Waterloo).

Figure 19E. Coarse fragments showing quartz (white) within Fe-rich fragments. (Sample 129991B, TW29 area, Waterloo).

Figure 19F. Coarse polymictic fragments derived from Campaspe Formation. Note the rounding of kaolinite-coated quartz grain as base of picture. (Sample 129904, TW29: 9-10 m).

Figure 19G. Coarse fragments of Trooper Creek Formation. Note angular, milky quartz grain. (Sample 129916, TW29: 21-22 m).

Figure 19H. White bleached rim to rounded ferruginous pebble as found elsewhere in Campaspe Formation. (Sample 129897, TW29: 2-3 m).


A
B
10 mm
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10 mm
D
10 mm
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10 mm
F
10 mm
G
10 mm
H
10 mm

Geochemistry (Table 5) indicates that the Campaspe Formation has much lower levels of As, Au, Ba, Cu, Pb, Zn and S than the underlying weathered volcanics (Trooper Creek Formation). The levels are similar to those found in the indurated Campaspe Formation in the floor of the erosion gully at Stop 3 (Table 3) except for the elevated Ba and S at that site. Thus despite the presence of low grade mineralisation at 22-27 m, *i.e.* within 5-10 m of the Campaspe Formation there does not appear to be dispersion into the overlying unit. Manganese is enriched in the upper 22 m of the drill hole, within the Campaspe Formation its presence reflects Mn oxides (as at Stop 3) whereas below the unconformity it is incorporated into dolomite.

Use of Ti/Zr ratios would suggest that this hole penetrates ~5 m of dacitic-andesitic material before entering more felsic material associated with mineralisation (Table 5).

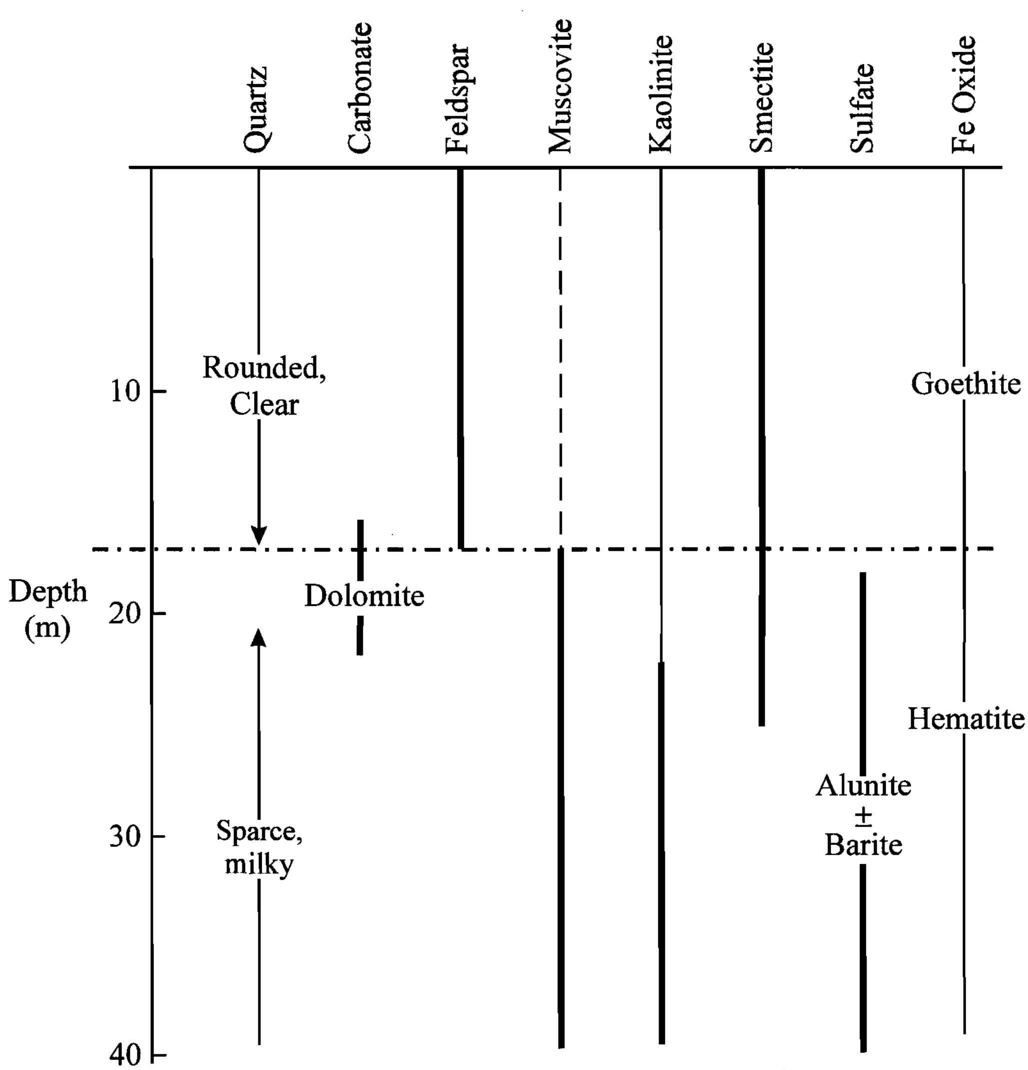



Figure 20. Mineralogical variations in the top 40 m of TW29, Waterloo.

**Table 4. Composition of soil fractions, TW29 area**
(major components, wt%; minors, ppm)

| Fraction<br>Sample No. | Coarse<br>+2 mm<br>129990A | Fine<br>-75 µm<br>129990F | Coarse<br>ferruginous<br>129991A` | Coarse<br>+2 mm<br>129991B | Fine<br>-75 µm<br>129991F |
|---|---|---|---|---|---|
| $SiO_2$ | 60.0 | 50.1 | 48.1 | 56.5 | 73.3 |
| $Al_2O_3$ | 7.68 | 20.6 | 10.2 | 9.70 | 12.0 |
| $Fe_2O_3$ | 25.7 | 8.80 | 33.5 | 24.9 | 3.85 |
| MgO | 0.19 | 1.09 | 0.11 | 0.12 | 0.28 |
| CaO | 0.07 | 0.48 | 0.05 | 0.07 | 0.26 |
| $Na_2O$ | 0.35 | 1.16 | 0.05 | 0.34 | 0.49 |
| $K_2O$ | 0.58 | 0.72 | 0.22 | 0.22 | 0.40 |
| $TiO_2$ | 0.67 | 0.89 | 0.55 | 0.44 | 1.14 |
| MnO | 0.10 | 0.05 | 0.58 | 0.22 | 0.10 |
| $P_2O_5$ | 0.12 | 0.06 | 0.06 | 0.06 | 0.03 |
| $SO_3$ | 0.03 | 0.04 | <0.01 | 0.01 | 0.02 |
| | | | | | |
| As | 29 | 3 | 41 | 32 | 3 |
| Au (ppb) | <5 | 9 | <5 | <5 | 10 |
| Ba | 240 | 220 | 690 | 250 | 140 |
| Br | <2 | 17 | <2 | <2 | 5 |
| Ce | 91 | 67 | 520 | 270 | 83 |
| Cl | <10 | 440 | <10 | <10 | 390 |
| Co | 24 | 10 | 160 | 57 | 34 |
| Cr | 41 | 20 | 160 | 130 | 20 |
| Cs | <1 | 2 | 1 | <1 | 2 |
| Cu | 69 | 34 | 29 | 41 | 20 |
| Ga | 15 | 24 | 17 | 16 | 16 |
| La | 34 | 31 | 23 | 25 | 56 |
| Nb | 5 | 9 | 11 | 5 | 19 |
| Ni | 11 | 16 | 11 | 24 | 18 |
| Pb | 52 | 33 | 93 | 78 | 29 |
| Rb | 23 | 45 | 20 | 12 | 39 |
| Sb | 2 | <1 | 2 | 1 | 1 |
| Sr | 18 | 65 | 16 | 16 | 36 |
| Th | 18 | 13 | 12 | 11 | 16 |
| W | 7 | <2 | <2 | 3 | 2 |
| U | <2 | <2 | <2 | <2 | <2 |
| V | 390 | 140 | 560 | 400 | 77 |
| Y | 14 | 30 | 25 | 24 | 70 |
| Zn | 14 | 50 | 12 | 12 | 24 |
| Zr | 140 | 170 | 200 | 190 | 730 |
| | | | | | |
| Ti/Zr | 30 | 31 | 16 | 14 | 9 |

**Table 5. Composition in upper portion of TW29**
(ppm, except where indicated otherwise)

| | | Trooper Ck Fm | | |
|---|---|---|---|---|
| **Zone** | **Campaspe Fm.** | **Dolomite** | **Highly Mineralised** | **Mineralised** |
| **Interval (m)** | **0-17** | **17-22** | **22-27** | **27-40** |
| **No. of samples** | **17** | **5** | **5** | **13** |
| As | 3 | 13 | 20 | 16 |
| Au (ppb) | 0.7 | 3.0 | 3.0 | 5.3 |
| Ba* | 530 | 1300 | 1.16% | - |
| Cu | 26 | 69 | 210 | 180 |
| Pb | 10 | 170 | 1300 | 540 |
| Zn | 33 | 28 | 70 | 110 |
| Fe% | 2.96 | 3.04 | 4.72 | 2.56 |
| Mn | 240 | 540 | 87 | 9 |
| S | 78 | 220 | 620 | 380 |
| Ti/Zr* | 25 | 37 | 21 | - |

* Ba and Ti/Zr averages based on smaller number of analyses

# 4.0 PAJINGO AREA

*I.D. Campbell*

**STOP 6: Scott Lode Pit**

**STOP 7: Cindy Pit**

**STOP 8: Wahines Prospect**

## 4.1 Introduction

The Pajingo area which includes the Scott Lode gold deposit occurs within the Janet Range which is centred on Latitude 20°32'S and Longitude 147°27'E or some 150 km south-southwest of Townsville.

Several types of terrain occur over the Pajingo area. A central area is dominated by the high, steep hills of the Janet Range. These hills are composed of outcropping andesite volcanics. The hills have not been cleared of vegetation and are densely covered with eucalyptus, acacia and other shrubs. Heavy lancewood woodland covers many of the mesas, growing in Fe-rich gravelly soils.

To the east-north-east of the Janet Range lies a region of sandstone and siltstone hills, the Balaclava Range. These hills are covered with moderate to heavy stands of eucalyptus and shrubs, while the low flat areas between hills are more sparsely vegetated. Grasses, shrubs and bare soils form the understorey on the low-lying areas.

The rocks of the Pajingo area include mafic lavas, volcaniclastics and sediments. Mineralisation at Pajingo is exposed within the Janet Range, 53 km south-southeast of Charters Towers, where auriferous quartz veins are hosted by Carboniferous andesites. The Scott Load is 560 m long with a maximum width of 23 m; the strike has a dog-leg, with part striking being E and the remainder NE. The lode plunges 80 degrees south to a depth of 140 m.

Gold mineralisation is confined to quartz veins with an average Au:Ag ratio of 70:30. There are several generations of gold mineralisation. Gold shows little relationship to Fe oxides, however the bonanza Au occurs as a late-stage infilling with either Fe oxides or clays. Silver halides, cerargyrite ($AgCl_2$), bromargyrite ($AgBr_2$) and iodargyrite ($AgI_2$) occur in the oxidised zone. Within the non-oxidised parts of the vein, gold occurs with galena, sphalerite, chalcopyrite and pyrite. K/Ar dating of Scott Lode gives ages from 319 to 340 Ma.

The Wahines prospect, located 15 km southwest of Pajingo is centred around a porphyry plug. Known gold mineralisation occurs in quartz veins and sulphide fractures of either porphyry or epithermal origin.

## 4.2 Regolith-landform Relationships

Two 6 x 4 km areas were selected for mapping. The first is centred on the Pajingo minesite and has been mapped at 1:10 000; the second is centred on the Wahines Prospect and has been mapped at 1:20 000 (Figures 21 and 22).

The basement in the Pajingo and Wahines areas consists of outcropping volcanics. The rocks are relatively fresh either lacking any weathering profile or weathered to saprock where the primary lithology can be identified. The basement forms the Mt Janet Range which rises 180 m above the surrounding, lateritised plain.

Remnants of a poorly formed lateritic profile occur on the Devonian volcanics at a similar altitude as lateritic profiles on the Southern Cross Formation. The height concordance over small distances and the similarities of the profiles imply a single planation and lateritisation event. Its surface expression is a Fe-rich pisolitic duricrust similar to that developed on the Tertiary sediments but lacking in cobbles. The duricrust is dominantly hematite, with some goethite, gibbsite and kaolinite cementing the pisoliths. There is no natural exposure, so its substrate could not be determined.

The lateritic profile developed on the Southern Cross Formation is very variable. In most of the Pajingo area it consists of massive to weakly pisolitic Fe duricrust. In a few places, the duricrust has been broken down into pisolitic gravels. Pisolitic duricrust is limited to the local high areas on the plateaux, where the incision of the plateau has increased drainage. Ferruginisation occurs throughout the top few metres of the profile, but pisolith development only occurs in the top half metre.

The lateritic duricrust is generally exposed in breakaways where the duricrust appears thicker, due to recent Fe crusting of the mottled zone. Chipping away the first ten centimetres shows the true horizon.

Mottled clays are very extensive in the Pajingo Area. The Southern Cross Formation is extensively mottled, and this is not limited to one specific horizon in the profile (Figure 25B, C). The dominant clay is kaolinite and the mottles are formed of goethite and hematite. In some places a very thin lithosol has been developed on the mottled sediments, though it can be covered by a thin veneer of proximal colluvium.

Mottled saprolite on volcanic is equivalent to the mottled Tertiary sediments, except it is developed on a volcanic substrate. Mottles are confined to one horizon and the mottling is much more intense than on the Tertiary sediments. The mineralogy is similar to that of the mottled sediments and distinguishing between the two can be difficult; generally the vegetation on this unit tends to be more sparse than on the mottled sediments. In places, mottles have been broken into a very coarse lag of ferruginous saprolite (Figure 25A).

Alluvium is extensive in low lying areas to the east of Scott Pit. The alluvium ranges from boulder gravels, exposed in the creeks, to massive clays (Figure 23E). Exposures in gullies provide good exposure where it can be up to 4 m thick. Most exposures have basal gravels which fine upward to massive silts (Figure 23F).

The alluvium is well sorted but is mineralogically immature with common cobbles of weathered volcanics and vein quartz. Ferruginous pisoliths occur in the alluvium which is derived from erosion of the volcanic hills and the Tertiary sediments. It is likely that many of the cobbles in the alluvium have been inherited from the Southern Cross Formation, and so have been through at least two periods of erosion and deposition.

Size distribution in the alluvium in the existing creek beds are bimodal, with well-sorted coarse sands and cobbles of volcanics. This contrasts with the palaeo-alluvium exposed in the gully walls.

Extensive soil development has occurred on the alluvium. The dominant soil processes have been eluviation of the clay fraction in the A horizon, and development of a well-defined B horizon where the clays have illuviated. The effect the extensive soil development has had on the geochemistry of the alluvium has not been determined.

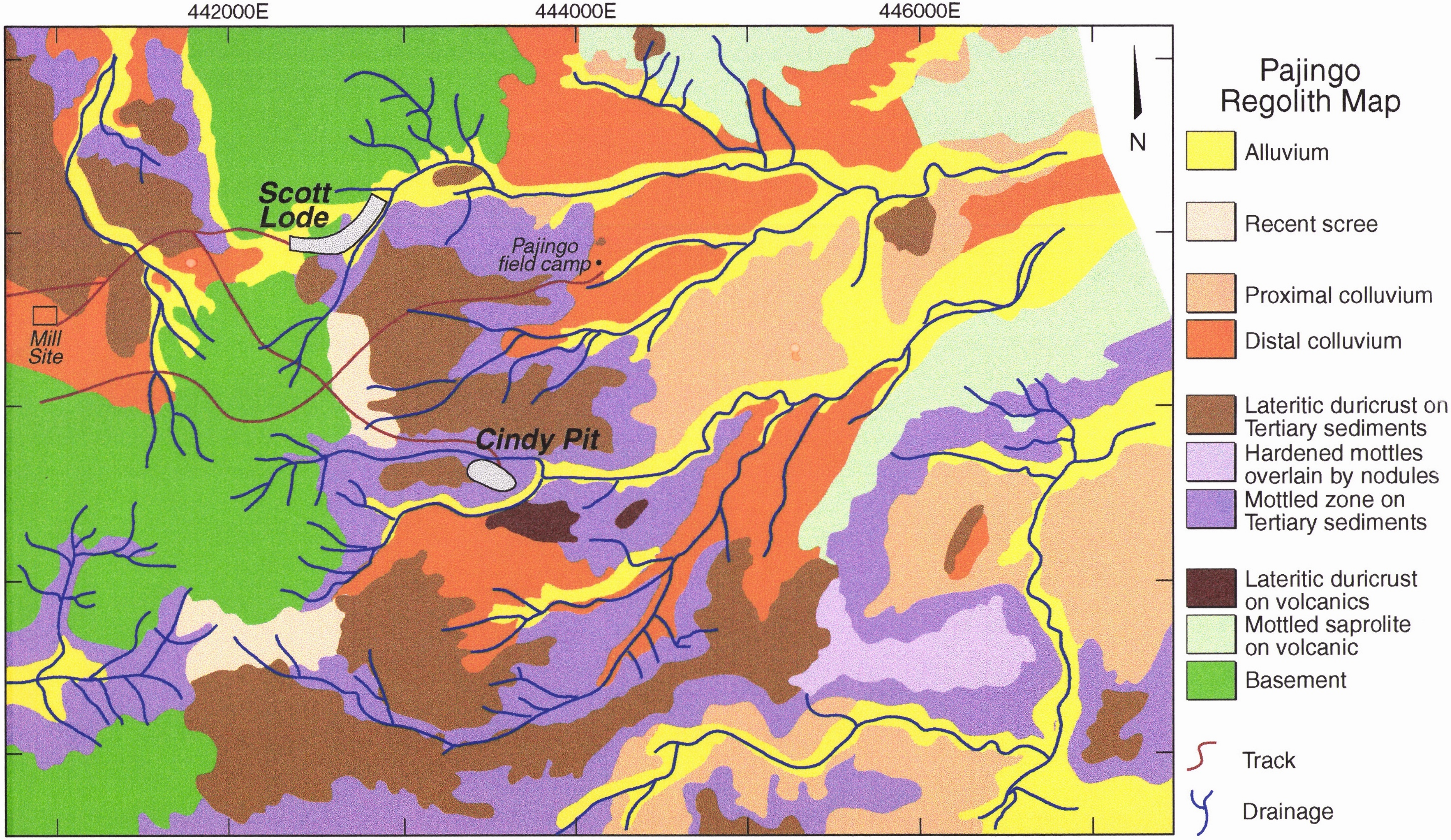



**Figure 21. Regolith map showing the distribution of regolith units in the Pajingo Area.**

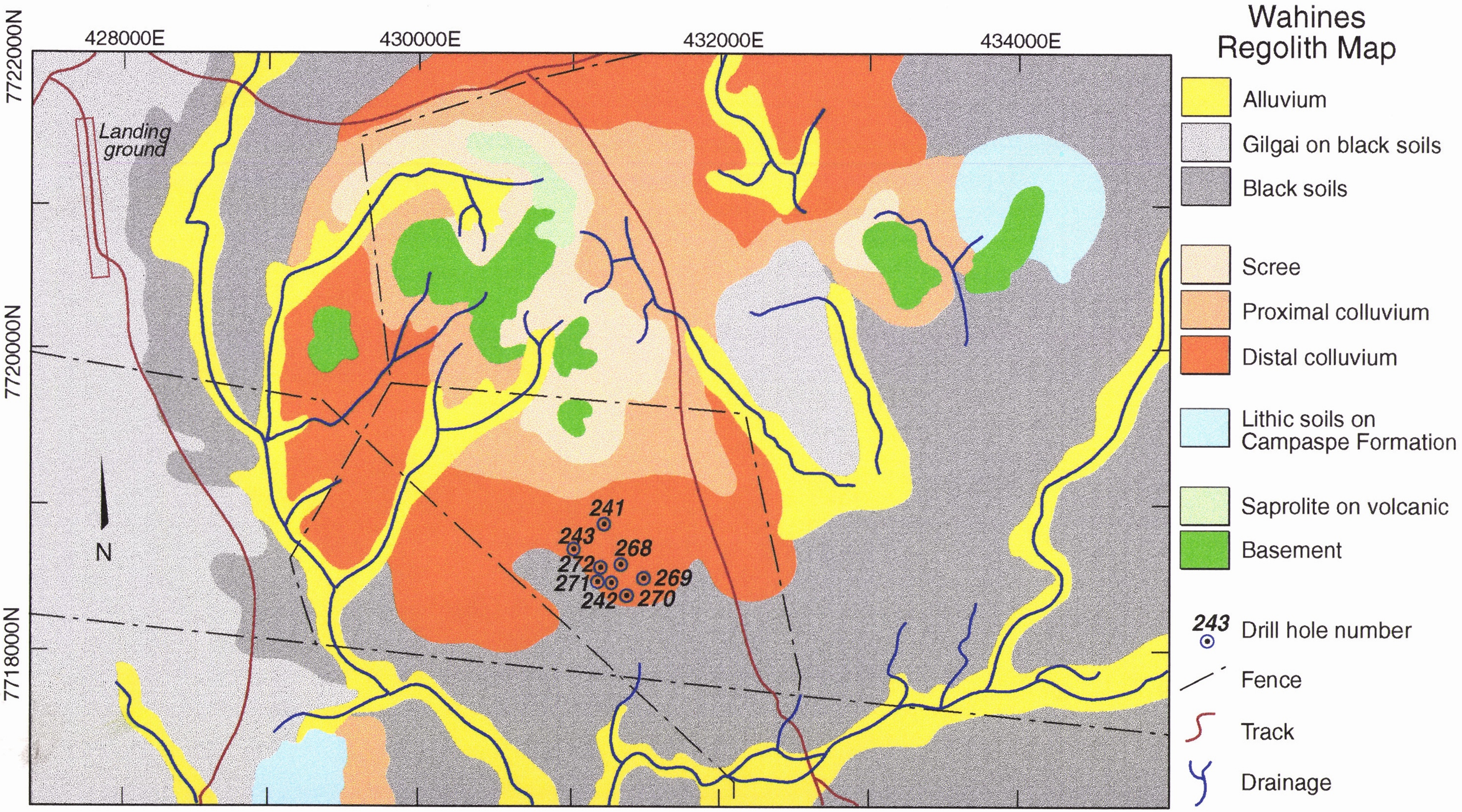



Figure 22. Regolith map showing the distribution of regolith units around the Wahines Prospect.

## 4.3 Regolith Characteristics

### *4.3.1 Southern Cross Formation*

The Southern Cross Formation forms an extensive blanket over the northern Drummond Basin and the Lolworth-Ravenswood Block (Figure 23A, B). It consists of proximal and distal colluvium, alluvium and lacustrine sediments. In much of the northern Drummond Basin, it has been extensively dissected and is covered by younger sediments.

The Southern Cross Formation at Pajingo consists dominantly of massive, kaolinitic clays and shales with cobbles of volcanic material and vein quartz. Weathering has caused the breakdown of some lithic grains, alteration of feldspars and the formation of secondary gibbsite, hematite and goethite. It cannot be determined whether the sediments have been weathered to their base or were deposited as kaolinite. Gross bedding of cobble rich horizons occur towards the top of the colluvium in the Scott Pit but it seems that all fine sedimentary features, that may have originally existed, have been obliterated by weathering (Figure 24A-D).

The sediments exposed on the southern wall of the Scott Lode have a variety of sedimentary units with very different characteristics. The one feature common to all the sediments is the large number of cobbles. The massive bands of volcanic lithic cobbles are due to episodic influx of relatively fresh material (Figure 24E).

The colluvium forming the Southern Cross Formation in the Pajingo area is locally derived and has had a limited lateritic profile developed in a fairly uniform peneplain sloping away from its source in the Mount Janet Range (Figure 26). The lateritised surface is bounded by escarpments to the north, south and east of the Range. Its relief and form suggests that the Southern Cross Formation surrounded the Mt Janet Range and did not cover them. Quartz veins of the Scott Lode were never covered by the Southern Cross Formation allowing it to continually shed material over the Southern Cross Formation. A substantial weathering profile has developed in it and Fe rich concretions and nodules occur throughout. Some of the concretions are detrital, being derived from older profiles and some have formed *in situ*. Cobbles were derived from the topographically higher Scott Lode, volcanics from Mt Janet and sediments from Mt Molly Darling.

The weathering profile near the Scott Pit is typical of the Pajingo area, and is more poorly developed than those common on the Yilgarn Craton. Although pisoliths have formed at the top of the profile, little duricrust has developed. The top 3-5 m are dominated by pisoliths, with surficial cementing of these to form a duricrust. Mottled saprolite is poorly defined with a diffuse boundary between the mottled zone and saprolite. Mottling occurs all through the profile and the original sediments had very poorly developed textures. There are areas where intense bleaching has occurred, yet the sediments have retained their gross bedding. The profile has been overprinted by several redox fronts where Fe has precipitated as goethite and hematite (Figure 27).

Incision of the Southern Cross Formation can be seen in Scott Pit, where a palaeochannel is exposed (Figure 24F). Sediments in the creek are dominated by kaolinite, fresh volcanic cobbles and pisoliths derived from the breakdown of an earlier lateritic profile. The Southern Cross Formation below the creek is extremely mottled and Fe has been leached and redistributed from weak, diffuse mottles into strong mottles with sharp boundaries. The saprolite below the creek has been weakly silicified.

The weathering profile on the Southern Cross is thought to be dynamic, with Fe (and other elements) constantly moving within the profile. The Fe precipitates readily on encountering oxidising conditions and this precipitation can mask the nature of the profile. This is evident in breakaways around the Pajingo area, where exposed profiles are cemented with Fe and resemble lateritic duricrusts. However, the Fe cement is surficial and the material only a metre behind is mottled sediments.

**Figure 23**

A) A typical escarpment at the edge of the Southern Cross Formation plateau. Most of the escarpment is of mottled sediments cemented with Fe oxides. Lateritic duricrust outcrops at the very top of the escarpment, set slightly back from the edge.

B) Drill spoil from a hole drilled on an erosional plain, just off the edge of the lateritised plateau. Surface pisolitic gravels result from breakdown of the duricrust at the edge of the escarpment forming a proximal colluvium.

C) Ferruginous duricrust of cemented colluvium. This duricrust is widespread and has been mapped as the "Campaspe Surface" (Grimes, 1980).

D) A close up of the duricrust in Photo 23C. Nodules are clearly visible with lithic clasts and ferruginous saprolite. The cement may represent a later cementing of the earlier nodules. This material shows no relationship to a weathering profiles and does not appear related to a weathering surface.

E) Shallow, distal colluvium over mottled Southern Cross Formation. The Southern Cross Formation can contain similar sized clasts to the colluvium, but the colluvium can contain very fresh clasts of volcanic rock.

F) Alluvium exposed in gully. Two-upward fining cycles of gravel to sand at the base of the alluvium are overlain by fairly massive silty clays. The alluvial sediments overlie mottled Southern Cross Formation sediments.

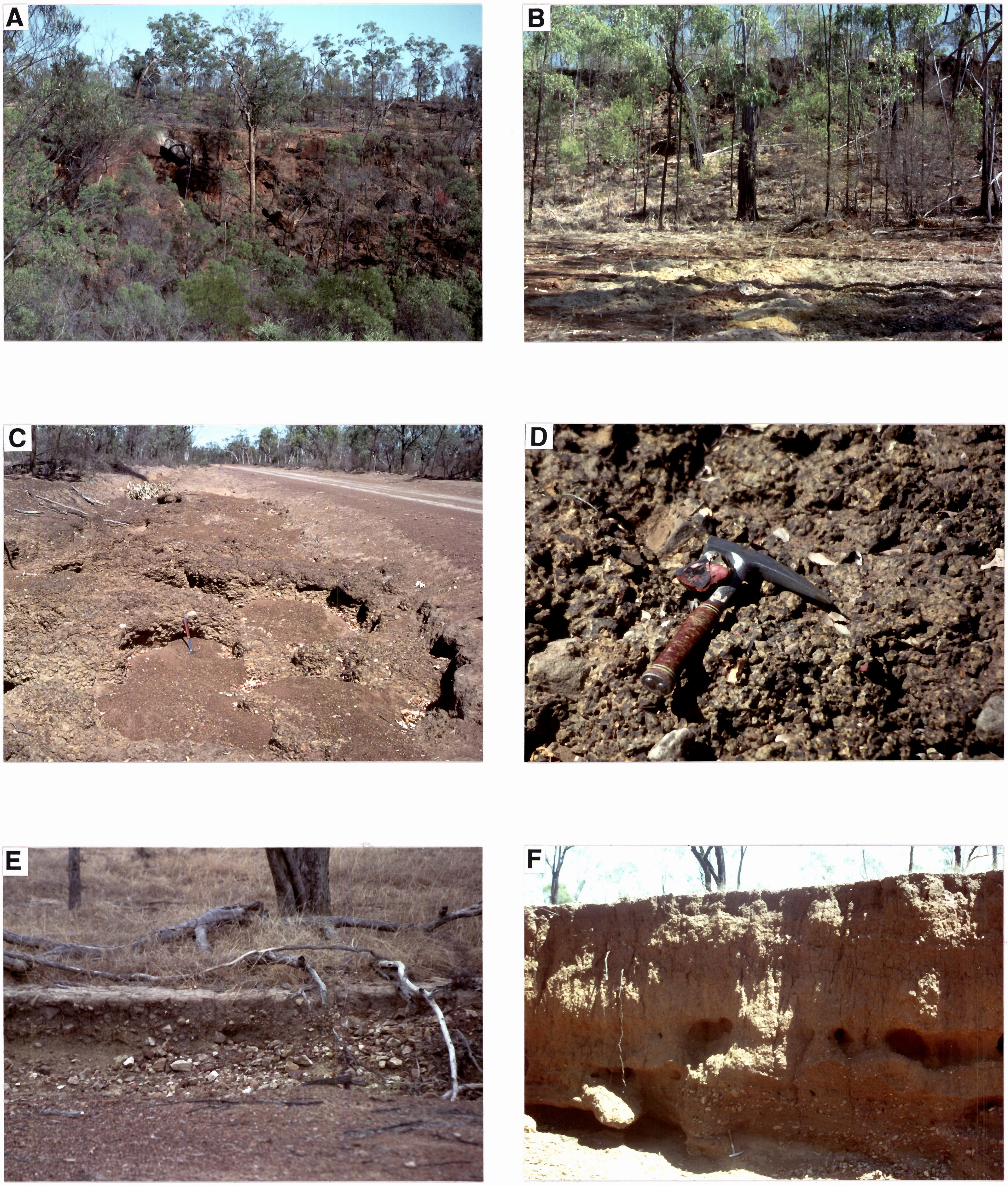

A
B
C
D
E
F

**Figure 24**

A) Western face of Scott Pit showing the extent of the Scott Vein (SV). Note extensive jarosite exposed in the Pit walls.

B) Boundary between the Southern Cross Formation (SCF) and the basement (BSS) exposed in the southern wall of Scott Pit. Mottling in the saprolite on volcanic is clear just below the contact. Lateritic duricrust (LD) is clearly visible in the top metre of the Southern Cross Formation.

C and D) Photographs of the Southern Cross Formation exposed in the Scott Pit. The oxidation state of the Fe cement is closely related to the lithology of the sediments. Goethite staining and cementing is more common in the sand-rich beds (SB); hematite is more common in the clay-rich sediments (CS).

E) Detail of the Southern Cross Formation, showing thin beds of cobbles (CB) surrounded by massive clays (MC). These thin beds represent episodes of mass flow, and are proximal to their source.

F) Recent mottling of the Southern Cross Formation sediments. These local redistributions of Fe are superimposed on older mottles consistent with the rest of the exposed Southern Cross Formation. Their proximity to a modern creek suggests that they were formed by increase of groundwater flow.

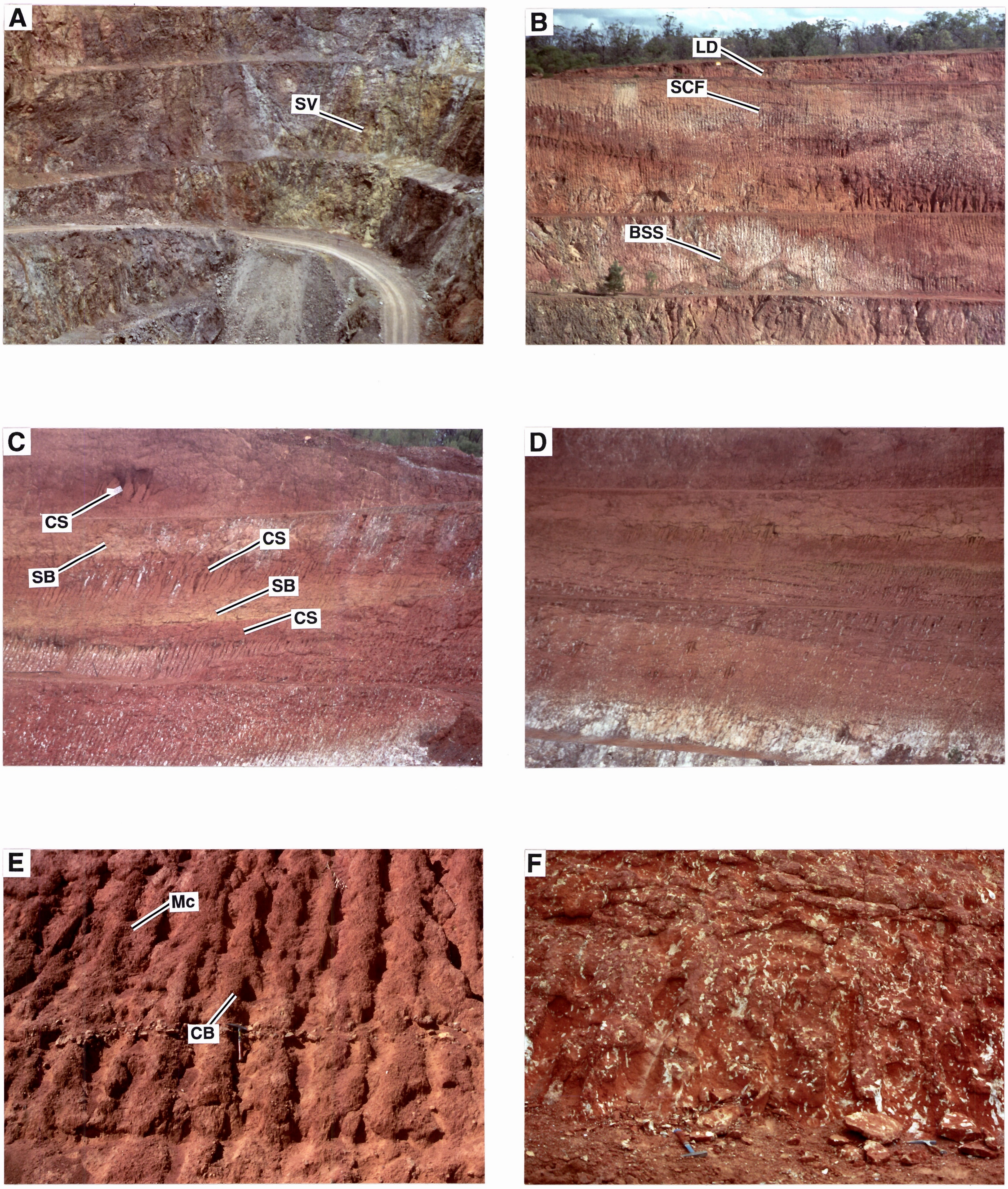

A
SV
B
LD
SCF
BSS
C
CS
SB
CS
SB
CS
D
E
Mc
CB
F

**Figure 25**

A) The surface expression of Mottled saprolite. The matrix has washed away, leaving a coarse lag on the surface. Very weakly silicified fragments of saprolite are also preserved at the surface.

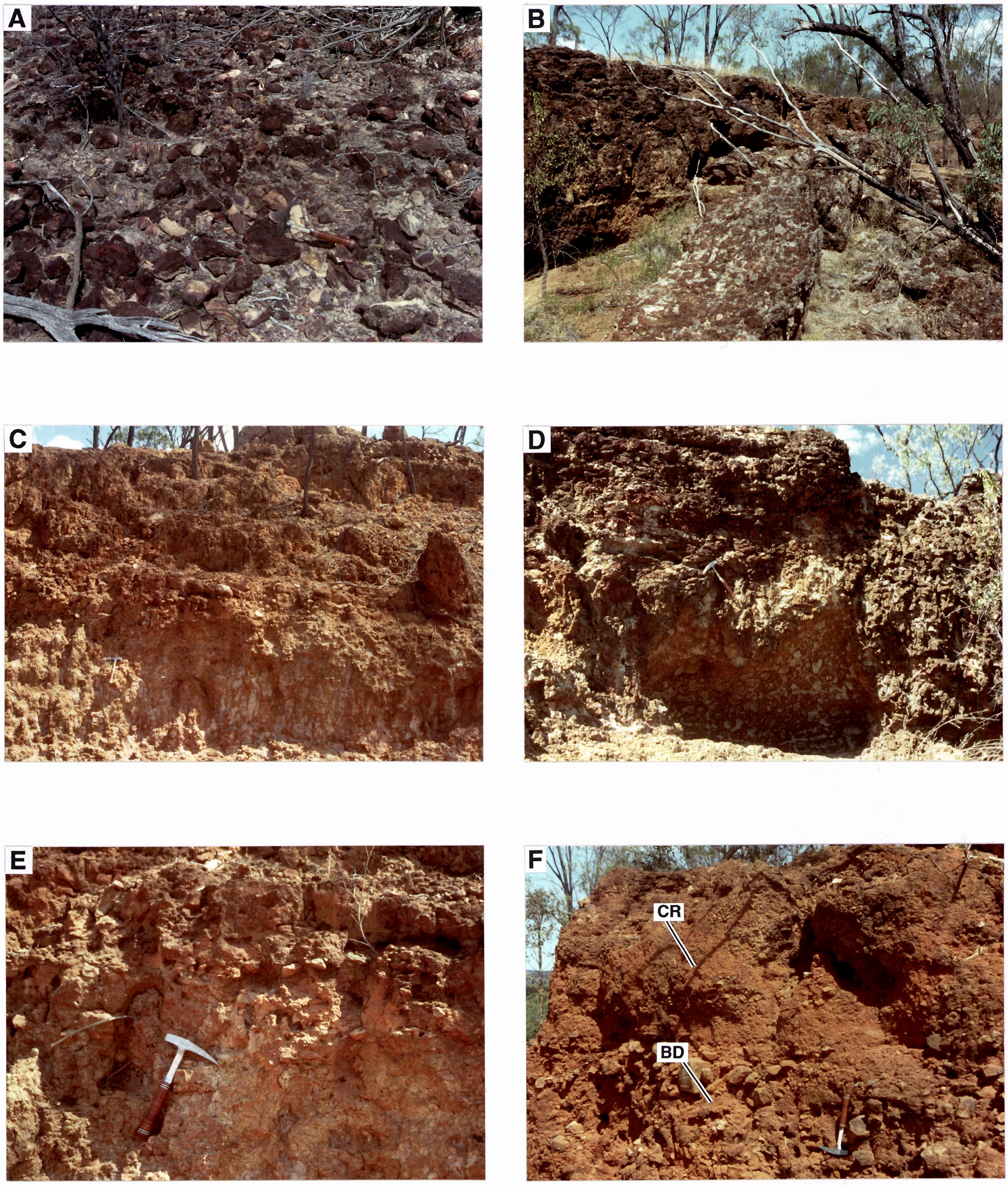
B) Breakaway of Southern Cross Formation mottled Sediments.

C) Breakaway on a lateritic profile developed on the Southern Cross Formation. Mottling increases towards the top of the profile and the top metre is of lateritic duricrust.

D) Fe oxide of mottled sediments in a breakaway on the edge of the "Featherby Surface". The material is very similar to a lateritic duricrust.

E) A close-up of the exposure in C. The true nature of the profile can be easily seen once the recent Fe-rich skin is broken away from the surface.

F) Breakaway near the exploration camp at Pajingo. The boulders at the base of the exposure (BD) are relatively fresh or partially silicified fragments of volcanic rocks. The clay-rich bed (CR) above this conglomerate contains the same variety of cobbles, but smaller and less common.


A
B
C
D
E
F
CR
BD

### *4.3.2 Campaspe Formation*

The Campaspe Formation is dominated by continental sands with a few interbedded silts and clays and covers much of the northern Drummond Basin and the Lolworths-Ravenswood Block. In the study areas, the Campaspe Formation has a limited outcrop where it occurs in low, subdued parts of the landscape. There are no breakaways developed on it, so profile study is limited to drill spoil.

The sediments range from poorly- to well-sorted sands, gravels and clay beds. The dominant clastic mineral is quartz, but some horizons have significant microcline and small lithic clasts. Monazite occurs as inclusions within some of the microcline and quartz. In drilling in the Wahines area, the Campaspe Formation is less than 30 m thick, and overlies the Southern Cross Formation. The stratigraphy in the Wahines area is complex at its base representing filling of a palaeovalley that became more subdued and uniform towards the close of deposition.

The range of lithologies found in the drill spoils of the Wahines Prospect is similar to that outcropping to the west of the study areas. The Campaspe Formation from drill spoils is characterised by abundance of lateritic pisoliths throughout. Pisoliths were noted in the Campaspe Formation around Charters Towers (Nind, 1988). They appear not to be related to profile development within the Campaspe but are clastic. They were derived from erosion of lateritic profiles developed on the Southern Cross Formation and deposited as detrital pisoliths in the topographically lower Campaspe Formation.

Nind (1988) describes numerous palaeosols around Charters Towers. Similar concretions to those described by Nind were found in the drill spoil from the Wahines Prospect. These horizons of Fe enrichment have been reinterpreted as redox fronts rather than as palaeosols.

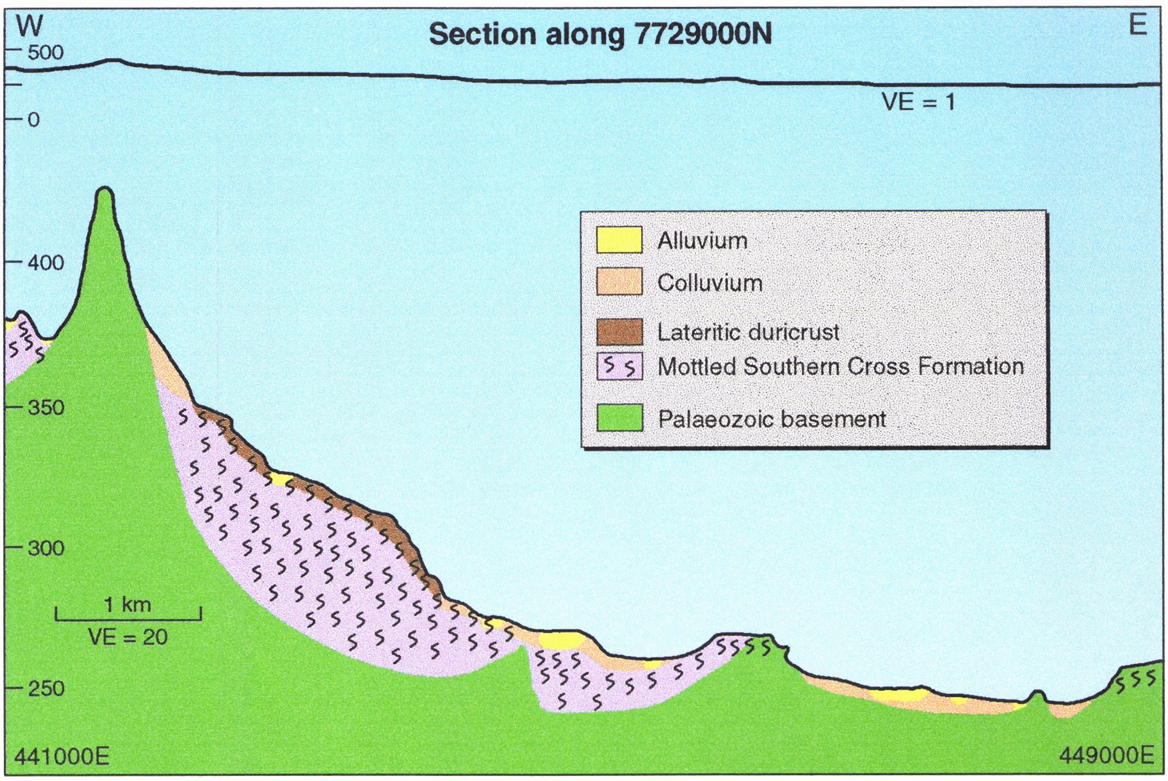



Figure 26. East-west cross section showing regolith-landform relationships for Line 7729000N, Pajingo Area.

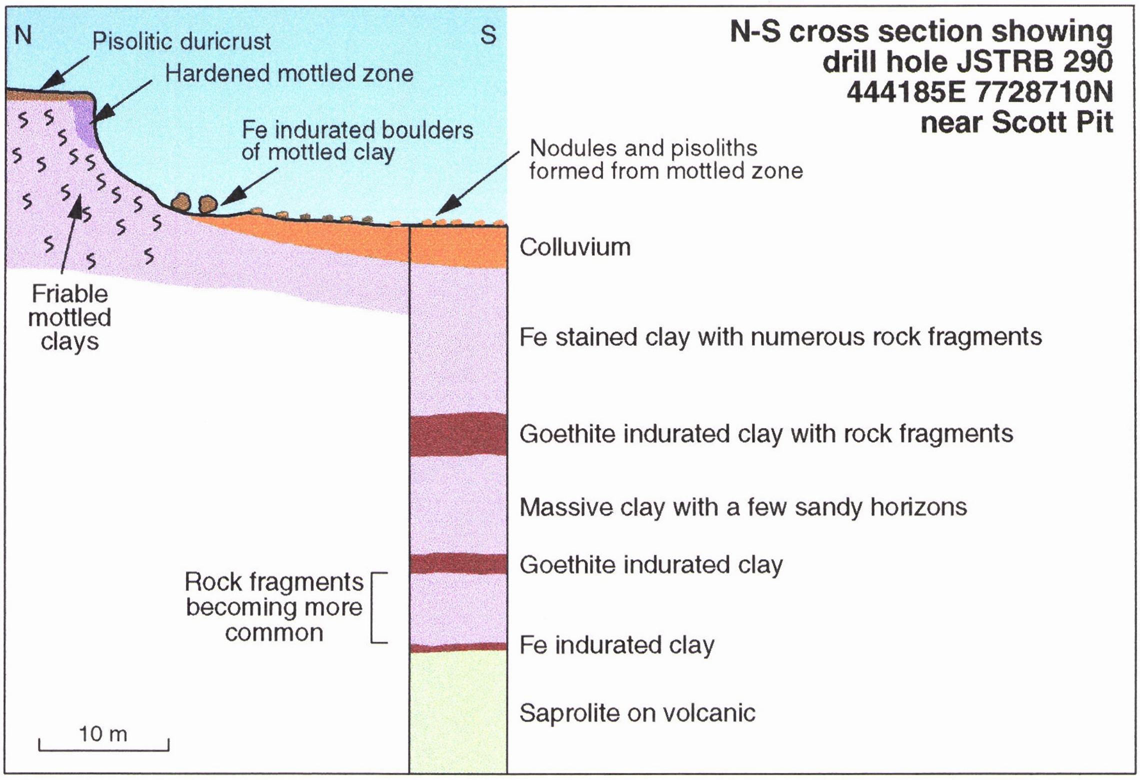



Figure 27. North-south cross section showing regolith-landform relationships around Scott Pit.

At the Wahines Prospect, the Campaspe Formation has been intensely silicified at a fairly consistent depth of 17-30 m to silcrete. Petrographic analysis of the silcrete showed several phases of silica precipitation following breakdown of much of the feldspar and etching of quartz grains. Initial silicification was by clean silica with very little associated Fe, Al or Ti. It formed both from an influx of external silica and from silica derived locally from weathering of feldspars in the Campaspe Formation. Later silica was precipitated with some Fe and Al. Goethite and kaolinite are surrounded by later growths of silica. The last stage of silica was off-white but contained some Fe.

After silicification, goethite and hematite have precipitated in fractures and voids in discrete horizons, pseudomorphing the remaining feldspars. Barite crystals occur in the Fe rich voids, and rare thorianite crystals have also precipitated in this last stage of weathering.

There is no evidence for a lateritic profile having developed on the Campaspe Formation. The sediments examined in drill spoil are very weathered but profile development is limited to zones of Fe concentrations at palaeowatertables. The drill spoil is dominated by the different units and even soil development seems limited on the sediments. The boundaries between the sedimentary beds are marked, and do not indicate intense profile development.

There are Fe-Al-rich pisoliths near the surface of the Campaspe Formation in some places. The lateral extent of this pisolitic unit has led Grimes (1980) to map the outcrop of the Campaspe Formation as an old landsurface (Figure 23C, D). This pisolitic material is generally less than 50 cm thick and is generally strongly cemented by goethite with some gibbsite. In some places, massive duricrust has formed preferentially to pisoliths, over relatively fresh sediments, without any deep profile development. The relatively unweathered nature of the substrate suggests that Fe in these pisoliths and duricrusts is derived laterally from the surrounding uplands rather than from the basement below the Campaspe Formation.

In the Wahines area, the Campaspe Formation is covered by up to 4 m of black soil, which is predominantly smectite with some quartz and kaolinite (Figure 28). The black soils directly overlie well-sorted coarse sands of the Campaspe Formation, with only a thin lithosol at the boundary. The lack of pisoliths or duricrust at the boundary suggests that the formation of pisoliths and duricrust occurred after the formation of the black soils in higher parts of the landscape.

#### *4.3.3 Distinguishing the Southern Cross Formation from the Campaspe Formation*

The Southern Cross Formation lies stratigraphically below the Campaspe Formation, but can be topographically higher. The lateritic profile developed on the Southern Cross Formation provided the source material for the Campaspe Formation in the study areas, yet it can be found under the Campaspe Formation in some drill holes. The time interval between the end of deep weathering of the Southern Cross Formation and the initiation of Campaspe deposition is unknown.

In drill spoil, the Southern Cross Formation is more clay-rich than the Campaspe Formation and contains clasts of basement rock, some of which is relatively fresh. The Campaspe Formation tends to be sand-rich and more sorted than the Southern Cross Formation. The Campaspe Formation contains detrital nodules and pisoliths throughout the sediment, whereas most of the pisoliths and nodules in the Southern Cross Formation are concentrated at its top.

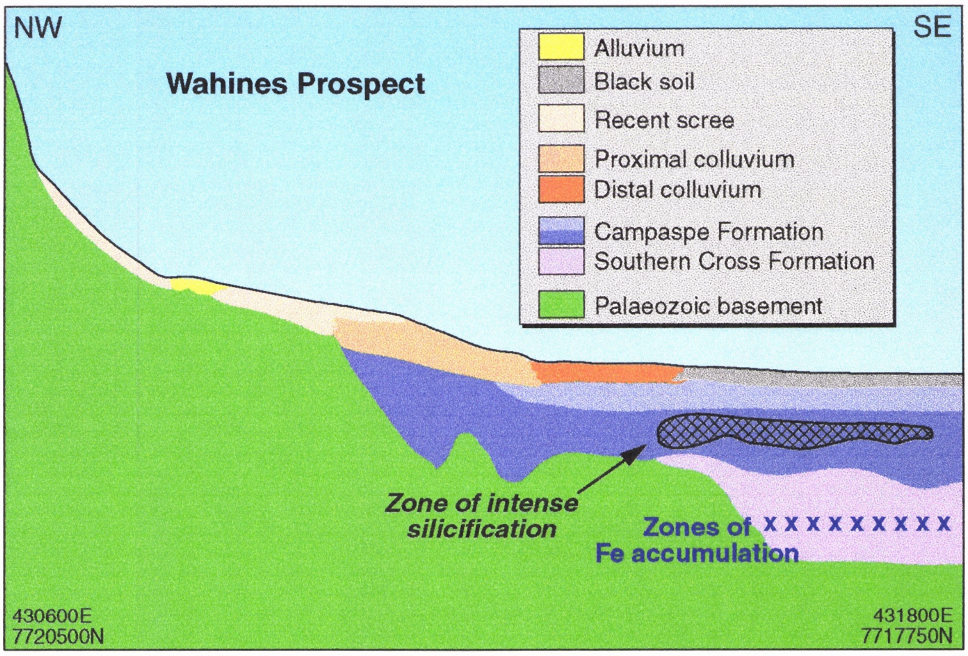



Figure 28. Northwest-southeast cross section through Wahines Prospect.

## 4.4 Regolith Geochemistry

### *4.4.1 Scott Lode Pit*

The dispersion of elements from the mineralisation into the Southern Cross Formation is studied using size fractions >2000µm (coarse) and <100µm (fine). Figure 29 shows the distribution of selected major and trace elements. No depths are given due to lack of information. The nature of the two size fractions are reflected by the major oxides. The coarse fraction consists of slightly higher $Fe_2O_3$ and $SiO_2$ whereas the fine fraction contains slightly more clay indicated by higher content of $Al_2O_3$ and $K_2O$, the latter possibly from mica.

The Au concentration ranges from 27-349 ppb in the Southern Cross Formation and is anomalous througout this unit in both size fractions, but with higher concentration in the fine fraction, suggesting hydromorphic dispersion into the clay. At the surface, the As concentration of 312 ppm and Pb concentration of 61 ppm are high whereas the subsurface As and Pb concentration are from 26-90 ppm and 12-31 ppm respectively. The Sb concentration ranges from 4.0-9.2 ppm. The two higher concentration values of W are possibly due to detrital grains in the sediment. The Cu and Zn concentration are <10-59 ppm and 25-89 ppm respectively.

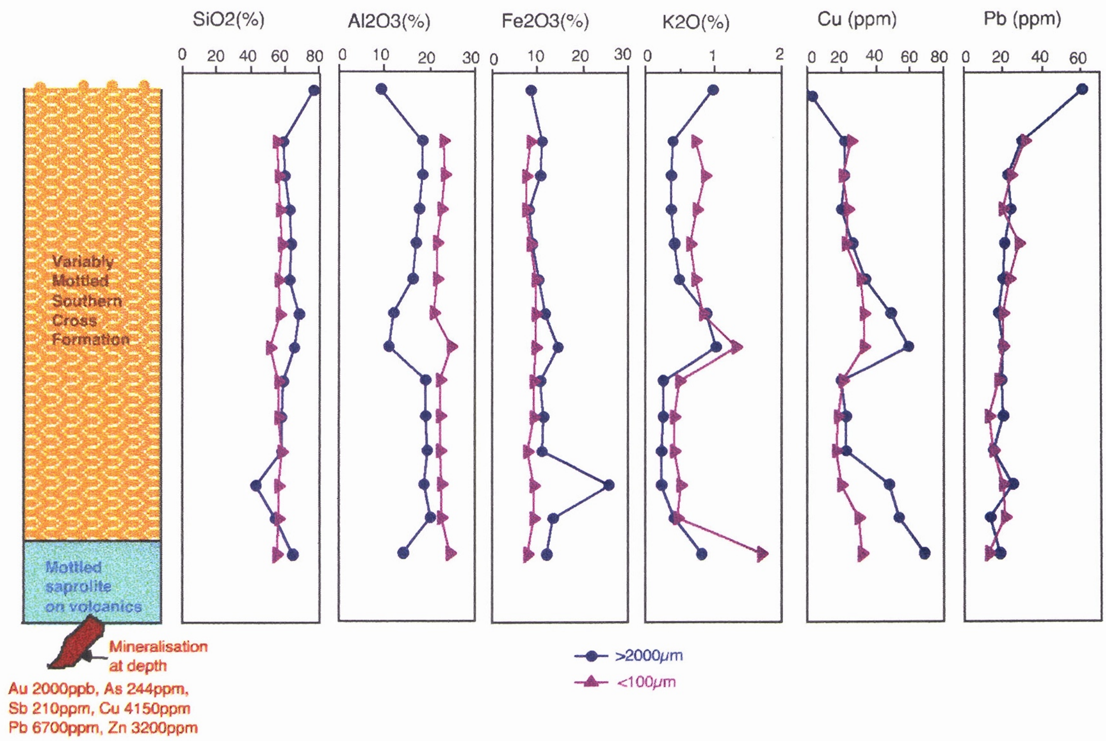
### *4.4.2 Wahines Prospect*

Eight RAB drill holes (WHNRB 241, 242, 243, 268, 269, 270, 271 and 272) were selected from the Wahines Prospect for an orientation study of the regolith geochemistry. These drill holes intersected the four major lithologies, black soil, Campaspe Formation, Southern Cross Formation and basement. The results for holes 241, 242 and 270 are shown in Figures 30, 31 and 32 and Tables 6A & 6B.

The Southern Cross Formation contains greater contents of most pathfinder elements (As, Sb, Pb) than the Campaspe Formation. Arsenic, Pb and Sb are all concentrated in the Southern Cross Formation of WHNRB 242. The concentrations of pathfinder elements are generally greater at the base of the Southern Cross Formation and decrease up the profile. Superimposed on this are later ferruginous bands that have greater concentrations of most of the elements of interest. High concentrations of Sb, As, Cu, and Au in the Campaspe Formation are all related to ferruginous materials that have formed in these sediments. Some of the Campaspe Formation has been silicified to silcrete which does not appear to be enriched in these elements. SEM and microprobe analysis of these silcretes has shown that goethite and hematite have precipitated within voids in the silcrete and these Fe precipitations hold the As, Sb and Au.

Variation in As, Sb and Pb concentrations is greatest in the basement and is not significant in the black soil of the Wahines area. The saprolite in the Wahines Prospect has a wide range of concentrations for most possible pathfinders. WHNRB 242 and WHNRB 270 revealed the greatest contents of most of these elements. There appears to have been hydromorphic dispersion from the basement into the Southern Cross Formation.

The range in particle sizes in the drilled regolith samples is due to i) size variation of the original sedimentary particles, ii) subsequent modification by weathering and iii) the mechanical influence of drilling. Most of the >2000 µm fraction of the Campaspe Formation comprises quartz grains and detrital pisoliths; most of the <100 µm fraction is kaolinite and goethite. The fine fraction almost always has greater contents of Pb. The nugget effect would be greater in the pisoliths, which contained greater concentrations of Cu and Pb prior to sedimentation and subsequent hydromorphic dispersion.



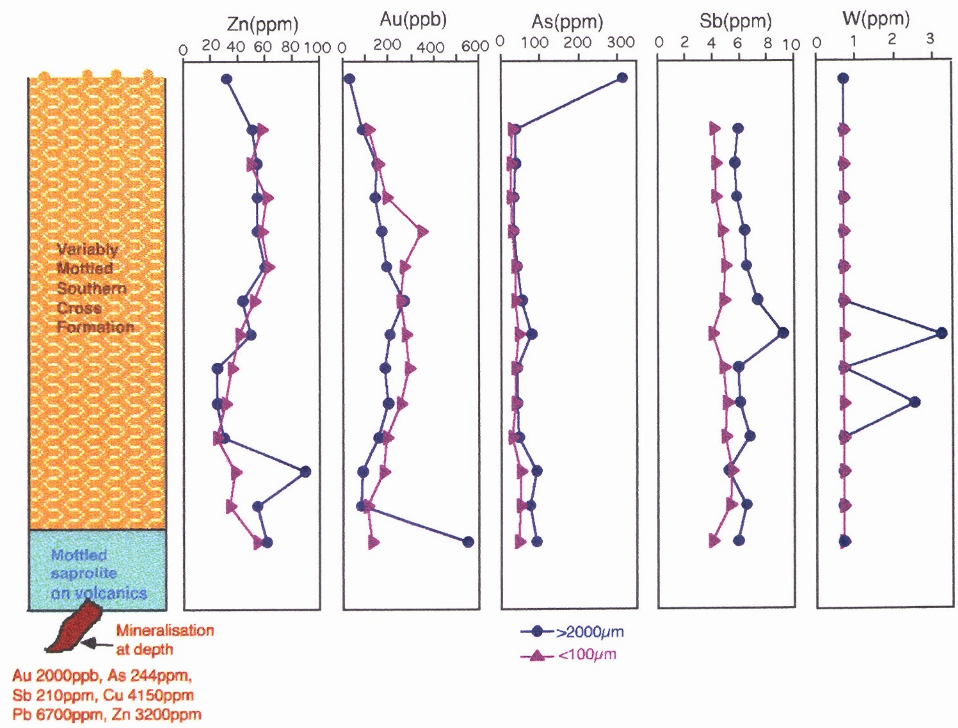




Figure 29. Distribution of selected major and trace elements in Southern Cross Formation, Scott Lode Pit.

The concentration of Au, Sb and As in the Fe-rich horizons shows that hydromorphic dispersion into the Tertiary sediments and adsorption by Fe oxides is an important process. Mechanical dispersion of pisoliths has occurred in the Campaspe Formation but these contribute an insignificant proportion of the bulk of the sample. It is possible that pathfinder concentrations of Fe-poor zones of the Campaspe Formation in the Wahines prospect are regionally anomalous but this has not been established to date.

Sampling of ferruginous zones within the cover sequences is effective in increasing the gold concentrations of the material. The difficulty in using these zones in exploration is in recognising mechanical from hydromorphic dispersion.

Sampling of the unconformity between the Southern Cross and Campaspe Formations, and the base of the Southern Cross Formation (interface sampling) also enhances the Au, As and Sb concentrations. This technique may be limited by difficulty in accurate identification of these interfaces in drill spoil.

Where pisoliths occur in the Southern Cross Formation, they can be used as they have higher concentrations of Sb, As and Ba. The fine fractions are richer in Pb in the Southern Cross Formation and probably indicate an early dispersion of this element into this fraction. Not enough Au has been found in the Southern Cross Formation of the Wahines area for its relationship with the materials to be established.

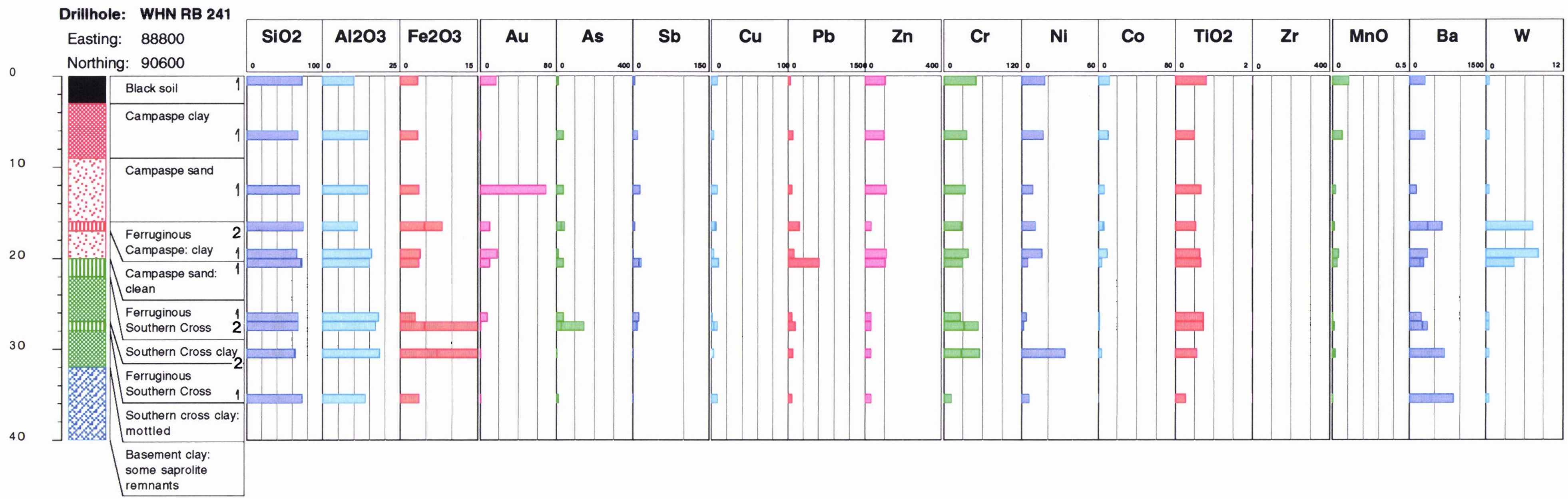



Figure 30. Geochemistry of selected regolith units (1=>2000 µm fraction, 2=<100 µm fraction); from drill hole 241.

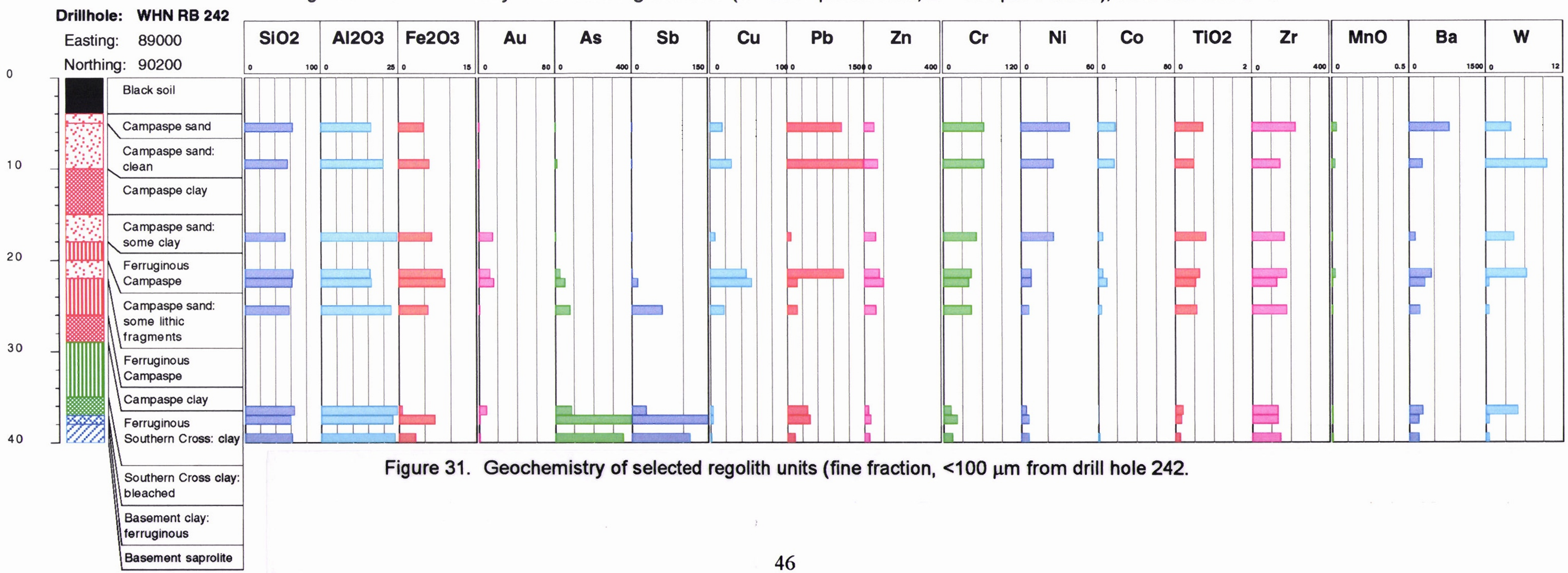



Figure 31. Geochemistry of selected regolith units (fine fraction, <100 µm from drill hole 242.

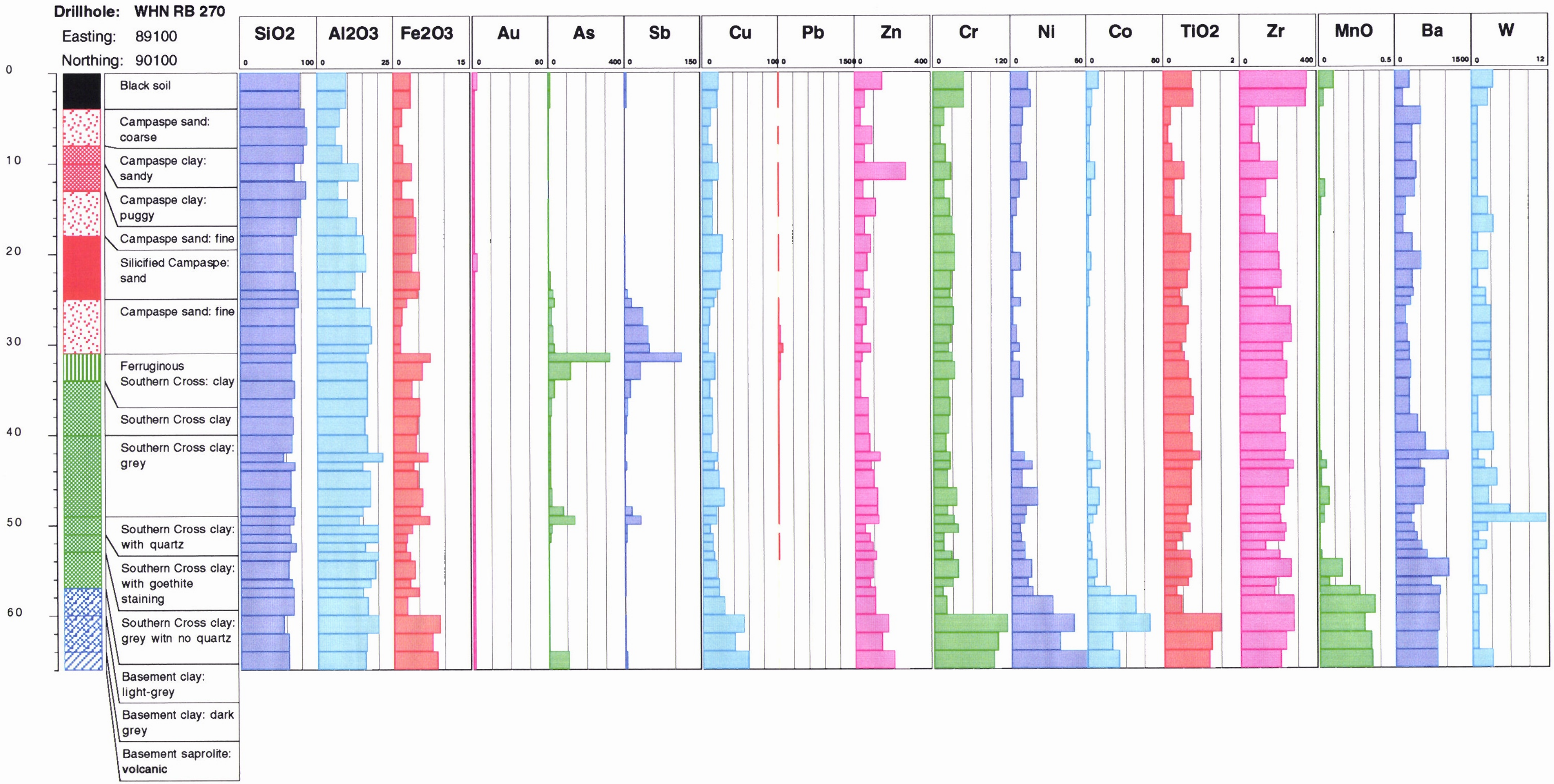



Figure 32. Geochemistry of selected regolith units (bulk sample) from drill hole 270.

**Table 6A. Chemical composition of size fractions, Wahines Prospect (WHN241)**

| Interval (m) | Campaspe Formation 16-17 | | Southern Cross Formation | | | | Volcanic Saprolite | |
|---|---|---|---|---|---|---|---|---|
| | 16-17 | | 20-21 | | 27-28 | | 30-31 | |
| Fraction | >2000 μm | <100 μm | >2000 μm | <100 μm | >2000 μm | <100 μm | >2000 μm | <100 μm |
| $Fe_2O_3$% | 8.23 | 4.73 | 3.48 | 3.76 | 22.61 | 4.82 | 21.86 | 7.15 |
| Au ppb | 8.9 | 11.1 | 1.6 | 11.3 | 1.6 | 1.6 | 1.6 | 1.6 |
| As ppm | 48 | 25 | 41 | 40 | 145 | 29 | 8 | 4 |
| Sb ppm | 4 | 5 | 16 | 23 | 11 | 7 | 2 | 2 |
| Pb ppm | 47 | 227 | 70 | 636 | 43 | 144 | 26 | 92 |

**Table 6B. Chemical composition of size fractions, Wahines Prospect (WHN242)**

| Interval | Campaspe Formation | | Southern Cross Formation | | | | | | Volcanic Saprolite | |
|---|---|---|---|---|---|---|---|---|---|---|
| (m) | 17-18 | | 21-22 | | 22-23 | | 25-26 | | 39-40 | |
| Fraction | >2000 μm | <100 μm | >2000 μm | <100 μm | >2000 μm | <100 μm | >2000 μm | >100 μm | >2000 μm | <100 μm |
| $Fe_2O_3$% | 11.20 | 6.39 | 8.76 | 8.53 | 9.71 | 8.91 | 4.36 | 5.74 | 1.1 | 3.26 |
| Au ppb | 1.6 | 14.8 | 1.6 | 12.1 | 17.9 | 15.7 | 1.6 | 1.6 | 1.6 | 1.6 |
| As ppm | 17 | 6 | 33 | 28 | 58 | 54 | 80 | 77 | 95 | 35 |
| Sb ppm | 2 | 2 | 4 | 3 | 14 | 13 | 48 | 60 | 38 | 115 |
| Pb ppm | 28 | 72 | 215 | 1093 | 64 | 199 | 172 | 190 | 34 | 145 |

## 5.0 ROAD CUTTING, MARANDOO NEAR BELYANDO

*Li Shu and K.M. Scott*

### 5.1 STOP 9: Road cutting, Marandoo near Belyando

***Location:*** *442554E 7662013N*
***Geology:*** *Carboniferous sandstone*
***Landform:*** *Rise*
***Regolith:*** *Lateritic nodules, pisoliths and mottled saprolite on sandstone*

On the way from Pajingo to Mt Coolon there are many places where a lag of ferruginous pisoliths and nodules occur on the surface. This site is an example of lag of pisoliths and nodules on mottled saprolite (Figure 33).

This area was a low rise on the floodplain of Bullock Creek. Carboniferous sandstone has been mottled, with a thin layer of alluvial and colluvial material at the top. As the matrix of the mottled zone is dissolved, the mottles collapsed one another and so become increasingly abundant towards the top of the profile. Alluvial material in the upper part of the profile has been also mottled.

Pisoliths and nodules are mixed with the alluvium in the upper part of the profile. This results from biological activities such as soil churning by tree roots and/or termites. It can also occur where fine material move along a slope with pisoliths. Therefore, it shows a mobile landscape in this respect, and the pisoliths and nodules are weathering products of locally derived material.

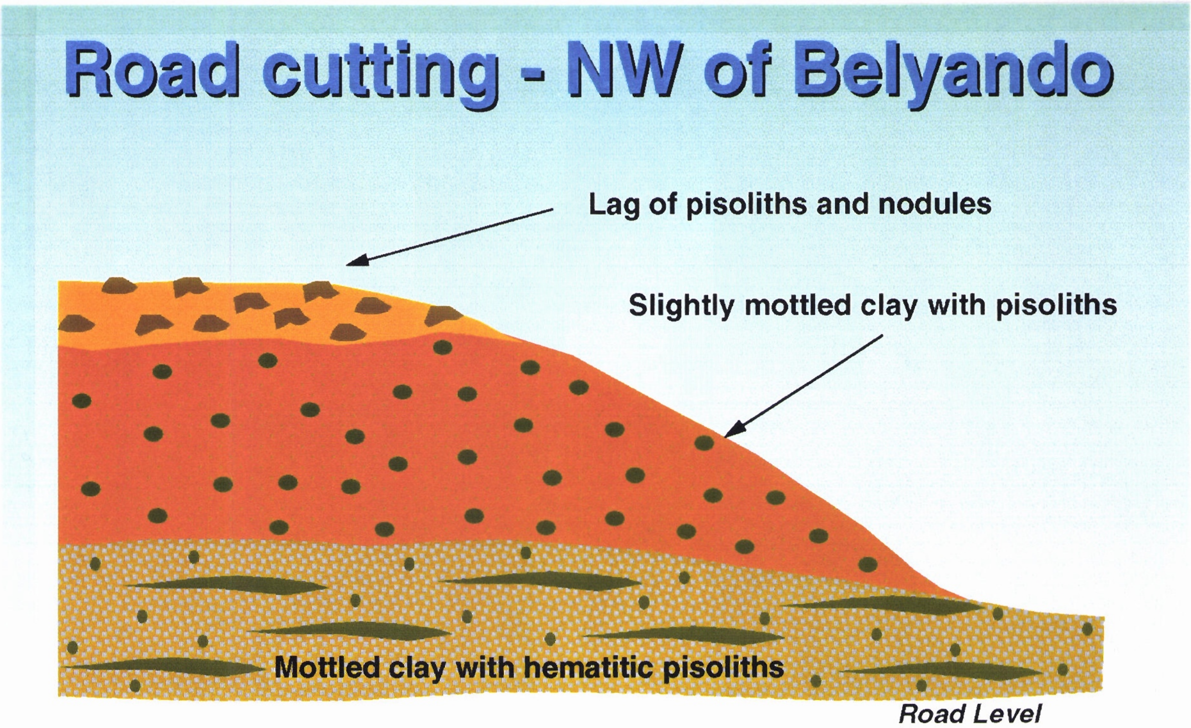



Figure 33. Weathering profile at 442554E 7662013N along the road from Pajingo to Belyando.

## 6.0 MT COOLON-POLICE CREEK AREA

*K.M. Scott and Li Shu*

### 6.1 Regolith Landforms of the Mt Coolon-Police Creek Area

The Mt Coolon area (Figure 34) lies between latitudes 21° - 21°30'S and longitudes 147°10' - 147°30'E, about 250 km south of Townsville in the northern Drummond Basin. It has been geologically mapped by the Geological Survey of Queensland and many mining companies. A preliminary map on a scale of 1:100 000 is available with an explanatory record (Hutton *et al.*, 1991), and geological details for individual exploration licences within the area can be found on open file at the Geological Survey of Queensland. However, previous mapping has been largely based on interpretations of aerial photographs and mapping by individual companies needs to be consolidated.

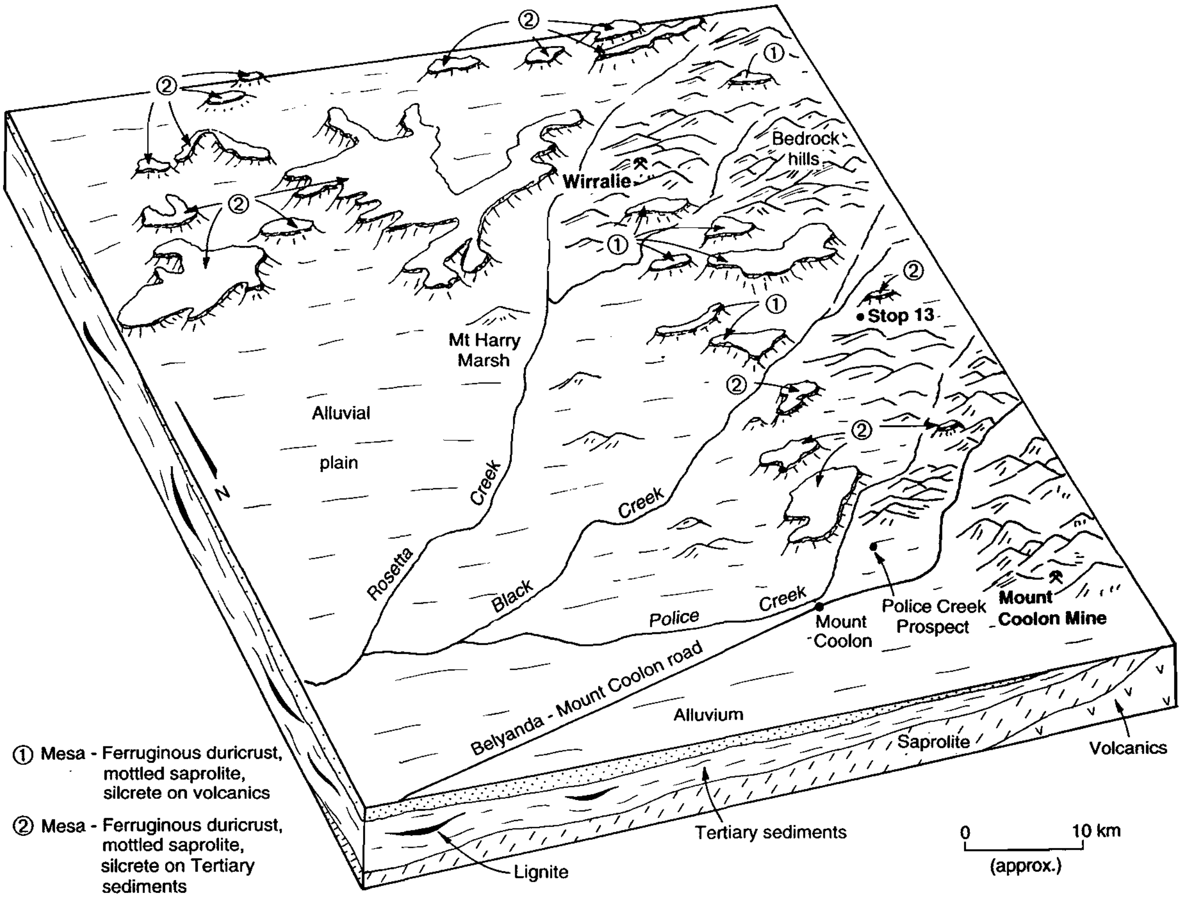



Figure 34. Block diagram showing landforms in the Mt Coolon Area. A large part of the area is an alluvial plain formed by deposition of sediments brought down by Police Creek, Black Creek and Rosetta Creek. Ferruginised Tertiary sediments and deeply weathered saprolite on basement rocks form mesas. The eastern part of the area is dominated by hills of bedrock.

#### *6.1.1 Geology*

The Mt Coolon area consists of three major structural units, the Drummond Basin, the Anakie Inlier and the Bulgonunna Volcanics. The Drummond Basin comprises the Mt Wyatt Formation and Silver Hills Volcanics, a mixed sequence of Devonian to Carboniferous sediments and volcanics. Lithologically, these sequences consist of medium to thick bedded ignimbrites, rhyolitic and dacitic tuffs, sandstones, siltstones and shales (Hutton *et al.*, 1991). Within the Drummond Basin, the Anakie Inlier strikes north through Mt Coolon. This unit consists of metamorphosed fine-grained sandstone, siltstone, slate, phyllite and schist. The Bulgonunna Volcanics is a sequence of Late Carboniferous rhyolites and ignimbrites outcropping in the northeast and the east of the area.

The Drummond Basin contains a thick sequence of Tertiary, unlithified sediments with lignite lenses, known as the Suttor Formation. At Rutherfords Table, immediately to the north of the study area, the sediments are 73 m thick and form a large mesa (Figure 35). In the west part of the study area, however, the Suttor Formation occurs beneath an alluvial plain. Drilling shows the sediments to be about 120 m thick (Strickland, 1993).

The International Mining Corporation NL drilled intensively through the Suttor Formation in the 1980's in search for oil shale in the lower part of the sequence. It is found that bodies of oil shale were distributed around basement highs of Devonian volcanoclastics at Mt Harry Marsh; two of these oil shale bodies were inferred to have oil reserves of 174 Mt at 136 l/t under 20 to 40 m of overburden (d'Auvergne, 1984; Hawley and Marosszeky, 1992).

Quaternary sediments are widespread in the area, covering most part of the Suttor Formation on the plain. The sediments are unconsolidated colluvium and alluvium brought down by Rosetta, Black, and Police creeks. They were derived from weathering of basement rocks as well as reworking of the Suttor Formation. Although the sediments are similar to the Campaspe Formation, further to the north around Charters Towers, at present they lack a formal name.

#### *6.1.2 Regolith*

Profiles on basement rocks, in particular the Anakie Metamorphic sandstone and siltstone, show that these rocks have been subject to complicated processes of prolonged weathering. In many cases, the bedrocks have been changed to saprolite; Fe was bleached from them to leave white clay and, subsequently, either ferruginised or silicified, forming silcrete and ferruginous saprolite. In the case of granite or ignimbrite, where dark minerals are weathered and bleached, they can turn to white silicified saprolite. As these deeply weathered saprolite also form mesas and as the Tertiary sediments, where intensely weathered, have similar characteristics, it can be difficult to differentiate, even in the field, between mesas formed on the Anakie Metamorphic rocks from those formed on Tertiary sediments. Geological maps of the area are largely based on aerial photograph interpretation. As the mesas on these different parent rocks are so similar, field mapping by this means is difficult.

During this field excursion, weathered Tertiary sediments will be seen at the Police Creek Prospect, at Stop 13, and at the Wirralie Mine. These are highly ferruginised with mottles and megamottles developed through the whole profile. Duricrusts have formed in the top part. Silicification has taken place wherever water, with a high silica content, was available. Silcrete occurs at the top of mesas, in the middle or at the bottom of weathered profiles. A lag of Fe nodules, pisoliths and fragments of broken mottles occur at the top of the mesas or surrounding them.

Weathering of Quaternary sediments also occurred in the area. Small mottles have been developed in the sediments under soil profiles, as exposed by gully erosion at the Police Creek Prospect and the nearby Wirralie Mine. However, they are incipient and not comparable to those developed in basement saprolite or in the Suttor Formation. Along many modern creeks in particular along their beds, recent sediments are found silicified, indicating the process of silicification is still operating at present.

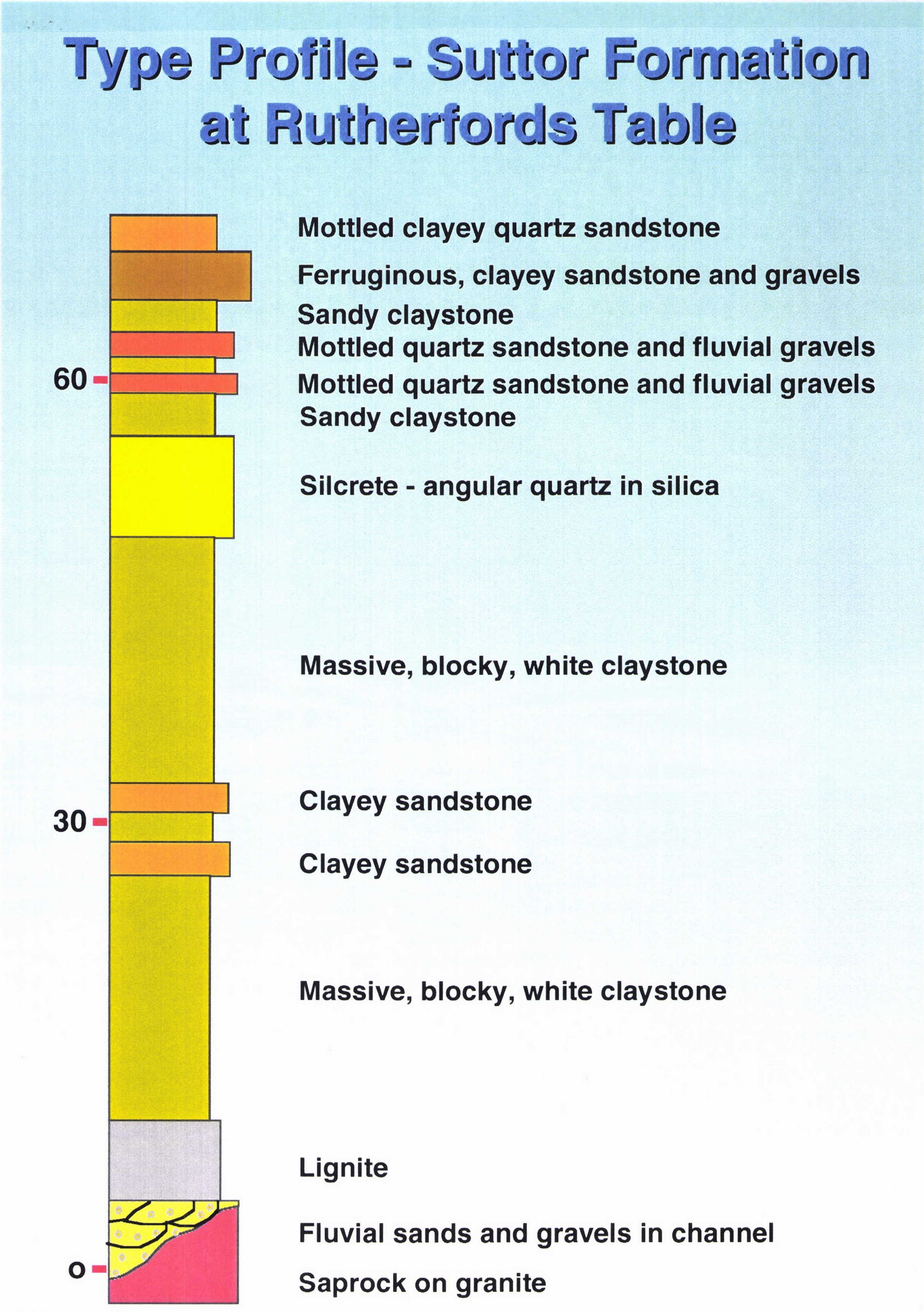



Figure 35. Type profile of Tertiary sedimentary units at Rutherfords Table, 25 km north of the Wirralie Mine. The lower part of the profile can be seen only in a mine shaft.

### *6.1.3 Landforms*

There are three major groups of landforms within the Mt Coolon; hills of bedrock, mesas and alluvial plains.

*Hills of bedrock*

The Bulgonunna Volcanics appears to be more resistant to erosion and forms low hills with a general relief of less than 100 m in the east part of the area. These provide abundant detritus to supply alluvial plains in the central and west. Hills formed on the Anakie Inlier are smaller, 20 to 50 m above the surrounding plain.

*Mesas*

Prominent geomorphic features of the area are flat-topped mesas bounded by scarps and colluvium. Duricrusts (ferruginous duricrust, silcrete) are common on all mesas and form a hard cap which protects a vertical scarp. Colluvium, fallen from the top, generally piles at the foot of the scarp and covers the lower part of the mesa. Profiles, lacking a covering of colluvium, are uncommon. The tops of the mesas are at 270-300 m elevation and stand 5-20 m above their surrounding. Most are isolated, but there are a few large mesas about 3 km wide and 5 km long to the northwest of Rosetta Creek. Around Police Creek, the mesas are only a few metres above the alluvial plains.

*Alluvial plains*

Alluvial plains occupy a large proportion of the area and are commonly referred to as black soil plains. However, the soil developed on Quaternary alluvium is grey, and the swelling and cracking feature common to most of black soil is not very apparent. The plains have been constructed by deposition from major creeks by channel filling and backwater sedimentation. Data from drilling on the plain of Rosetta Creek show that the Tertiary and Quaternary sediments are 20-120 m thick. To the east of the Anakie Inlier, where less data are available, the alluvium thickness is estimated at 10-20 m.

### *6.1.4 Landscape evolution*

The landscape around Mt Coolon has a long and complex history. Mesas formed on bedrock-derived saprolite and mesas formed of Tertiary sediments appear to have top surfaces at a similar level, suggesting that this area experienced intensive weathering prior to Tertiary sedimentation. Saprolite must have developed on basement rocks first and later, after extensive stripping, gave rise to an erosional plain, with bedrock outcropping as hills in the east part of the area. Within the erosional plain, active streams were gradually filled with sediments and colluvium, forming the Suttor Formation. The erosional plain was dissected in the mid-Tertiary and Miocene lignite was developed in the southwest.

Tertiary sediments stand up as mesas in the northwest part of the area but, about 10 km away to the south, the sediments are buried about 100 m below the surface. This is possibly due to episodic events of deposition and erosion over a long time span. The sediments forming mesas could have been deposited first and, after intense weathering, were eroded and dissected into ancestral mesas. During the erosive episode, early sediments in the lower reaches of the creeks were partially removed.

As oil shale is found in some places but not in adjacent blocks, an assumption has been made that the oil shale near the base of the Tertiary sediments is restricted to down-faulted blocks either during oil shale deposition or shortly after, and hence a system of graben and half graben structures and a lacustrine depositional environment are suggested (d'Auvergne, 1984; Hawley, 1990). The graben structure was thought to be associated with Tertiary re-activation of NNE and NW basement faults which are evident from airborne magnetics and air photos. Field evidence of the deformation in the Tertiary sediments is, however, still to be found.

The depositional environment of the Tertiary sediments has been long regarded as fluvial and lacustrine (Grimes *et al.*, 1986; Hutton *et al.*; 1991). The model for oil shale exploration used by International Mining Corporation NL is a lacustrine model which is used to delineate the boundaries of groups of Tertiary lakes and their volume. However, lignite deposits can be formed outside a lacustrine environment. Their discontinuous distribution may not necessarily indicate structural deformation since they also may be developed in abandoned channels, similar to modern organic deposits developed in the large billabongs of the Murray Basin.

Recent drilling by Ross Mining NL for water for the Yandan Mine have successfully located a major palaeochannel to the west of Mt Harry Marsh, from which the palaeochannel ran south-east, closely following the modern Rosetta Creek but 80-110 m beneath the surface (Strickland, 1993). A thick, graded sequence of well-sorted sandstones and a basal pebble conglomerate represent an active, braided stream system. The siltstone and claystone sequence represent a lower wet overbank swamp deposit containing lenses of lignite. The work also infers levees and crevasse splays.

As the Tertiary and Quaternary sediments over the bed of buried palaeochannels is about 120 m thick, this would imply a depositional rate of 2.4 m per million years over 50 Ma. This means that the formation of the plains may not involve any down faulting. In last October, after one storm event, many channels on the plains were almost completely filled with sediments (Figure 36). This would prompt channel changes and gradually build up the alluvial plain.

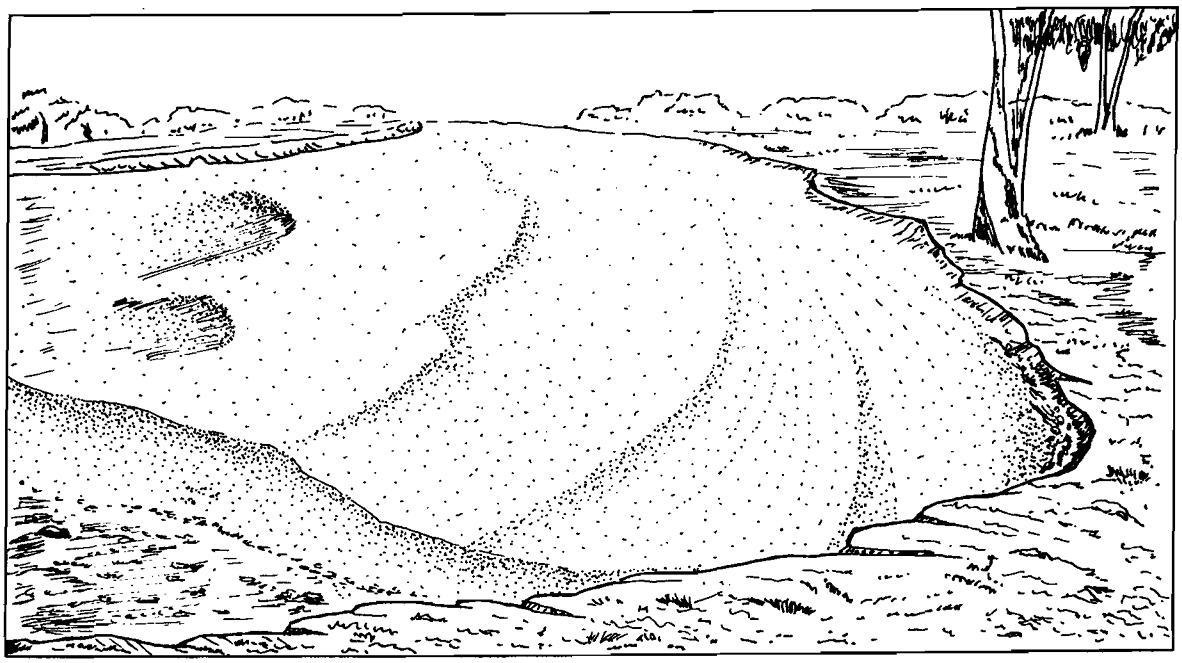


Figure 36. Formation of the alluvial plain by channel filling along Bungobine Creek. The sediments shown here were deposited after 130 mm of rain in October, 1995.

## 6.2 STOP 10: Police Creek Case Study

Within the northern portion of the Drummond Basin Au mineralisation occurs at Yandan, Mt Coolon, Wirralie and in the Bimurra-Conway area, all within 50 km of Police Creek (Figure 37). All of these deposits are characterised by sericitic alteration assemblages which are frequently overprinted by kaolinite. Adularia is locally present as an alteration mineral with pyrophyllite and alunite also common minor associates (Wood *et al.*, 1990). The Au:Ag ratio is ~10:1 at Yandan and between 2:1 and 3:1 at Wirralie and Mt Coolon but Ag contents are much higher in the Bimurra-Conway area with ratios locally 1:10 or more (Wood *et al.*, 1990; Seed, 1995a). The gold in these deposits tends to be fine grained, *e.g.* 50% of the gold at Yandan is less than 5 microns and 92% less than 30 microns in diameter (Seed, 1995a).

At Police Creek, the Silver Hills Volcanics are the host to pervasive silica-pyrite alteration which contains discrete zones of quartz+pyrite±marcasite breccia (up to 10 m wide) and narrow quartz-carbonate veins. Such mineralisation grades up to 0.5, 3 and 10 g/t respectively (R. Mustard, pers. comm., 1994). The silica-pyrite alteration is surrounded by successive zones of illite and chlorite/carbonate typical of epithermal mineralisation (*e.g.* Hayba *et al.*, 1986). Obvious base metal sulfides are not developed in the alteration zones.

As indicated below, the Silver Hills Volcanics are affected by a mid-late Tertiary lateritisation event and subsequent weathering events. Complete weathering of sulfides occurs to a depth of 30 m, with partial weathering extending for another 10-20 m. Within the zone of partial weathering (transitional zone) there is some supergene Au enrichment to grades ~1 g/t. Gold is however depleted in the saprolite above the supergene zone except where the gold is armoured by quartz. It is however present in the transported material which overlies the mineralised Silver Hills Volcanics.

Quartz latite ignimbrites of the Carboniferous Silver Hills Volcanics are characterised by the presence of 5-10% quartz phenocrysts and are stratigraphically equivalent to the Bimurra Volcanics (Hutton *et al.*, 1991). During the Early Tertiary these rocks were overlain by the sandstones of the Suttor Formation with some incorporation of locally derived material (viz. epithermal quartz vein material and quartz phenocrysts from the underlying volcanics) into the unit. In the Police Creek area the Suttor Formation is generally ~10 m thick. During the Middle to Late Tertiary period lateritisation processes affected the Drummond Basin (Wells *et al.*, 1989). In the Police Creek area this results in surface ferruginisation of the Suttor Formation and mottled and clay zone development in the underlying bedrock (Silver Hills Volcanics). Subsequently the lateritic profile has been incised to a depth of 15-20 m thereby exposing the mottled and clay zones within the Silver Hills Volcanics before deposition of the alluvium and colluvium which form the present surface.

In the Police Creek area the alluvial and colluvial material forms a pediment about 10 m below the top of a scarp composed of Tertiary Suttor Formation. The transported material of the pediment is up to 6 m thick and is subject to pedogenic processes giving rise to incipient pisolith development and mottling about tree roots. Pediment material may be incised by the current streams with several periods of fluvial deposition occurring. Basement rocks may form areas of outcrop up to several metres above the pediment level but areas of coarse float suggest that the basement occurs beneath very thin cover in other areas, especially close to the Suttor Formation scarp. The extent of such areas where residual material is incorporated into shallow residual soils is probably greater than originally estimated. The geomorphic and stratigraphic relationships are shown in Figure 38.

The original exploration in the area by Australian Consolidated Minerals Limited (ACM) used the -80 mesh (-180 μm) fraction of the alluvium to define a 1200 x 600 m anomalous Au zone which occurs above mineralisation in the basement rocks (Figure 39). Silver, As, Cu and Sb (but not Pb and Zn) were also found to be anomalous within the anomalous Au zone (R. Mustard, pers. comm., 1994). Because the bedrock below the alluvium is depleted in Au, ACM believed that the transported material was up to 30 m thick. However mapping of the costean faces by Ross Mining geologists revealed that quartz phenocrysts derived from the basement rocks are present at 2-3 m depth above mineralisation and the transported material is less than 6 m thick.

Detailed work during the course of this project (Scott, 1995a) suggests that analysis of the -75 μm (*i.e.* kaolinite-rich) fraction of the soil results in a more intense Au anomaly than the -80 mesh (-180 μm) fraction. Although As > 50 ppm and Sb > 5 ppm occur in the fine fraction, these elements are concentrated in the Fe rich + 2 mm fraction of the soils. Thus As > 200 ppm, Sb > 10 ppm, Mo > 5 ppm in the coarse fraction also define the area defined by Au > 40 ppb in the fine fraction. In addition use of both the fine and coarse fraction of soils leads to the identification of a second anomaly defined by Au > 100 ppb, As > 140 ppm and Sb > 10 ppm in the coarse fraction (Figures 40-42). This second anomaly is present in residual soil and was not identified by the original -80 mesh sampling.

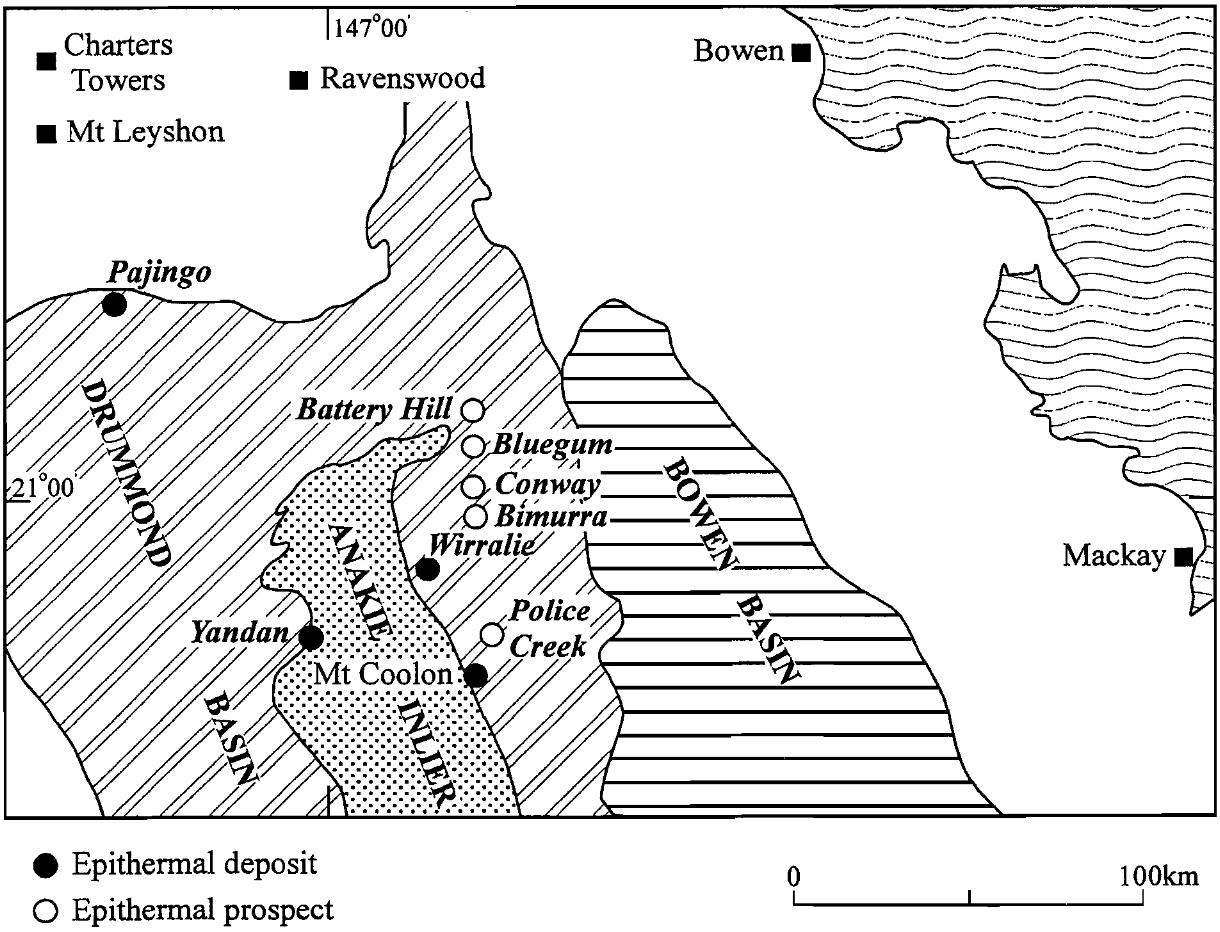



Figure 37. Regional geological setting of epithermal gold deposits, Drummond Basin, Qld.

**Regolith Stratigraphy**

*Youngest*

- Local colluvium
- Fluvial alluvium
- ? Residual soil
- Sheetwash (qtz-rich) - poorly developed in prospect area (not shown below)
- Alluvial soil
- Suttor Formation

*Oldest*

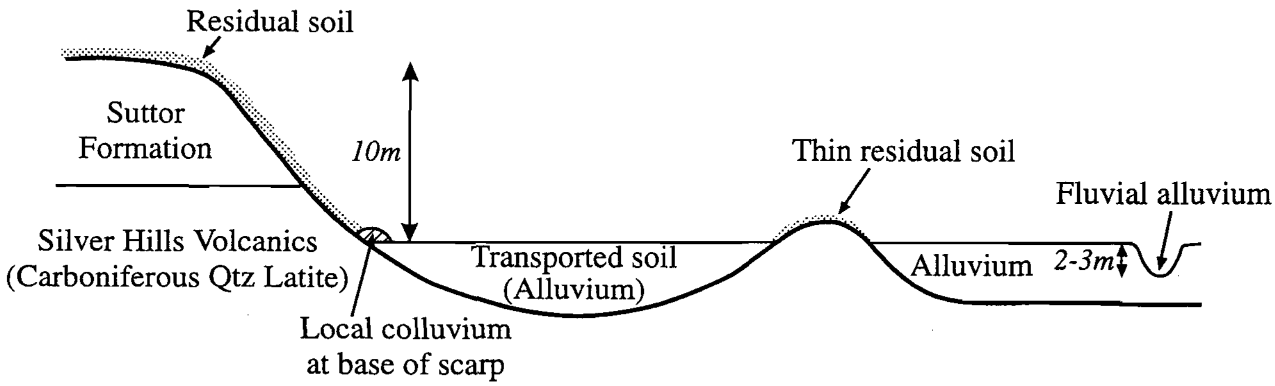



**Figure 38. Schematic representation of the landscape and stratigraphy in Police Creek prospect area.**

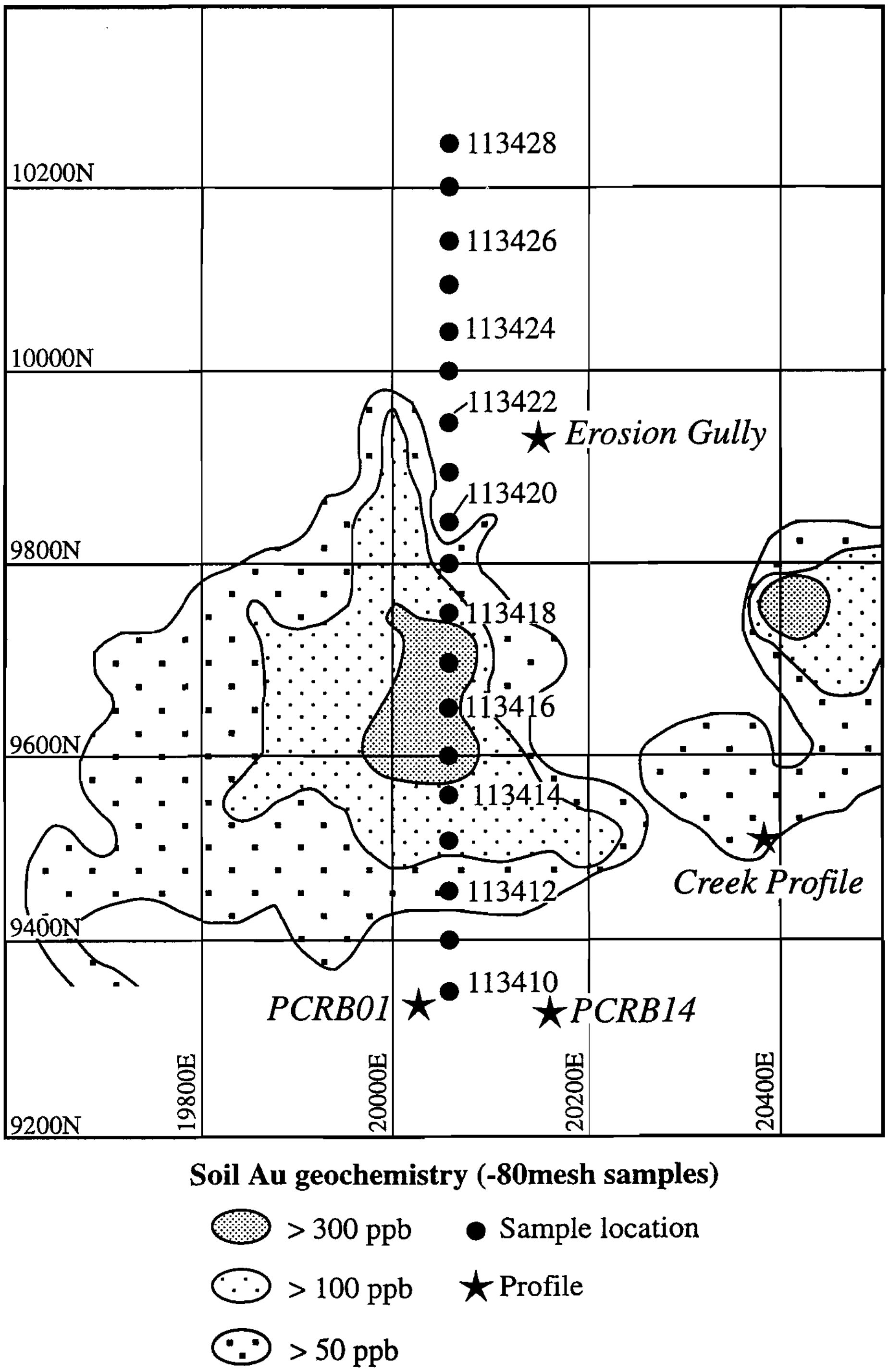



Figure 39. Plan of the Police Creek anomaly, showing locations of samples and ACM's - 80 mesh Au geochemistry.

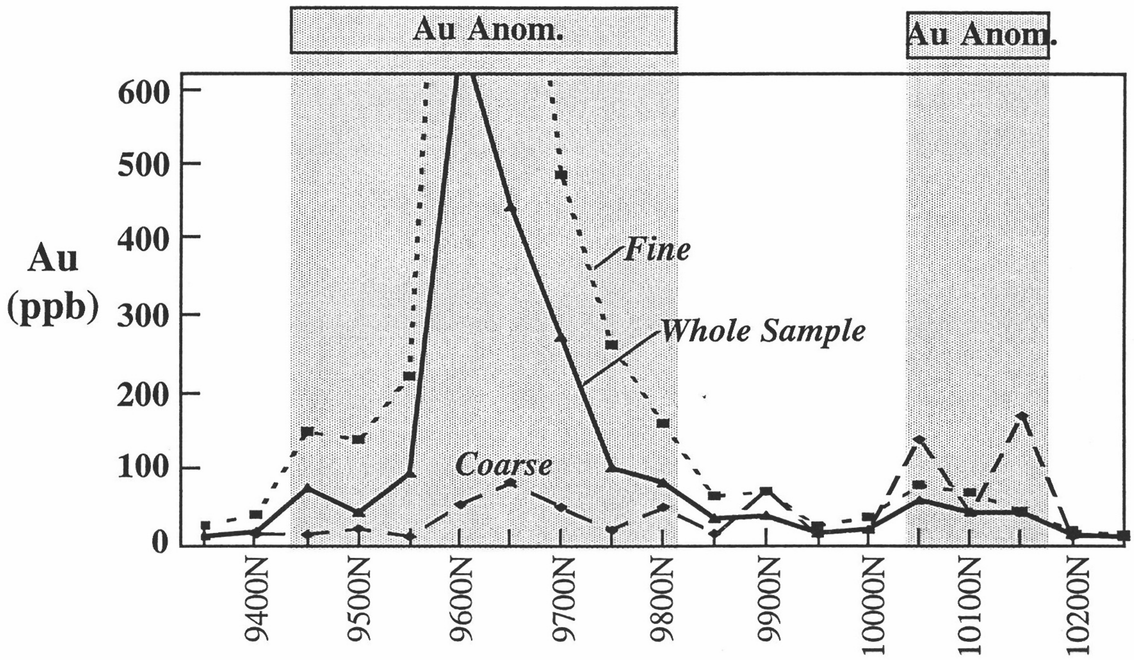



Figure 40. Distribution of Au in various fractions of soil along 20050E Traverse.

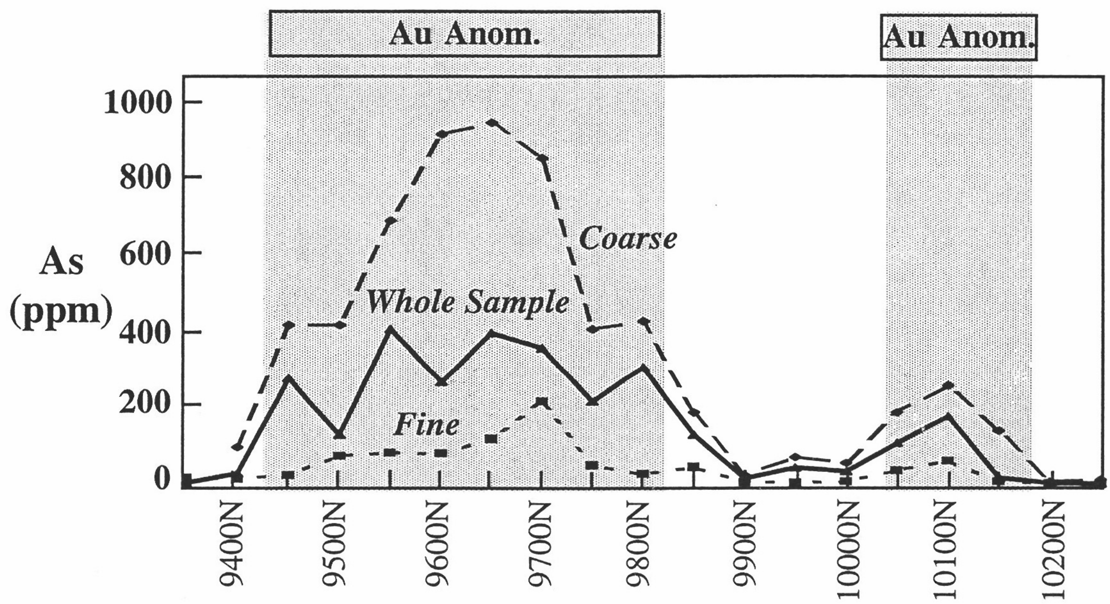



Figure 41. Distribution of As in various fractions of soil along 20050E Traverse.

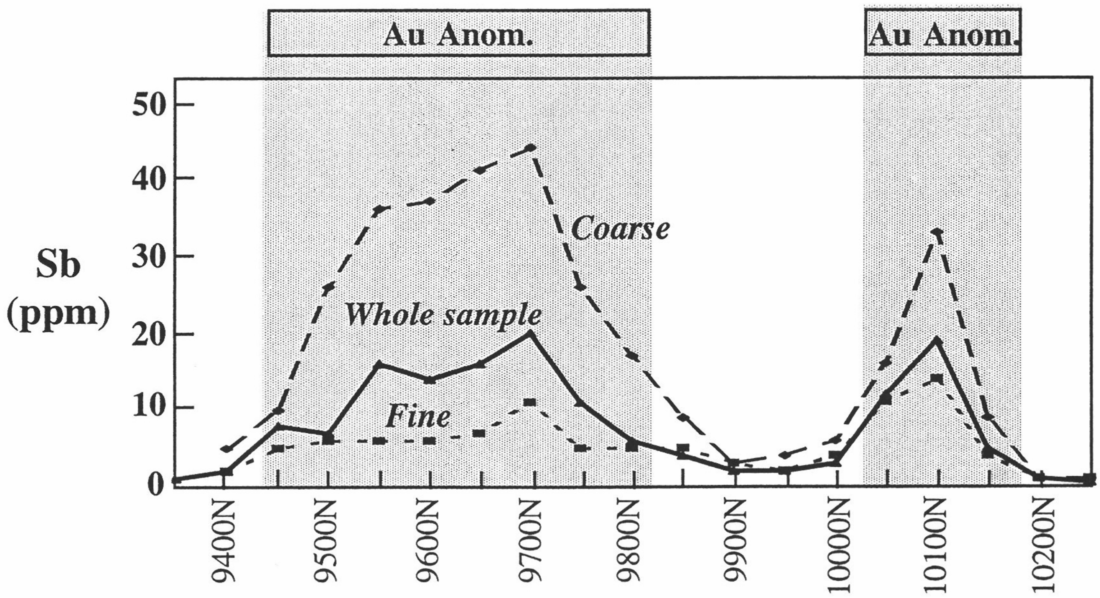



Figure 42 Distribution of Sb in various fractions of soil along 20050E Traverse.

## 6.3 STOP 11: Creek Section/Profile

*Location:* *20380E 9500N*
*Geology:* *Silver Hills Volcanics*
*Landform:* *River terrace*
*Regolith:* *Mottled saprolite, saprolite*

This section provides some details on the nature of weathering of altered/mineralised Silver Hills Volcanics (Figures 43 and 44).

Four samples from the creek bank at 20380E/9500N and its vicinity have been analysed. Two adjacent samples of weathered altered volcanics consisting of white kaolinitic and more reddish ferruginous stained material (112838 and 112839 respectively) were sampled from the creek bank. Both samples consist of assemblages of quartz, muscovite, hematite and anatase with kaolinite, alunite and halite also present in the white kaolinitic sample and some hematite in the more ferruginous sample. The kaolinitic sample thus has higher Al (reflecting kaolinite and alunite), Na, Cl, Br (reflecting halite), S and ?Sr (reflecting alunite) with Ti and Zr reflecting anatase and zircon. Although As is greater in the more ferruginous sample, other differences *e.g.* slightly higher K and Rb reflecting the higher mica contents in 113839 are not significant. Mottled material (112840) is exposed in low outcrop slightly west of the creek samples (Figure 44B). It has very high Fe (27.7%) and quite high As (1700 ppm) and Sb (77 ppm). The lag sample (112841) from the same general

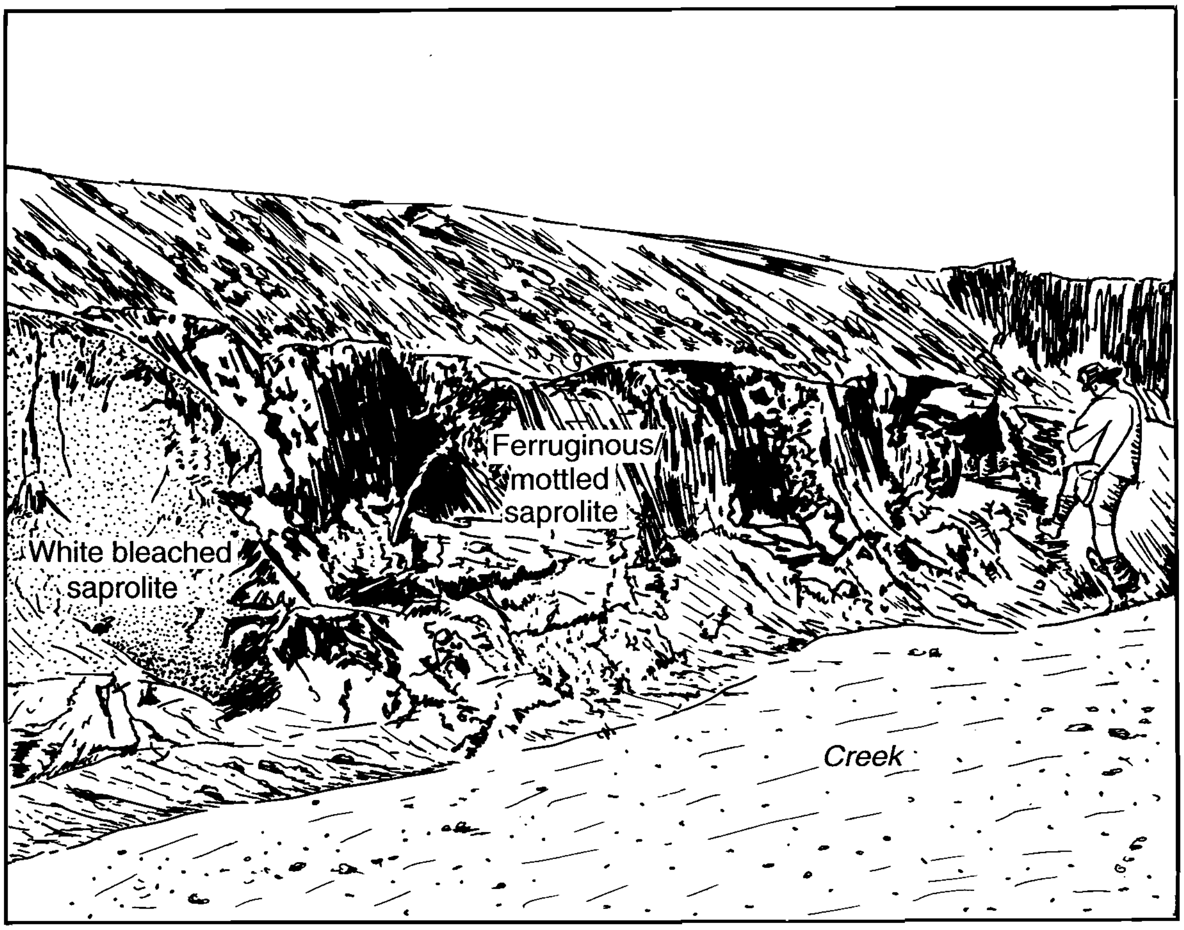



**Figure 43.** **Weathered Silver Hills Volcanics exposed in the bank of a small Creek near the Police Creek Prospect.**

area as the mottled material, was divided into +2 mm and -75 μm fractions like the soils. The +2 mm fraction contains a significant proportion of angular magnetic fragments. Arsenic and Sb are again associated with the Fe in the coarse fraction and Au with the finer fraction. Molybdenum and Ba are high in both fractions and Cr and W are high in the finer fraction (Table 7).

Assuming that the alunite, and hence the significant $SO_3$, in sample 112838 (Table 6) is derived from weathering pyrite, the samples from the creek profile at 20380E/9500N appear to reflect the effects of weathering of altered/mineralised Silver Hills Volcanics. In addition to the $SO_3$, As, Sb and perhaps W and Mo from the original Au-bearing pyrite assemblages are retained but Au itself is severely depleted. Assuming a typical Au content ~500 ppb in unweathered quartz-pyrite altered material, the reduction to <50 ppb in the creek bank samples imply an order of magnitude loss of Au due to weathering. Such severe leaching could reflect very acid weathering conditions (indicated by the presence of alunite). The separation of Au from its pathfinders is also a feature of the soils at Police Creek (see case study). Of the pathfinder elements S, As, Sb, Mo and W, all except W would be expected to be partially mobile under acid weathering conditions. Although the nature of the original occurrence of W is not known (*i.e.* it could have been as scheelite, wolframite or other accessory minerals), its greater presence in the kaolinite-rich samples rather than the more ferruginous samples from the creek bank may suggest that it accumulates in the fine grained fraction, probably as a resistate mineral. If this is so W may provide evidence of whether the presence of potentially more mobile elements (Au, As, Sb, Mo, S) in a particular sample reflect an *in situ* situation or could reflect hydromorphic dispersion. (Further work to better document the occurrence of W is needed).

A more complete profile through highly mineralised Silver Hills Volcanics is provided by diamond drill hole 93 PCDH03. This diamond drill hole is collared at 20033E/9650N (*i.e.* within the major transported-soil hosted Au anomaly at Police Creek) and was drilled at 60° along the grid east bearing.

Soils in the top 3 m are pale brown-grey in colour with some jarosite staining on volcanics in the basal metre. Between 3 to 5 m the material is pink-grey in colour and strongly kaolinitic. From 5 to 21 m kaolinitic and siliceous fragments often with jarosite and/or Fe staining occur. The samples between 25 and 27 are Fe stained and kaolinised but with residual feldspar. Fresh material below 40 m consists of grey silicified volcanics with disseminated pyrite and pyrite veins.

Figure 44A. Creek Bank showing kaolinitic and more ferruginous areas within Silver Hills Volcanics (Police Creek).

Figure 44B. Mottled zone in Silver Hills Volcanics, Creek Profile. (Sample 112840, Police Creek).

**Table 7. Chemical composition of samples in Creek Profile, Police Creek**
(major components, wt%; minors, ppm)

| Sample No. | 112838<br>White clay | 112839<br>Fe-stained clay | 112840<br>Mottled clay | 112841A<br>Lag | 112841F<br>Fines-75 µm |
|---|---|---|---|---|---|
| $SiO_2$ | 82.7 | 89.8 | | | |
| $Al_2O_3$ | 8.48 | 4.14 | | | |
| $Fe_2O_3$ | 1.05 | 2.63 | 27.7 | 19.0 | 4.29 |
| MgO | 0.37 | 0.08 | | | |
| CaO | 0.04 | 0.10 | | | |
| $Na_2O$ | 0.59 | 0.11 | 0.35 | 0.05 | 0.11 |
| $K_2O$ | 1.11 | 2.13 | 1.77 | 1.20 | 1.28 |
| $TiO_2$ | 0.39 | 0.12 | | | |
| MnO | 0.01 | 0.02 | | | |
| $P_2O_5$ | 0.05 | 0.01 | | | |
| $SO_3$ | 0.59 | 0.03 | | | |
| As | 120 | 230 | 1700 | 1200 | 280 |
| Au (ppb) | 9 | <5 | 12 | <5 | 48 |
| Ba | 110 | 140 | <100 | 900 | 570 |
| Br | 24 | 4 | 13 | 5 | 8 |
| Ce | 66 | 50 | 33 | 29 | 46 |
| Co | <1 | <1 | 11 | 3 | 6 |
| Cl | 6000 | <20 | | | |
| Cr | 8 | 6 | 12 | 19 | 230 |
| Cs | 4 | 6 | 5 | 4 | 5 |
| Cu | 9 | 1 | | | |
| Ga | 9 | 5 | | | |
| Mo | <5 | <5 | <5 | 24 | 19 |
| Nb | <1 | 3 | | | |
| Pb | 13 | 21 | | | |
| Rb | 65 | 150 | 150 | 80 | 89 |
| Sb | 11 | 10 | 77 | 55 | 14 |
| Sc | 9 | 8 | 13 | 8 | 9 |
| Sr | 170 | 17 | | | |
| Th | 6 | 8 | 16 | 10 | 10 |
| U | <2 | <2 | 4 | <2 | 4 |
| V | 47 | 28 | | | |
| W | 12 | 6 | 6 | <2 | 22 |
| Zn | 6 | 8 | <100 | <100 | <100 |
| Zr | 130 | 75 | | | |

The chemistry of samples from the drill hole are summarised in Table 8 within five groupings down the profile. (It should be noted that the use of the drill core for other purposes precluded sampling between 37 to 39 m where good Au grades occur about the base of oxidation).

As would be expected from previous study (Scott, 1995a) the soils are relatively Fe rich and show anomalous As, Au and Sb. The strongly weathered material between 3 and 5 m is relatively Fe poor and hence contains lower As than the soils but still contains significant Au. Both these zones (soil and top 2 m of the weathered volcanics) contain elevated Cr relative to deeper samples. Weathered volcanics between 5 and 21 m are depleted in Au relative to the higher samples but As and Sb are quite anomalous. Below 21 m presence of feldspar is reflected by K contents and indicates that weathering is less intense, as does the retention of Zn (Table 8). Although As and Sb are anomalous the Au grades are low, however there are some unsampled intervals of >1 g/t Au in the zone 21-40 m. Fresh material contains significant Au and associated As, Sb, Co, W and Zn.

Weathering of highly mineralised assemblages of quartz, adularia, pyrite, illite and kaolinite at 20022E/9650N (93PCDH03) is characterised by the destruction of adularia and pyrite to form additional kaolinite, jarosite and Fe oxides. As indicated above, K, As, Au, Co, Rb, Sb, W and Zn are leached during such weathering. Gold itself is concentrated in the near-surface kaolinitic samples (and in the overlying transported soil) with As and Sb still abundant enough in the near-surface samples to be useful as gold pathfinders. Arsenic is particularly well concentrated in the overlying soil relative to the rock below.

**Table 8. Average composition of zones in 93PCDH03 (main anomaly) profile, Police Creek (major components, wt%; minors ppm)**

| Zone | Soil | Kaolinitic clays | Fe-stained clays | Saprolite | Fresh bedrock |
|---|---|---|---|---|---|
| Depth (m) | 0-3 | 3-5 | 5-21 | 21-40 | 40-55 |
| No of analyses | 3 | 2 | 6 | 2 | 3 |
| $Fe_2O_3$ | 4.68 | 1.76 | 4.29 | 2.60 | 3.90 |
| $Na_2O$ | 0.24 | 0.33 | 0.17 | 0.22 | 0.11 |
| $K_2O$ | 1.24 | 0.90 | 1.79 | 5.59 | 6.98 |
| As | 290 | 75 | 450 | 410 | 1050 |
| Au(ppb) | 230 | 410 | 90 | 24 | 620 |
| Ba | 480 | 310 | 390 | 460 | 390 |
| Br | 5 | 7 | 6 | 3 | 4 |
| Ce | 65 | 100 | 100 | (68) | (86) |
| Co | 6 | 5 | 2 | 2 | 21 |
| Cr | 20 | 13 | <5 | <5 | 8 |
| Cs | 8 | 12 | 9 | 12 | (32) |
| Rb | 120 | 140 | 210 | 380 | 410 |
| Sb | 15 | 14 | 18 | 20 | 54 |
| Sc | 10 | 11 | 14 | 11 | 10 |
| Th | 10 | 11 | 11 | 11 | 10 |
| U | <2 | <2 | 2 | <2 | 7 |
| W | 6 | 3 | 4 | 6 | 17 |
| Zn | <100 | <100 | <100 | 170 | 300 |

Note: Average in parenthesis includes one anomalously high analysis
Mo < 5 ppm

## 6.4 STOP 12: Erosion Gully Profile

***Location***: *20150E 9930N*
***Geology***: *Silver Hills Volcanics*
***Landform***: *Gently sloping plains*
***Regolith***: *Soils with Fe-granules, mottled alluvium*

The erosion gully at 20150E/9930N provides the opportunity to study variations in the upper part of a profile above unmineralised volcanics (Figure 45 and 46). The upper 0.2 m of the profile consists of fawn-coloured gritty soil occurring above a further 0.2 m of pale fawn soil with granules and pebbles (many of which are Fe-stained) and then grey-brown clay with Fe mottling occurs from 0.4 to 1.3 m at which depth indurated mottled saprolite occurs. Despite these variations, the mineralogy is uniform - assemblages of quartz, kaolinite, anatase and hematite although some maghemite occurs at 0.2-0.4 m and kaolinite is more abundant below that level.

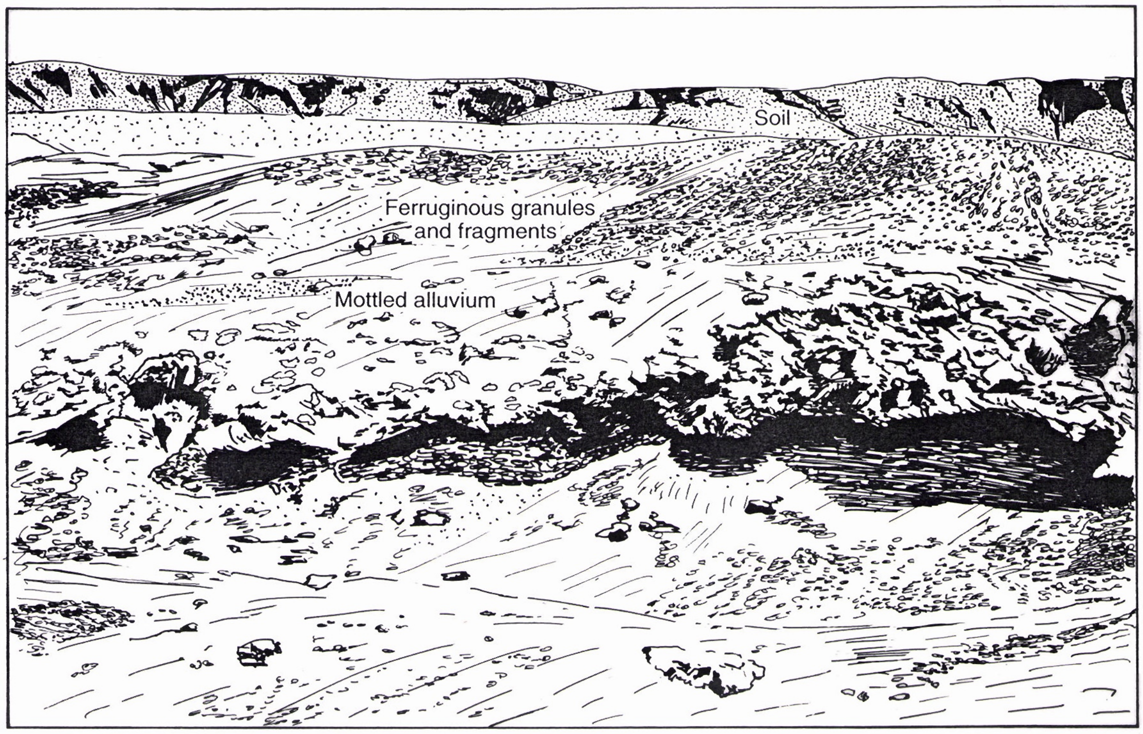



Figure 45. Mottled alluvium exposed by gully erosion at the Police Creek prospect.

The chemistry of the profile reflects the greater Fe content below 0.4 m but Au, As and Sb contents are low, especially relative to transported material above mineralisation (*cf.* Table 9). That material also shows higher K, Na, Ba and Rb reflecting the presence of illite in the soil above mineralisation. The Au, As and Sb contents can probably be regarded as background values for these elements in the region. Barium is significant in the saprolite (Table 9).

Figure 46. Erosion gully Profile, Police Creek.

**Table 9. Chemical composition of samples in Erosion Gully Profile and above mineralisation (drill hole 93 PC DHH03)**
(major components, wt%,; minors, ppm)

| | Erosion Gully Transported Material | | | | | Saprolite | 93 PC DH03 Transported Material | | |
|---|---|---|---|---|---|---|---|---|---|
| **Sample** | **113405** | **113406** | **113407** | **113408** | **113409** | **112842** | **128280** | **128281** | **128282** |
| **Depth (m)** | **0-0.2** | **0.2-0.4** | **0.4-0.7** | **0.7-1.00** | **1.0-1.3** | **~1.3** | **0-1** | **1-2** | **2-3** |
| $Fe_2O_3$ | 2.80 | 3.23 | 3.93 | 5.09 | 5.06 | 4.40 | 7.26 | 3.57 | 3.20 |
| $Na_2O$ | 0.03 | 0.04 | 0.09 | 0.16 | 0.24 | 0.09 | 0.11 | 0.29 | 0.33 |
| $K_2O$ | <0.20 | <0.20 | 0.46 | <0.20 | 0.46 | <0.20 | 1.29 | 1.23 | 1.19 |
| As | 56 | 79 | 63 | 71 | 69 | 61 | 470 | 220 | 170 |
| Au (ppb) | 10 | 15 | 15 | 11 | 7 | 13 | 350 | 150 | 190 |
| Ba | 270 | 320 | 270 | 190 | 220 | 530 | 430 | 640 | 380 |
| Ce | 31 | 26 | 40 | 40 | 37 | 53 | 59 | 62 | 75 |
| Co | 1 | 1 | 2 | 3 | 3 | 1 | 6 | 6 | 7 |
| Cr | 14 | 13 | 26 | 33 | 31 | 10 | 18 | 18 | 23 |
| Cs | 5 | 4 | 8 | 10 | 11 | 10 | 6 | 7 | 10 |
| Rb | 23 | 24 | 38 | 43 | 42 | 26 | 120 | 120 | 130 |
| Sb | 5 | 6 | 5 | 5 | 5 | 10 | 25 | 11 | 9 |
| Sc | 5 | 5 | 8 | 10 | 9 | 6 | 11 | 9 | 11 |
| Th | 10 | 10 | 14 | 14 | 14 | 12 | 10 | 9 | 10 |
| U | 4 | 3 | 3 | 3 | 3 | 2 | 3 | <2 | <2 |
| W | 5 | 4 | 8 | 8 | 10 | 7 | 6 | 8 | 3 |

Note: Zn < 100 ppm

## 6.5 STOP 13: Black Creek

***Location***: *541413E 7655675N*
***Geology***: *Suttor Formation*
***Landform***: *Mesa*
***Regolith***: *Mottled sediments and duricrust*

A fine to coarse crossbedded quartz sandstone with fluvial gravels forms a bluff about 7 m high (Figures 47 and 48) and provides a good example of the Suttor Formation, an equivalent to the Southern Cross Formation in the Charters Towers 1:25,000 sheet area. The Suttor Formation is extensively developed as discontinuous tracts of isolated mesas, low rises on alluvial plains or infills of localised sedimentary valleys concealed beneath younger alluvial material. Day (1981) reported that the Suttor Formation can reach a maximum thickness of 120 m. Around Mt Coolon, the formation forms mesas 5-25 m high standing on saprolites of (what kind, what age?) basement rocks.

The type section of the Suttor Formation at Rutherfords Table, 25 km north of the Wirralie Mine, has white, massive, fine to medium sandy claystone in the middle and oil shale in its lower part. However, the type section is not as representative as it should; less claystone is found in the field. The Suttor Formation commonly is a deeply weathered, coarse, sandy to gravelly sediment, such as that at the Police Creek Prospect, with very minor white claystone (2-3 m thick). There have been no reports of oil-shale outcrops around this area; however, drilling on the alluvial plains west of Rosetta Creek penetrated oil-shale and lignite about 45-60 m below surface (d'Auvergne, 1984).

The Suttor Formation has been intensively weathered. Ferruginisation and silicification occur throughout the whole profile, with duricrusts developed at the top. Parts of the fluvial sediments have been bleached to white clay (kaolinite). Where silica or iron has been moved hydromorphically, the bleached sediments have been converted to silcrete and ferruginous duricrust. Field evidence and petrography show that some silcretes has been de-silicified subsequently. A similar process applies to ferruginous duricrust.

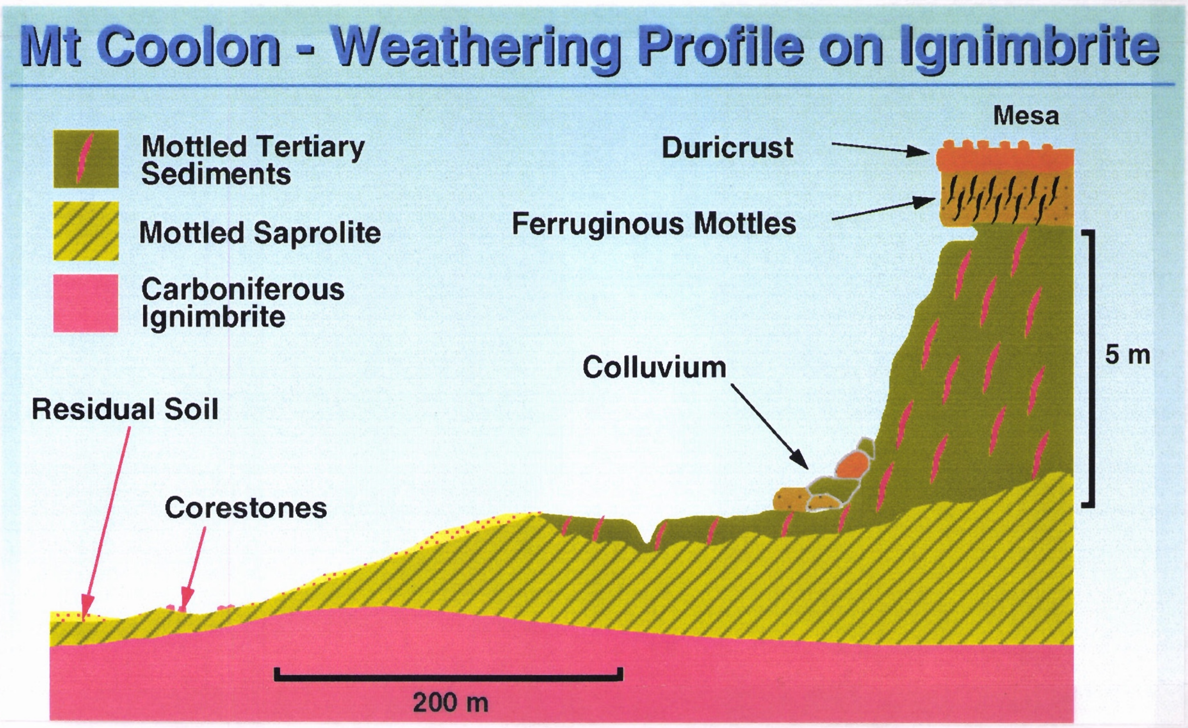



Figure 47. Section of ferruginised Tertiary sediments at 541413E 7655675N.

These complicated weathering processes obscure the original sedimentary structures and make field identification of parent rocks very difficult. Where diverse parents, such as Devonian sandstones or granites pass through all of these complex weathering processes, very similar products can be produced. This stop provides a pleasingly uncontroversial profile of the Suttor Formation, as crossbedded sands and gravels.

The age of the Suttor Formation is controversial. Early Miocene pollens were reported from oil shales (Chaffee *et al.,* 1984). East of Mt Coolon, in the Byerwen area, basalts, reported to underlie the formation, are dated at 23.1 to 29.2 Ma (Sutherland *et. al.,* 1977). This led Hutton *et al.,* (1991) to regard the Suttor Formation as the mid-Tertiary. Later work has shown that the Suttor Formation is interbedded with these basalts, and a date of 53 Ma, obtained from basalt overlying silcrete of the Suttor Formation at Mt. Dalrymple, indicates an early Tertiary age (Day *et al.,* 1983). All these data suggest that the Suttor Formation spans most of the Tertiary. In view of its extent and its fluvial nature, it may be more realistic if the Suttor Formation is regarded as deposited over a considerable time span and not restricted to a single event.

Figure 48. Ferruginised Tertiary sediments (Suttor Formation) at 541413E 7655675N.

## 6.6 STOP 14: Wirralie Case Study

Epithermal Au mineralisation at Wirralie crops out over a surface area of 600 x 600 m and was discovered in 1986 after following up a BLEG (-6 mm fraction) and -80 mesh As stream sediment anomaly (Fellows and Hammond, 1990). Although Cu, Pb, Sb and Zn were not found to be useful pathfinders in the stream sediment programme, subsequent rock chip sampling did find significant levels of pathfinder elements close to mineralisation, *e.g.* Hg up to 3370 ppb, As up to 1000 ppm and Sb up to 120 ppm (Seed, 1995b). After defining an oxide resource of 3.65 m tonnes at 2.75 g/t Au, mining by Australian Consolidated Minerals commenced in 1988 and concluded in 1992. Ross Mining acquired the property in 1992 and have since extended the oxide resource and are considering the potential of a leap leaching operation for the sulfide-associated mineralisation (Seed, 1995b).

The gold of the deposit contains 16-33% Ag, averages 25 µm in size and is associated with up to 5% sulfides (mainly arsenical pyrite and lesser amounts of marcasite, sphalerite, arsenopyrite and chalcopyrite). When weathered, as in the exploited resource, it occurs with Fe oxides along quartz boundaries.

The mineralisation occurs within the Late Devonian Mt Wyatt Formation within a window through the fluviotile and lacustrine sediments of the Early Tertiary Suttor Formation. In the area of the deposit, locally derived material from the Mt Wyatt Formation, up to 0.5 m in size and including clasts containing epithermal quartz veins, are incorporated into the basal portion of the Suttor Formation. During the mid to late Tertiary, lateritisation affects both the Suttor and Mt Wyatt Formations but much of the lateritic profile has been removed with only remnants preserved in mesas and plateaux. Ferricretes and silcretes are observed within the Suttor Formation in the Wirralie area (Seed, 1995b). Although the weathering extends to about 40 m in the Mt Wyatt Formation and results in destruction of the sulfides, Au appears to be only locally redistributed during weathering processes, *i.e.* no supergene enrichment zone is present.

Two profiles through the Suttor Formation have been studied, one forming the southern face of the open pit at 9815E 9685N and the other provided by drill hole W33, cored about 100 m to the north-east at 9900E 9770N (Figure 49). The southern face profile samples are generally white sandstones with a clay matrix although the top 5 m is weakly Fe stained. Clasts of silicified (and ferruginized) Mt Wyatt Formation material occur in the basal portion of the unit. (A boulder of highly ferruginized material has been analysed as sample 112843). Samples consist of assemblages of quartz, kaolinite and anatase. Sample 113390 is however silicified and contains no kaolinite. Excluding the ferruginous boulder, Au contents through the profile vary between 35 and 270 ppb (the latter being in the highly silicified sample) but As and Sb contents are generally low, reaching maxima of 20 and 12 ppm respectively. Barium contents are generally high, usually >350 ppm (Table 10). The ferruginous boulder shows that As, Cr and Sb are strongly associated with Au and the Fe. Mottled material from the top of the Mt Wyatt Formation is enriched in As but is relatively low in Au (Table 10).

The W33 profile allows more systematic sampling through the Suttor Formation which in this hole consists of sandstone, sometimes with clasts up to 5 mm, within a clay matrix. Its mineralogy is quartz, kaolinite ± trace illite, anatase ± ?alunite. Gold contents through the Suttor Formation are consistently higher than in the pit face profile with good ore grades between 8 and 13 m and in the basal sample (Table 11). Arsenic and Sb are also generally slightly higher in this section than in the pit face, with As being quite enriched in the basal sample. Barium contents are lower than in the pit face profile (Tables 10 and 11).

The upper portion of the Mt Wyatt Formation is finer grained than the Suttor Formation and contains consistent illite in addition to quartz, kaolinite and anatase. Although Au contents are low

(47-160 ppb) relative to those in the Suttor Formation, As contents are greater (≥ 20 ppm). Such a lack of Au in the Mt Wyatt Formation here suggests that the good Au grades in the Suttor Formation reflect entirely mechanical transport rather than hydromorphic dispersion.

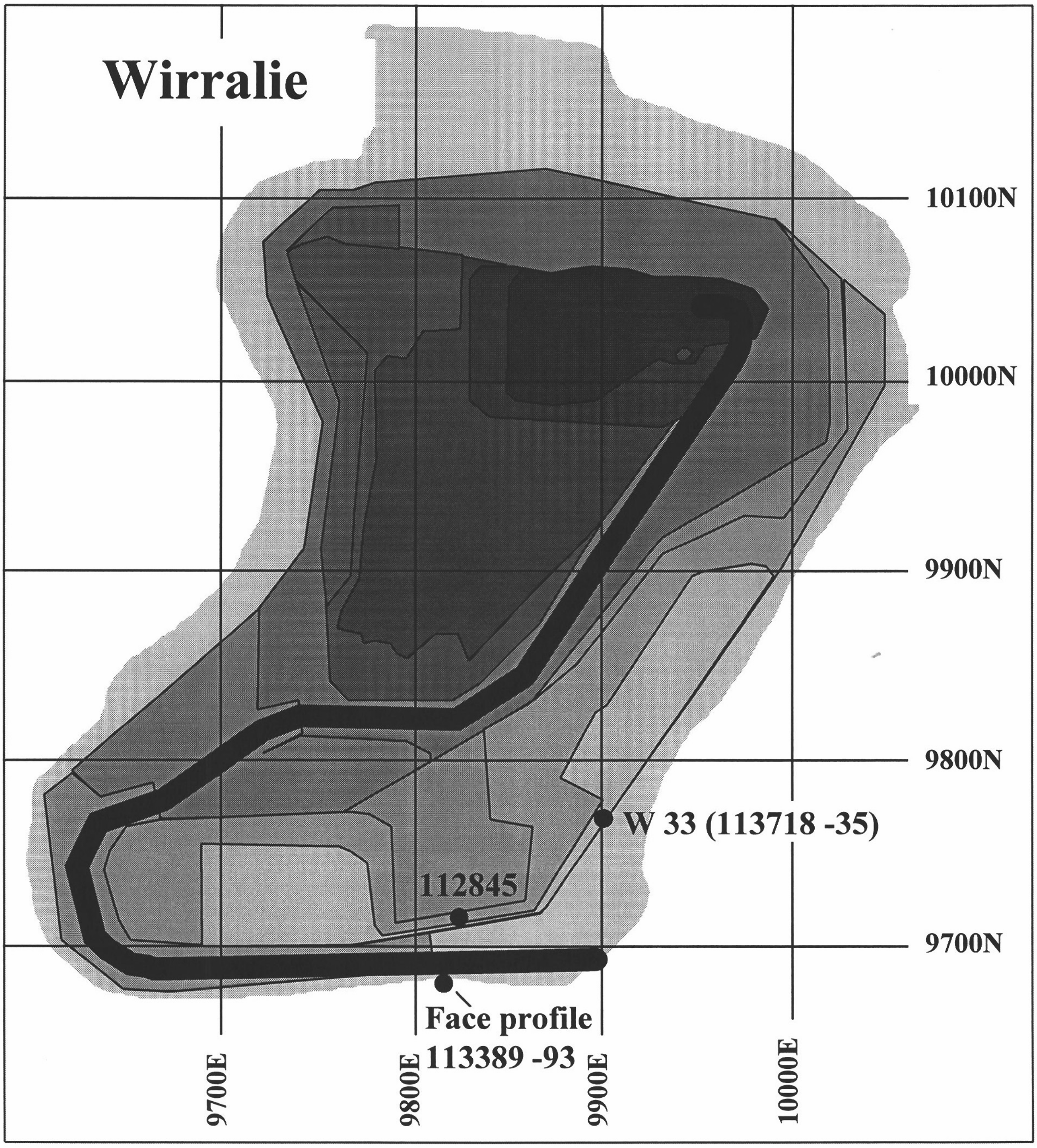



Figure 49. Location of samples Wirralie.

**Table 10. Compositions of samples southern face, open pit, Wirralie (major components, wt%; minors, ppm)**

| Sample No. | 113389 | 113390 | 113391 | 113392 | 112843 | 113393 | 112845 |
|---|---|---|---|---|---|---|---|
| | | Silicified | | | Ferruginous | | Mottled |
| Depth (m) | 0.3 | 5 | 5 | 10 | 10 | 12 | 15 |
| | Suttor Formation | | | | | | Mt Wyatt Fm |
| $Fe_2O_3$ | 0.67 | 0.23 | 0.27 | 0.27 | 36.0 | 0.33 | 2.92 |
| $Na_2O$ | 0.04 | 0.04 | 0.07 | 0.04 | 0.03 | 0.04 | 0.04 |
| $K_2O$ | <0.20 | <0.20 | <0.20 | <0.20 | 1.08 | <0.20 | 3.32 |
| As | 20 | 18 | 12 | 8 | 1300 | 5 | 330 |
| Au (ppb) | 100 | 270 | 100 | 130 | 590 | 35 | 7 |
| Ba | 450 | 480 | 530 | 350 | 160 | 230 | 210 |
| Ce | 37 | 64 | 38 | 46 | 43 | 17 | 11 |
| Cr | 12 | 10 | 7 | 7 | 86 | 14 | 17 |
| Cs | 2 | 1 | 1 | 2 | 7 | 2 | 7 |
| Rb | <20 | <20 | <20 | <20 | 80 | <20 | 190 |
| Sb | 8 | 12 | 6 | 5 | 26 | 10 | 4 |
| Sc | 6 | 4 | 5 | 6 | 12 | 6 | 14 |
| Th | 13 | 6 | 9 | 15 | 14 | 7 | 8 |
| U | 2 | 2 | <2 | 2 | <2 | <2 | <2 |
| W | 9 | 13 | 7 | 7 | <2 | 6 | 5 |

Note: Co <1 ppm, Zn < 100 ppm

**Table 11. Compositions of samples drill hole W33, Wirralie (major components, wt%; minors, ppm)**

| Sample | 113718 | 113720 | 113722 | 113724 | 113726 | 113728 | 113730 | 113731 | 113732 | 113733 | 113734 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Depth (m) | 2-3 | 4-5 | 6-7 | 8-9 | 10-11 | 12-13 | 14-15 | 15-16 | 16-17 | 17-18 | 19-19 |
| | | | | Campaspe Fm | | | | | | Mt Wyatt Fm | |
| $Fe_2O_3$ | 0.41 | 0.40 | 0.36 | 0.44 | 0.51 | 0.39 | 0.49 | 0.63 | 0.47 | 0.37 | 0.56 |
| $Na_2O$ | 0.04 | 0.04 | 0.04 | 0.04 | 0.03 | 0.04 | 0.03 | 0.03 | 0.03 | 0.03 | 0.03 |
| $K_2O$ | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | <0.20 | 0.77 | <0.20 | 1.34 | 1.53 |
| As | 10 | 14 | 12 | 16 | 29 | 22 | 23 | 94 | 44 | 20 | 87 |
| Au (ppb) | 430 | 730 | 1200 | 3600 | 2900 | 5400 | 290 | 43000 | 160 | 47 | 120 |
| Ba | 310 | 270 | 260 | 220 | 230 | 230 | 240 | 270 | 180 | 160 | 160 |
| Ce | 34 | 42 | 42 | 59 | 57 | 49 | 43 | 100 | 52 | 69 | 86 |
| Co | <1 | 2 | 1 | 2 | 1 | <1 | 2 | 1 | <1 | <1 | <1 |
| Cr | 15 | 15 | 14 | 19 | 16 | 11 | 14 | 14 | 19 | 17 | 8 |
| Cs | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 5 | 2 | 5 | 4 |
| Rb | <20 | <20 | <20 | <20 | <20 | <20 | <20 | 49 | 24 | 74 | 87 |
| Sb | 9 | 11 | 11 | 13 | 14 | 15 | 8 | 9 | 8 | 8 | 9 |
| Sc | 5 | 6 | 6 | 6 | 6 | 5 | 5 | 7 | 7 | 11 | 12 |
| Th | 9 | 12 | 12 | 13 | 13 | 10 | 11 | 17 | 11 | 9 | 8 |
| W | 16 | 11 | 9 | 10 | 10 | 9 | 6 | 9 | 6 | 3 | 4 |

Note: U < 2 ppm, Zn < 100 ppm

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