# Exploration Field Workshop
# Cobar Region 2004

## FIELD TRIP GUIDE AND LOCALITY DESCRIPTIONS

**24th and 26th May 2004**

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# INTRODUCTION

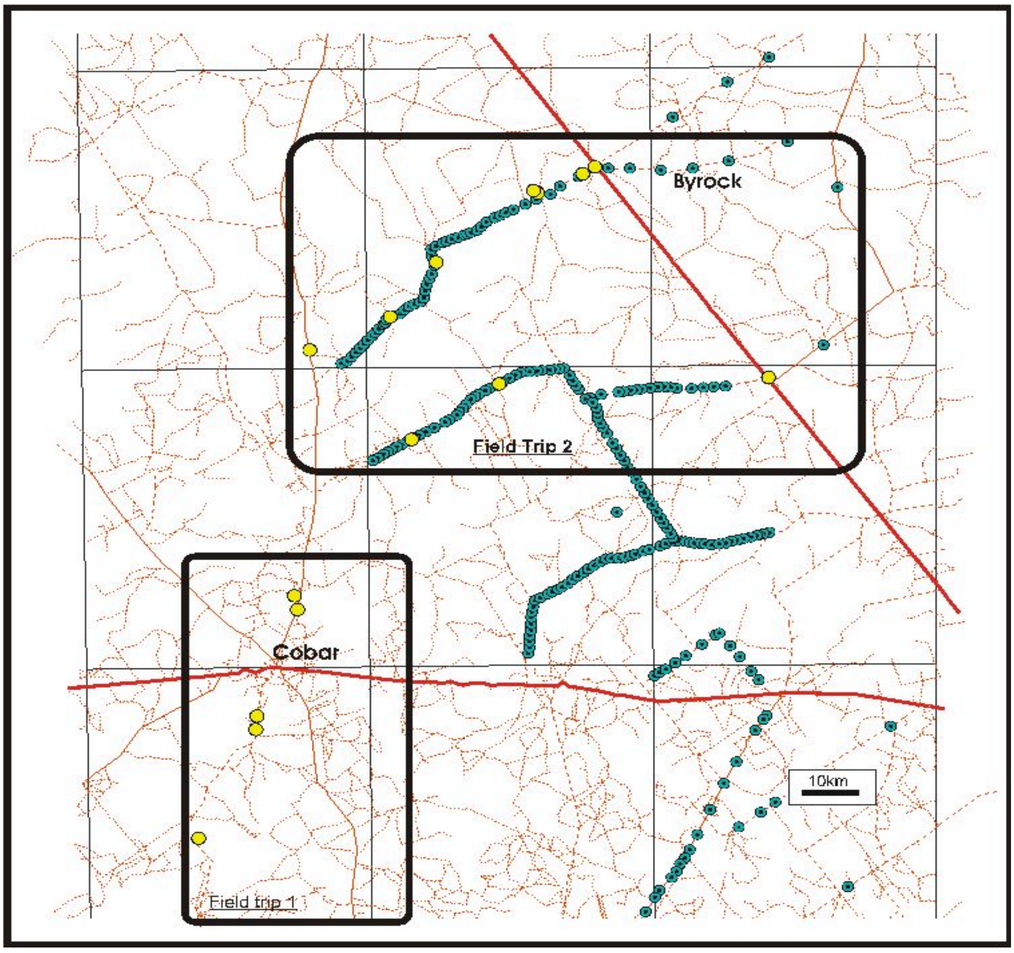
The two field trips associated with the Exploration Field Workshop are designed to illustrate features of the bedrock geology, weathering and landscape history, regolith materials and geochemical characteristics in the area around Cobar and to the northeast over the Girilambone Terrain. These features will be examined in the particular context of mineral exploration issues and procedures.

Recent work by CRC LEME, the NSW Geological Survey and industry geologists has contributed to a much better knowledge and understanding of the landscape history, regolith evolution and implications for successful geochemical exploration in this region. This work has recognised the deep weathering and chemical leaching events and the variable preservation of weathering profiles related to differential erosion. It has also revealed the importance of transported cover preserved at different levels of the present landscape, particularly in widespread palaeochannel systems. New procedures for regolith-landform mapping can now provide maps that will assist explorers in planning and interpreting geochemical and drilling surveys. This can be achieved through a better knowledge of cover thickness and type, as well as likely element dispersion pathways and traps. Improved knowledge of the regional soils, particularly quantitative data on the diluting aeolian component, can now provide firm guidelines for soil sampling techniques.

All sites covered in this field guide are on the Cobar and Bourke 1:250 000 topographic and geological map sheets. Grid references to site locations are in AMG 66.

**Safety Note**
Field trip participants are required to take all precautions for their personal safety, including proper use of appropriate personal protective equipment.

Participants are also cautioned to be alert to the dreaded "Cobar micro tick", which can be rife at this time of year. Avoid brushing up against vegetation such as woody weed and mulga. Symptoms are very itchy swellings that persist for several days. Infestation may require a full body search !




**Field Trip Locations**

o sites

● drill holes

# FIELD TRIP 1 COBAR BASIN

## Introduction to Day 1

This half-day field trip will examine a number of sites local to Cobar. All of these sites are within the Cobar Basin and in the general areas of the CSA Cu±Pb-Zn deposit, the Cobar gold field and the McKinnons gold deposit. The sites will provide the opportunity to examine a range of regolith materials and landscape features common to the region. They will also highlight some issues relevant to geochemical exploration, sampling and data interpretation.

## Site 1: Bourke Road Paleochannel

**Site 1a: Bourke Road 11 km north of Cobar (GR 0392801 6525046).**
Ken McQueen

The small borrow pit at this site exposes strongly weathered siltstones and sandstones of the Chesney Formation (this is the basal unit of the Cobar Supergroup which occupies the lower part of the Cobar Basin). Bedding here strikes 020º and dips 80ºE, Cleavage is oriented 020º/85ºW. The metasediments show ferruginous mottling and there is abundant calcrete developed in the upper part of the profile.

To the north there is a thin overlying layer (ca. 1 m thick) of palaeochannel sediments preserved as a small inverted remnant. The sediments are clay-rich with scattered sub-angular to rounded clasts (up to 3 cm in diameter) of ferruginous pisoids, quartz and resistant bedrock lithologies. Many of the smaller ferruginous clasts contain maghemite (sufficient to attract them to a hand magnet).

The calcrete here is a high-magnesium calcite or calcite-dolomite mixture. An analysed sample contains 13.9% Ca, 8.4% Mg, 2.13% Fe, 1.21% K, 800 ppm Ba, 700 ppm Sr, 7 ppm As, 12 ppm Cu, 17 ppm Pb and 40 ppm Zn. Gold content is at background levels of 2 ppb.

**Site 1b**: **Bourke Road, 14 km north of Cobar (GR 0393269 6527654).**
Ken McQueen, Dougal Munro, Ian Stockton and Maite LeGleuher

A small borrow pit just east of the road exposes a 2 m section of palaeochannel sediments. An aircore drill hole has revealed that these palaeochannel sediments are 8-9 m thick at this locality. The site is close to the western edge of a major north-south trending palaeochannel which has been extensively mapped and defined from magnetic imagery and drilling (Ford, 1996, Figs 1.1 and 1.2). The exposed sediments are mostly clay-rich with scattered clasts (similar to those at Site 1a) but there are also lenses of fine-grained gravel (Fgure 1.4). Clast orientations in some of the gravels indicate a palaeocurrent direction towards 030º.

Overlying the palaeochannel sediments there is a 0.5 m layer of the silty loam soil, typical of the region (Fig. 1.3). Between the soil and the underlying sediments there is a poorly consolidated layer of weathered and possibly partly reworked palaeochannel material. This layer is more ferruginous than the underlying sediments and appears to contain a soil component worked down from the upper part of the profile.

The palaeochannel sediments are now slightly inverted in the present landscape and form a very low rise. About 700 m south of this site the rise drops off, and basement rocks are exposed. Present drainage cuts across the palaeochannel trend.

Multi element analysis following aqua regia digest (Table 1.1) reveals that the palaeochannel sediments have high Fe content (due largely to the ferruginous clasts) and matching elevated Pb, Bi, Sb and As, reflecting association of these elements with hematite. Barium is also elevated in the palaeochannel sediments. Calcium and Mg are relatively enriched near the base of the palaeochannel sediments, reflecting development of calcrete near the bottom of the channel. Zones of higher Fe content below the unconformity reflect ferruginous mottling in the weathered bedrock. One of these zones has elevated Zn and As.

Table 1.2. shows comparative analyses for some elements for the soil (0.2 m) and overlying lag collected at the profile section at Site 1b, as well as saprock from Site 1a (large pit to east). These analyses were by ICP OES/MS following multi acid digest.

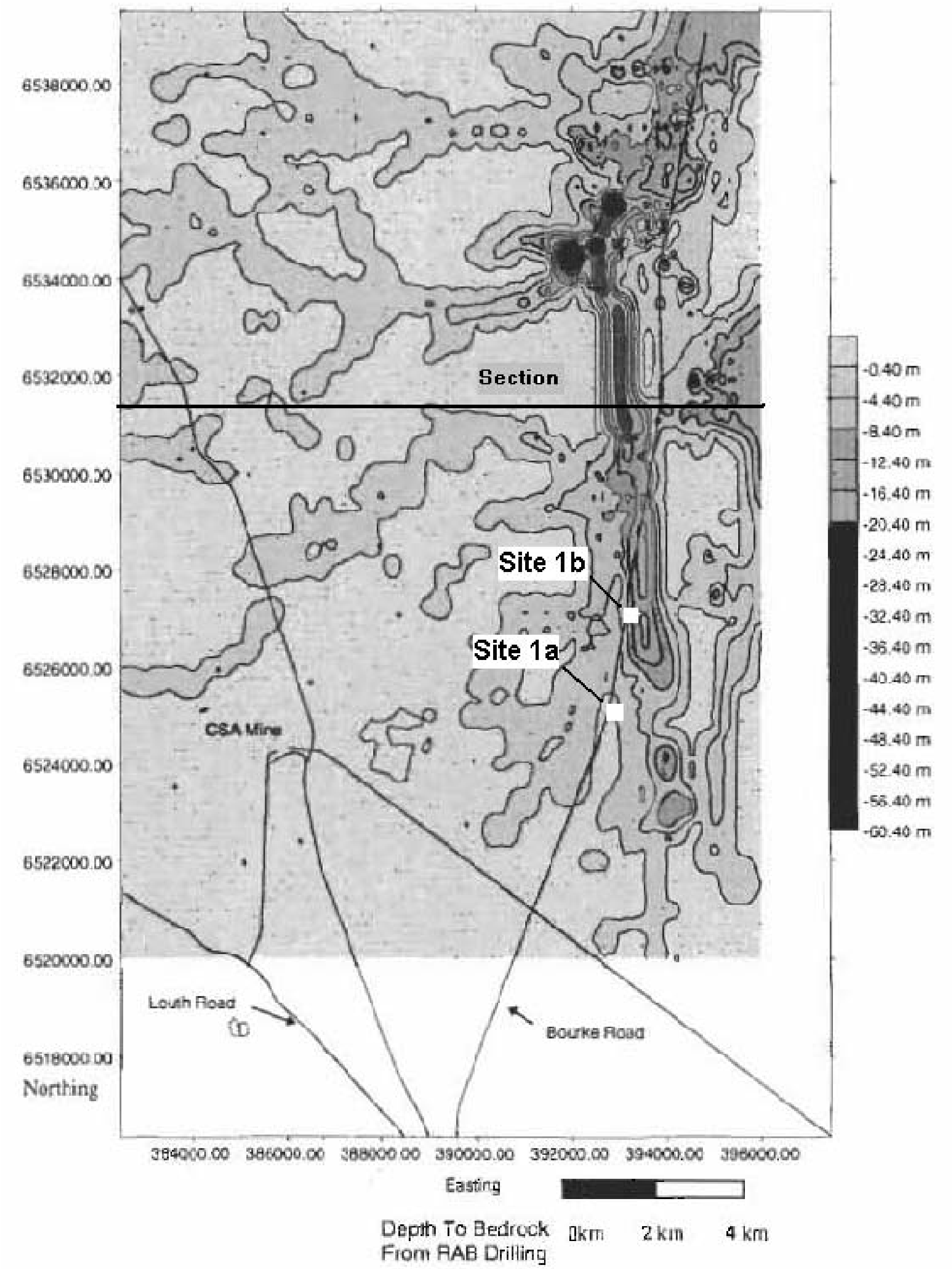



**Figure 1.1**. Depth contour map of the major palaeochannel along the Cobar-Bourke road. (from Ford, 1996) also showing location of field sites to be visited.

**Table 1.2.** Analyses of soil, lag and saprock from Sites 1a and 1b (multi acid digest ICP OES/MS & aqua regia digest solvent extraction graphite furnace AAS for Au, ALS Chemex).

| Sample | Al % | K % | Ca % | Mg % | Fe % | Au ppm | As ppm | Ba ppm | Cu ppm | Mn ppm | Ni ppm | P ppm | Pb ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Soil | 4.98 | 0.92 | 0.17 | 0.18 | 11.25 | 0.001 | 16 | 200 | 20 | 220 | 21 | 360 | 27 | 32 |
| Lag | 4.07 | 0.90 | 0.03 | 0.13 | 28.80 | 0.001 | 34 | 190 | 22 | 97 | 19 | 590 | 53 | 35 |
| Saprock | 8.01 | 2.58 | 0.11 | 0.45 | 10.90 | 0.002 | 14 | 510 | 97 | 32 | 12 | 440 | 38 | 42 |

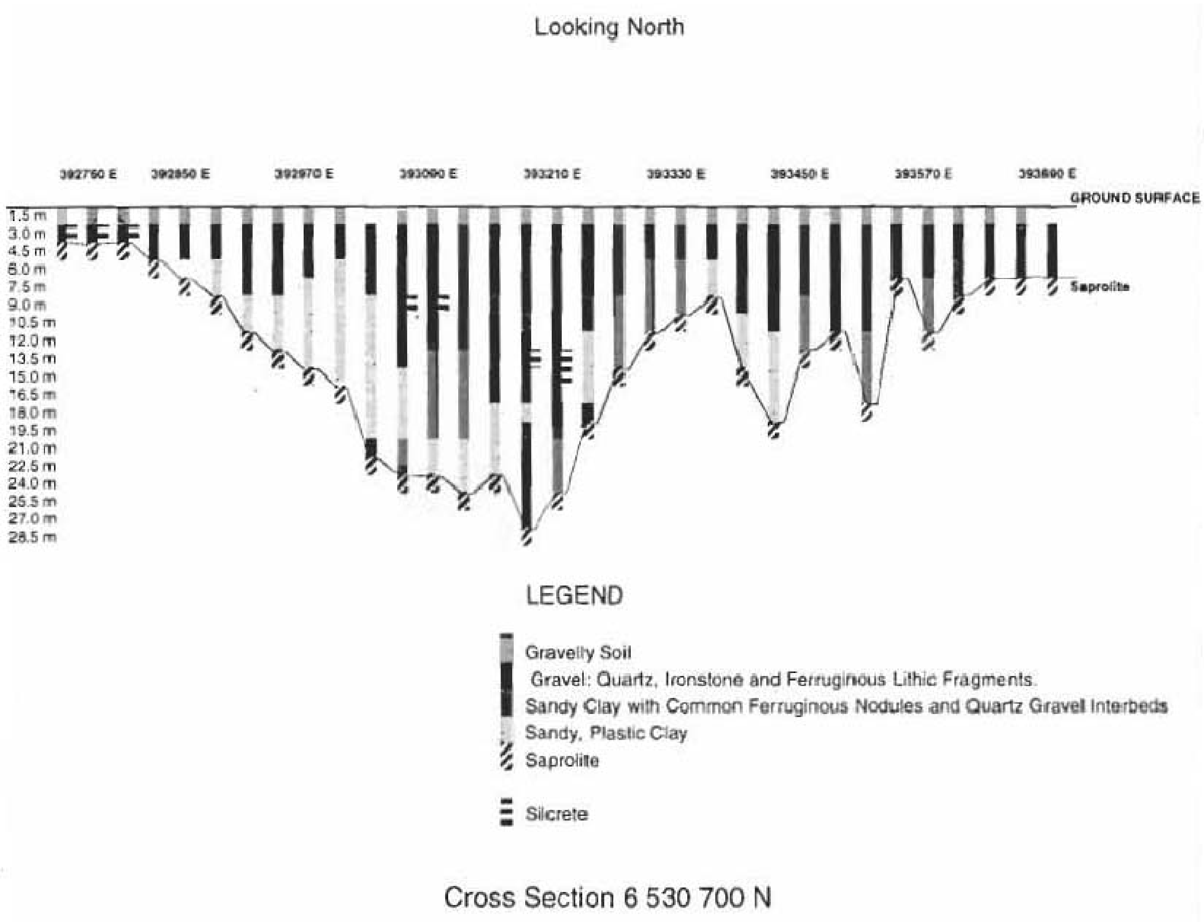



**Figure 1.2.** Cross section through the Bourke road palaeochannel system (from Ford, 1996).

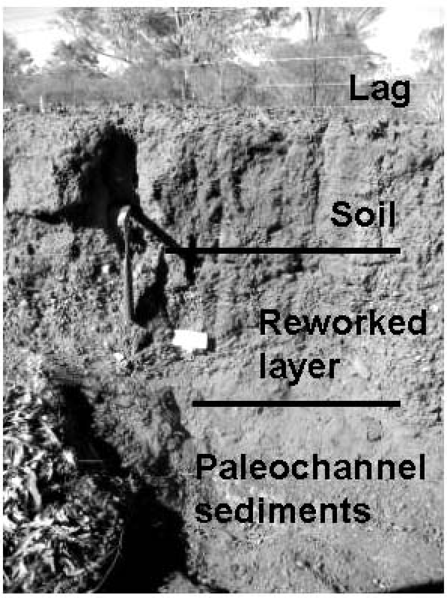



**Figure 1.3**. Profile into the upper part of the palaeochannel sediments at Site 1b.

**Figure 1.4**. Gravel lens in the palaeochannel sediments at Site 1b.

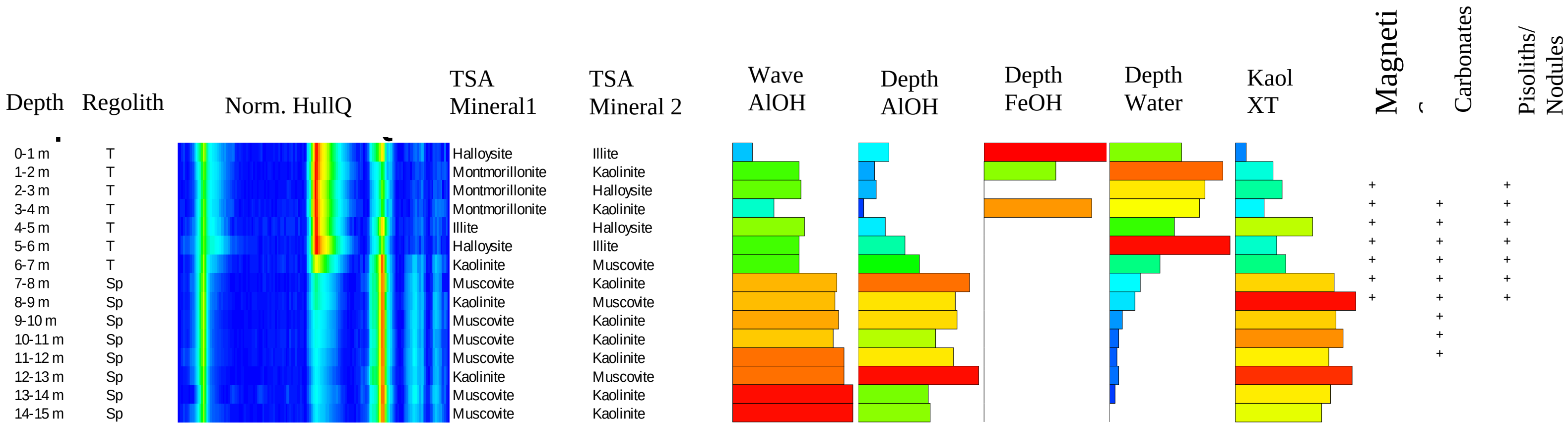



Figure 1.5. PIMA analysis of the regolith profile of drill hole BRAC1

**Table 1.1. Geochemical analyses of bulk aircore samples from BRAC1. Aqua regia partial leach and ICP OES/MS.**

| Depth from-to | Ca % | Mg % | Fe % | Ag ppm | As ppm | Au ppm | Ba ppm | Bi ppm | Cd ppm | Cu ppm | Hg ppm | Mn ppm | Mo ppm | Pb ppm | S % | Sb ppm | Se ppm | Te ppm | Tl ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0-1 m | 0.07 | 0.13 | 19.25 | 0.23 | 28.6 | 0.004 | 280 | 1.04 | 0.1 | 21 | 0.04 | 69 | 1.2 | 48 | 0.05 | 5.4 | 1.3 | 0.24 | 0.34 | 54 |
| 1-2 m | 0.48 | 0.28 | 17.25 | 0.15 | 30 | 0.003 | 576 | 1.02 | 0.2 | 25 | 0.03 | 87 | 1 | 72 | 0.13 | 3.7 | 0.8 | 0.21 | 0.38 | 68 |
| 2-3 m | 0.42 | 0.28 | 11.2 | 0.09 | 19.6 | 0.002 | 355 | 0.76 | 0.11 | 18 | 0.02 | 87 | 0.7 | 52 | 0.07 | 1.5 | -0.5 | 0.09 | 0.27 | 54 |
| 3-4 m | 0.07 | 0.29 | 5.48 | 0.1 | 19.1 | 0.001 | 103 | 0.38 | 0.1 | 18 | 0.02 | 158 | 0.9 | 35 | 0.04 | 1.3 | -0.5 | 0.04 | 0.24 | 38 |
| 4-5 m | 0.09 | 0.23 | 13.6 | 0.06 | 22.3 | 0.001 | 376 | 0.85 | 0.05 | 17 | -0.02 | 233 | 0.6 | 43 | 0.02 | 4 | 0.5 | 0.12 | 0.17 | 32 |
| 5-6 m | 0.49 | 0.37 | 16.45 | 0.08 | 31.1 | 0.001 | 178 | 0.96 | 0.09 | 18 | 0.02 | 257 | 0.9 | 57 | 0.04 | 6.6 | 0.7 | 0.17 | 0.18 | 38 |
| 6-7 m | 1.38 | 0.8 | 18.9 | 0.04 | 22.7 | 0.001 | 101 | 1.08 | 0.03 | 11 | -0.02 | 188 | 0.6 | 39 | 0.01 | 6.5 | 0.5 | 0.22 | 0.15 | 21 |
| 7-8 m | 2.4 | 1.4 | 2.38 | 0.02 | 5.5 | -0.001 | 66 | 0.22 | 0.03 | 17 | -0.02 | 113 | 0.1 | 24 | 0.01 | 0.3 | -0.5 | 0.02 | 0.08 | 23 |
| 8-9 m | 1.83 | 1.06 | 4.35 | -0.02 | 8.7 | -0.001 | 75 | 0.28 | 0.02 | 30 | -0.02 | 97 | 0.2 | 14 | 0.01 | 0.6 | -0.5 | 0.03 | 0.13 | 29 |
| 9-10 m | 0.66 | 0.4 | 2.97 | -0.02 | 7.2 | 0.001 | 73 | 0.36 | 0.02 | 18 | -0.02 | 118 | 0.2 | 11 | -0.01 | 0.4 | -0.5 | 0.02 | 0.14 | 16 |
| 10-11 m | 0.16 | 0.12 | 5.52 | -0.02 | 10.2 | 0.001 | 38 | 0.27 | -0.02 | 38 | -0.02 | 114 | 0.1 | 7 | -0.01 | 0.4 | -0.5 | 0.03 | 0.07 | 32 |
| 11-12 m | 0.02 | 0.07 | 1.94 | -0.02 | 4 | 0.002 | 102 | 0.25 | -0.02 | 15 | -0.02 | 51 | 0.1 | 7 | -0.01 | 0.3 | -0.5 | 0.03 | 0.13 | 13 |
| 12-13 m | 0.01 | 0.06 | 1.64 | -0.02 | 2.7 | 0.002 | 59 | 0.2 | -0.02 | 11 | -0.02 | 59 | 0.1 | 7 | -0.01 | 0.2 | -0.5 | -0.02 | 0.1 | 14 |
| 13-14 m | 0.01 | 0.03 | 2.88 | -0.02 | 5.3 | 0.001 | 22 | 0.18 | -0.02 | 26 | -0.02 | 61 | 0.1 | 2 | 0.01 | 0.3 | -0.5 | 0.02 | 0.02 | 31 |
| 14-15 m | 0.02 | 0.07 | 5.19 | 0.02 | 10.1 | -0.001 | 96 | 0.27 | 0.02 | 33 | -0.02 | 118 | 0.2 | 7 | 0.01 | 0.7 | -0.5 | 0.04 | 0.14 | 91 |

## Site 2: Geochemical Dispersion around the Cobar Gold Field

**Site 2a: Airport South Quarry, 10 km SSW of Cobar (GR 0386044 6505357)**
Ken McQueen

The pits on both sides of the road have exposed regolith carbonates developed in transported regolith (alluvium) and at the bedrock interface. The alluvium is part of an older palaeodrainage system now forming a terrace on the flanks of a more recent channel. This palaeodrainage system (as well as the present drainage) was sourced to the northeast in the eroding Cobar gold field.

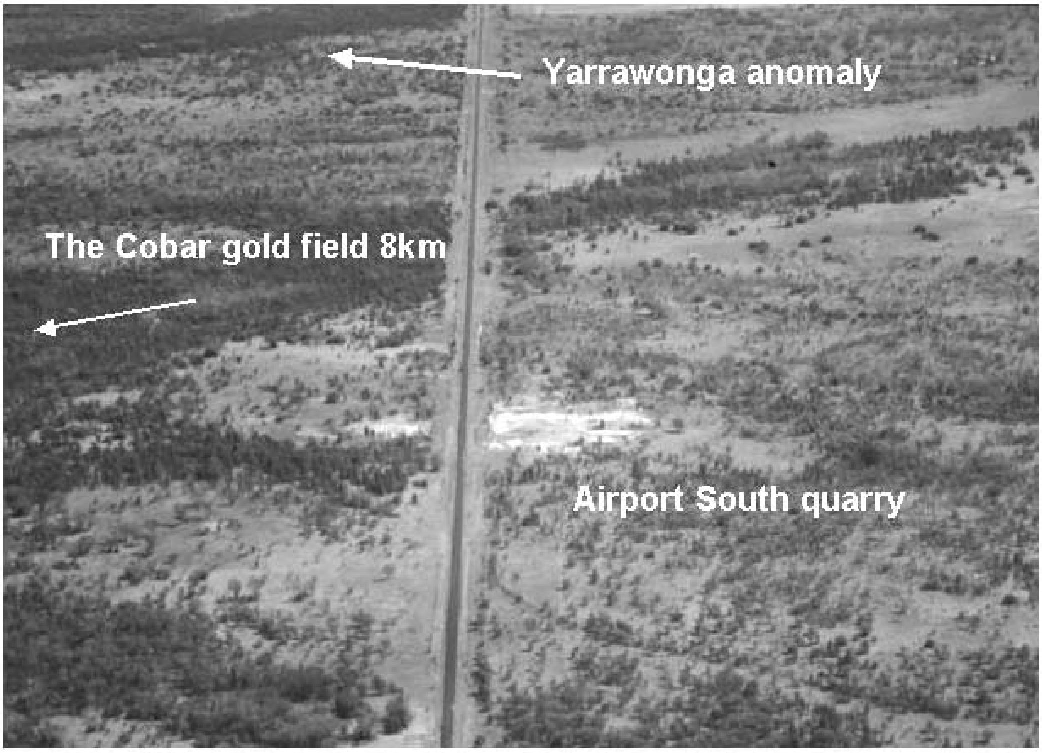



**Figure 2.1**. Aerial view looking south across the Airport South quarry towards the Yarrawonga anomaly.

The upper part of the profile on the east side of the road consists of a thin (<20 cm) layer of red silty loam soil with a pisoidal ferruginous lag (reworked from the undelyling palaeosediments). A 1.5 m thick zone of transported and reworked fine sand and maghemite-bearing gravel underlies this unit. This transported material has been heavily impregnated with carbonate (calcrete) that forms a powdery matrix and small carbonate veins in the upper 0.3 m. This passes down into variably coalesced nodular carbonate and coated grains with some laminated zones, and then into massive hardpan carbonate at the base immediately above partly weathered bedrock. Gold shows minor variation through the profile (from 5-7 ppb) and is correlated with the carbonate content, as reflected in Ca concentration. Both calcite and dolomite are present throughout the profile with dolomite increasing in abundance at depth, particularly in the hardpan facies (Fig. 2.2). Gold is generally not correlated with Fe, suggesting that it is not hosted by iron oxides/oxyhydroxides, except possibly in the surface lag. On the other hand Cu and Zn show distribution patterns very similar to that of Fe and appear to be negatively correlated with Ca and Au (Fig. 2.3).

The elevated gold levels (above a regional threshold of 3 ppb) probably reflect concentration of gold in the regolith carbonates from the palaeosediments after these were transported down catchment from the Cobar gold field. Alternatively gold may have been introduced by groundwater draining down from gold field, with accumulation in the carbonates. This site demonstrates the possibility of using calcrete as a reconnaissance sampling medium for gold, in a similar fashion to reconnaissance stream sediment sampling. This would probably work best in palaeodrainages as the presently active drainage systems do not appear to be precipitating calcrete (possibly because present surface waters are undersaturated with respect to carbonate).

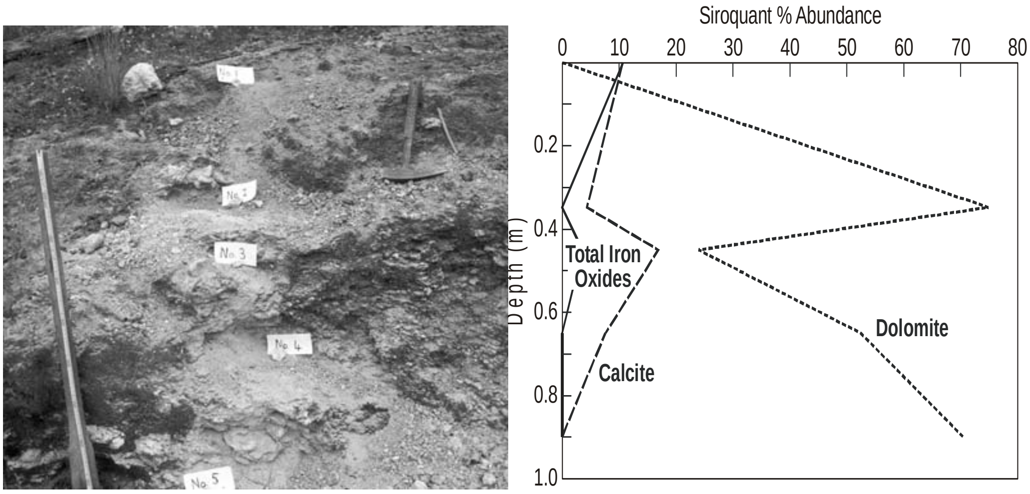



**Figure 2.2**. View of the carbonate profile and plot of mineralogical variation in bulk samples at the Airport South quarry SSW of Cobar (quantitative XRD by SIROQUANT).

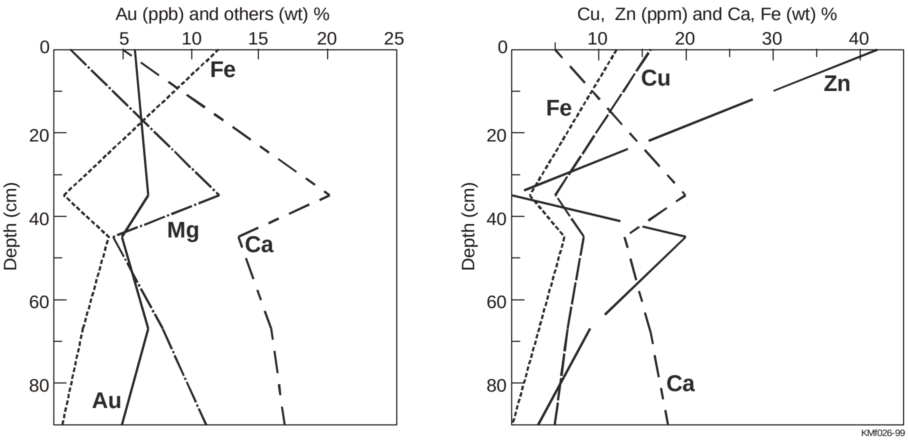



**Figure 2.3**. Geochemical trends through the Airport South regolith carbonate profile.

**Site 2b: Yarrawonga geochemical anomaly, 12 km SSW of Cobar (GR 0385900 6502900)**
Ken McQueen and Dougal Munro

A large multi-element geochemical anomaly in lag materials at this site has perplexed explorationists for many years. Initial lag sampling by Dominion Mining in the early 1990's revealed anomalous levels of Pb, As, Bi, Au. Subsequent RAB drilling and sampling of saprolite failed to detect any significant anomalies. The question has been - is this a displaced anomaly, down drainage (palaeo and present) from eroding deposits in the Cobar gold field, or is there a local source with strong leaching of the saprolite to explain the absence of a deeper anomaly ? To help resolve this question a study was conducted on the morphological, mineralogical and geochemical characteristics of the lag. Bulk lag was sampled with dust pan and brush from selected sites across the anomaly and up catchment to Fort Bourke Hill. The samples were split into the following fractions (see Figs 2.4 and 2.5):

- Micro lag (<120 µm) fraction
- Quartz lag
- Angular lithic lag
- Rounded lithic lag
- Angular non-magnetic ferruginous lag
- Rounded non-magnetic ferruginous lag
- Angular magnetic ferruginous lag
- Rounded magnetic ferruginous lag.

The degree of rounding was considered a general indicator of degree of reworking and transport of the lag.

These fractions for samples from 8 sites were analysed by INAA and ICP OES/MS for a wide range of elements. The aim was to determine which lag fraction/s contained elevated levels of the target and pathfinder elements. Quantitative XRD for mineralogical determination was conducted on the powders of lithic and ferruginous fractions from three of the sample sites.

The study produced some interesting findings. The predominant Fe-bearing mineral in the lag is hematite with variable but lesser amounts of maghemite in the magnetic lag (up to 20%) and minor goethite in the lithic lag. There is also a significant amorphous component (up to 15%), which may contain non-diffracting iron oxides/oxyhydroxides. There is a clear relationship between the degree of rounding and the hematite and Fe content of the lag. Potassium, largely hosted in muscovite, shows an inverse relationship with degree of rounding and increasing Fe content. This indicates that with exposure, reworking and transport, the lag has been progressively enriched in the most chemically and physically resistate components including mainly hematite and quartz. Additional hematite has also been precipitated on the more mature ferruginous lag. The abundance of maghemite appears to be independent of degree of rounding.

Some trace elements, including As, Pb, Sb, Bi, Ba and Th show an increase in abundance with increasing Fe content and degree of rounding (Fig. 2.6). This suggests that these elements are hosted in hematite and that they have become relatively enriched with physical (and chemical) maturation of the lag. The Th/Fe ratio is a particularly good index of this hematite-controlled fractionation trend. Lag composed predominantly of the well-rounded ferruginous component can have double the concentration of these elements when compared with lag composed of predominantly *in situ* lithic or ferruginous lithic material. This can explain the elevated As and Pb values in the Yarrawonga anomaly, particularly in its western portion where there is a high proportion of well round and transported ferruginous lag (Fig. 2.9).

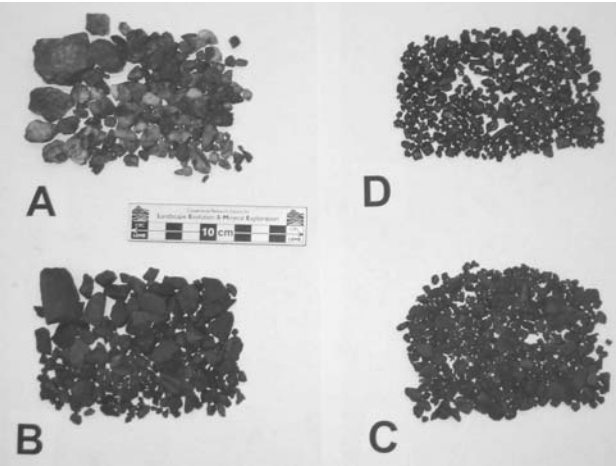
Copper and Zn are not fractionated with hematite and show a distinctly different distribution pattern in the anomaly (Fig. 2.8). Elevated levels of Cu and Zn (>120 ppm) occur in the angular lithic component at one site between the anomaly and the Cobar gold field. This probably reflects slightly elevated background levels at this location with the metals fixed in goethite.

Gold in most of the study samples was below detection (<5 ppb) although previous, more extensive lag sampling has reported up to 1 ppm (Scott Schultz, pers. comm. 1997). Elevated Au (140 ppb), with elevated Bi, was found in the rounded ferruginous lag at one site suggesting that the Au has been transported, probably from the Cobar gold field. Interestingly the micro lag component from two sites also has low but detectable Au (5-6 ppb).

The evidence suggests that the Yarrawonga anomaly has been generated by element transport from the Cobar gold field and regolith controlled fractionation of some pathfinder elements (particularly the Pb, As, Bi) into hematite-enriched lag.

When using lag as a geochemical exploration sampling medium it is important to take into account the history of transport of this material. It is also recommended that the lag data be normalised for Fe (hematite) content for those elements concentrated in hematite (e.g. Fig. 2.7). This can reduce the noise related to varying hematite abundance.

The evidence of higher Th contents in the more reworked ferruginous lag fraction raises the possibility of utilising the Th channel in airborne radiometric imagery to map out, on a regional basis, areas of dominantly transported ferruginous lag as distinct from areas with dominantly *in situ* ferruginous lag.



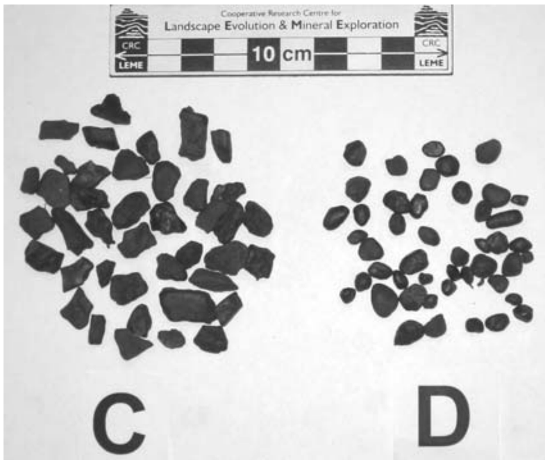




**Figure 2.4.** Separated lag fractions from Sample site 3, Yarrawonga Anomaly. (A) quartz fraction (B) lithic fraction (C) magnetic ferruginous fraction (D) non magnetic ferruginous fraction.
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**Figure 2.5**. Magnetic ferruginous fraction separated into (C) angular and (D) rounded components.

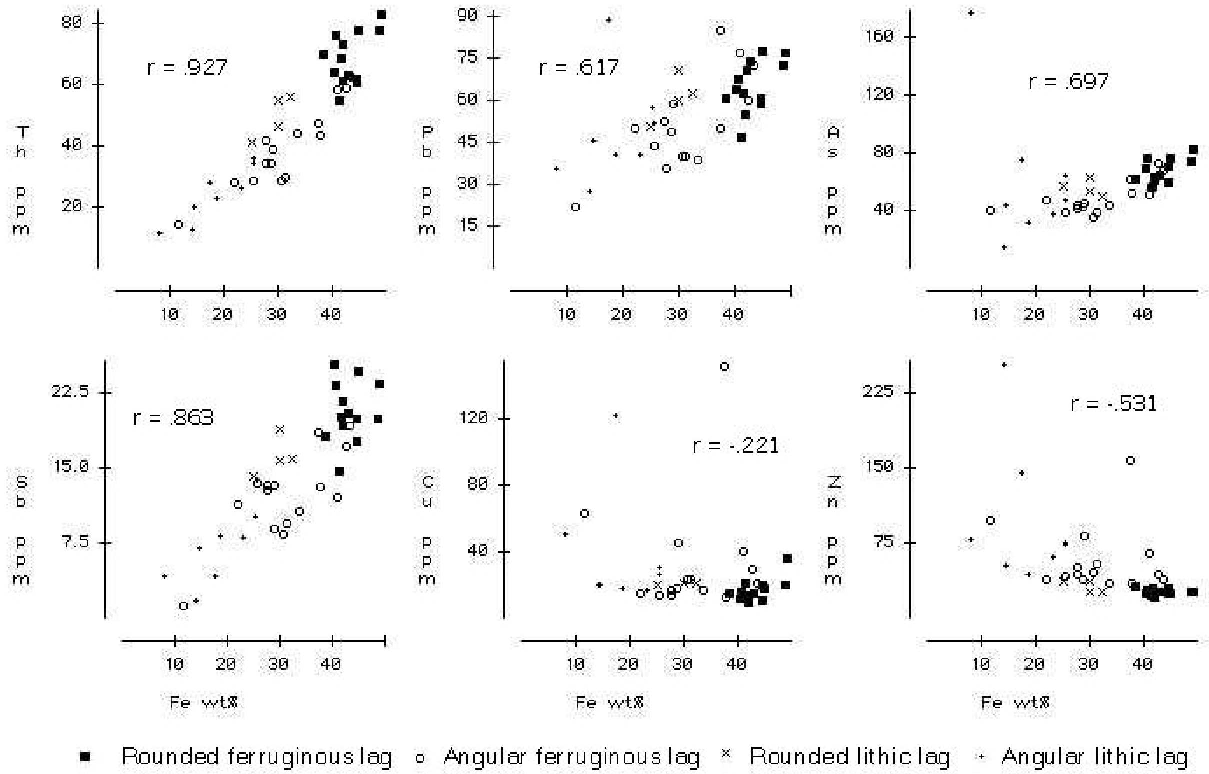



**Figure 2.6**. Bivariate plots of Fe versus pathfinder elements for lag samples from the Yarrawonga area. Each lag type has been subdivided into angular and rounded variants (r = correlation coefficient). Geochemical analysis was by INAA and ICP OES.

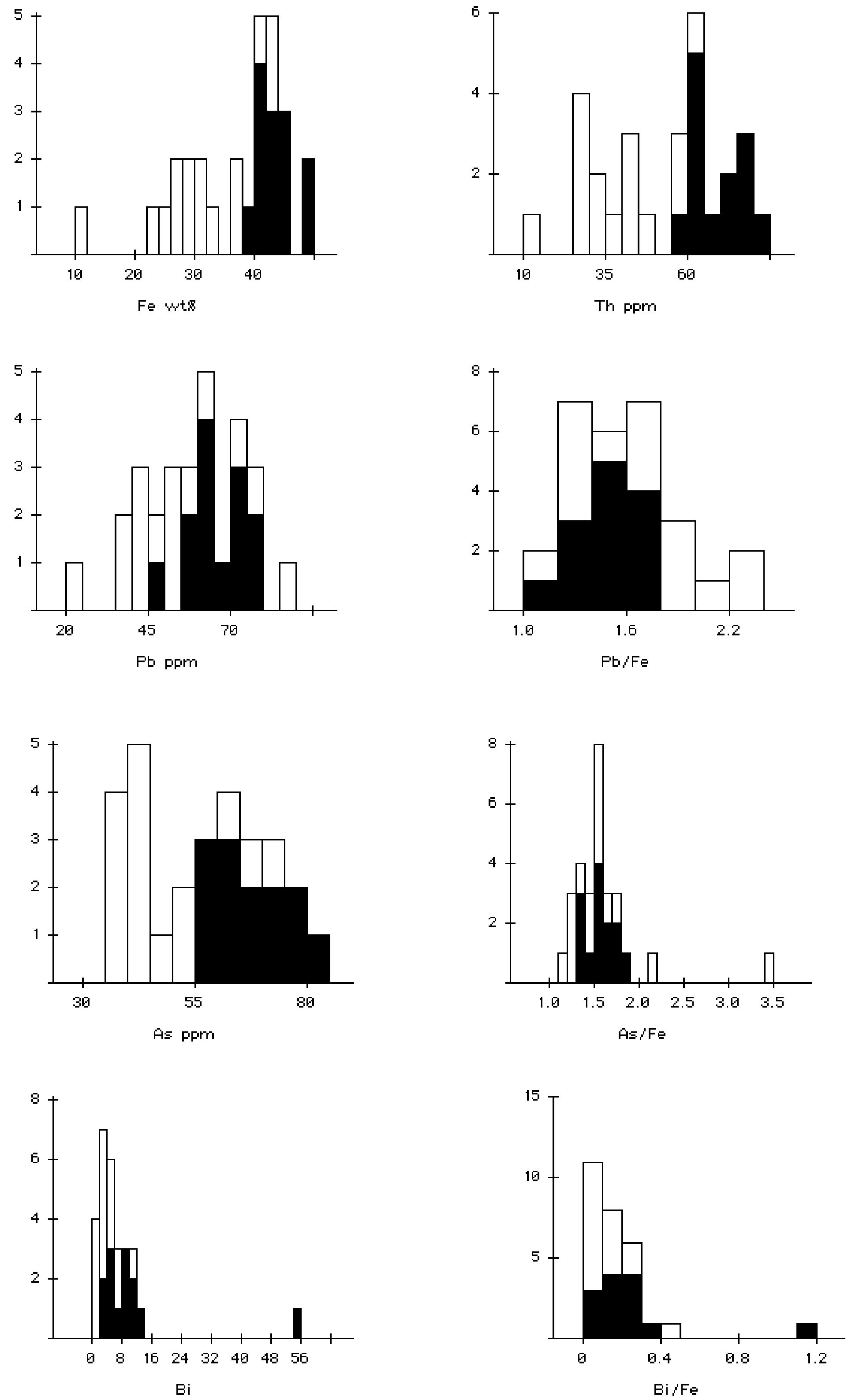



**Figure 2.7.** Histograms showing some element abundances for rounded (filled) and angular (open) ferruginous lag from the Yarrawonga-Peak area, as well as the effect of normalising these elements against Fe.

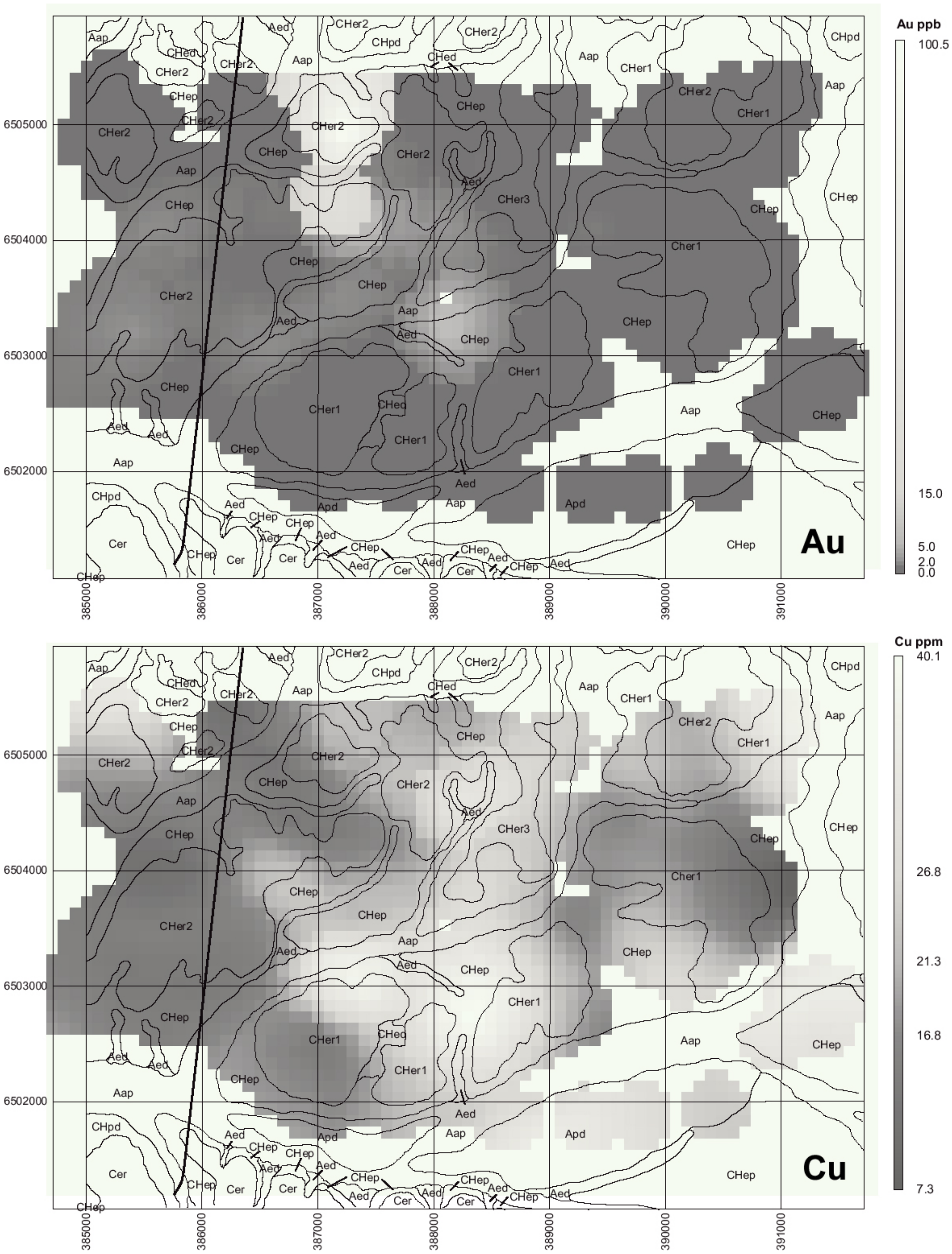



**Figure 2.8**. Inverse-Distance Weighted (IDW) greyscale contoured plots of Au and Cu concentrations in lag over the Yarrawonga area (survey and data from Dominion Mining). Scale values are in ppb for Au and ppm for Cu. Regolith-landform units are from mapping by Dougal Munro are overlain (see legend below).

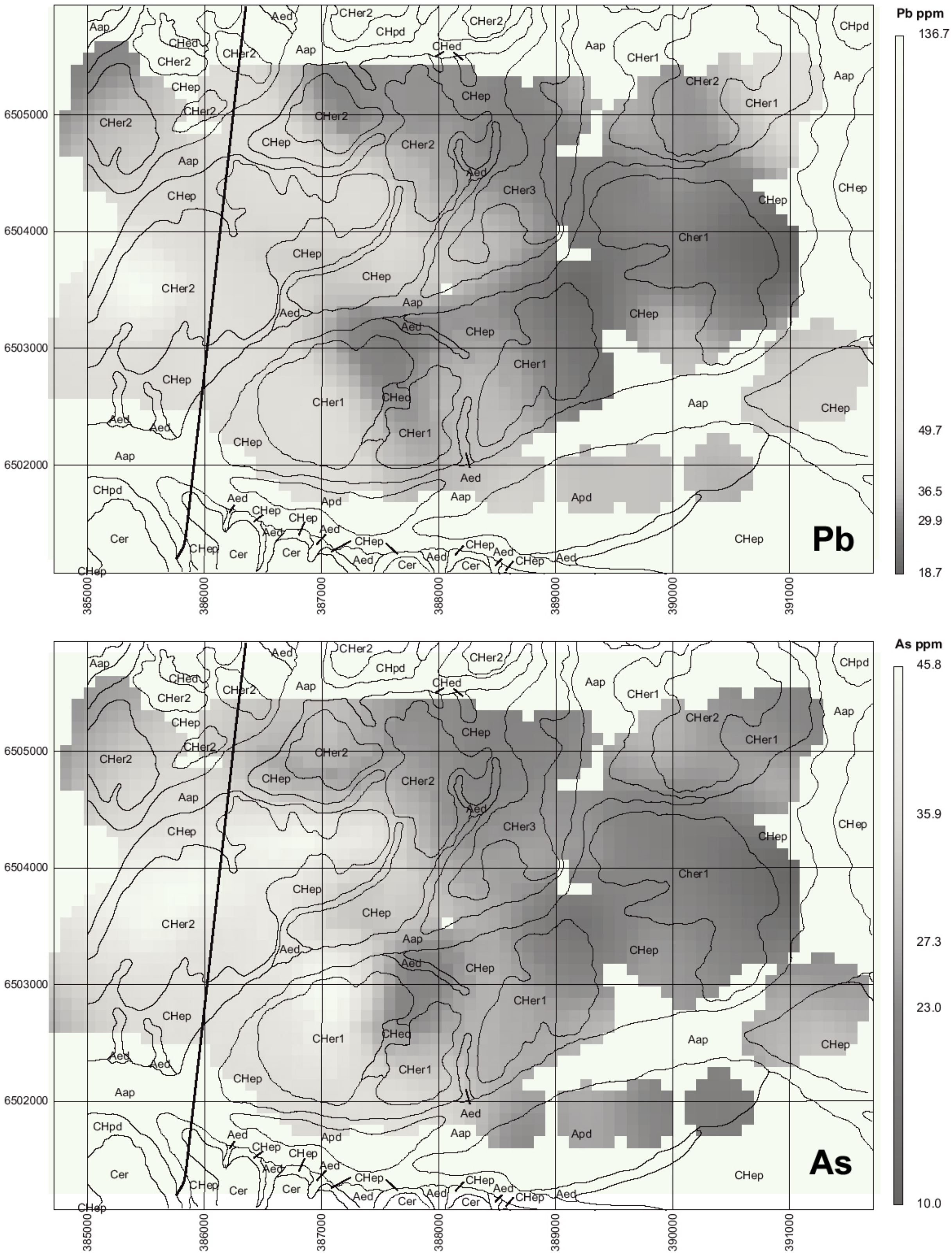



**Figure 2.9**. Inverse-Distance Weighted (IDW) greyscale contoured plots of Pb and As concentrations in lag over the Yarrawonga area (survey and data from Dominion Mining). Scale values are in ppb for Au and ppm for Cu. Regolith-landform units are from mapping by Dougal Munro are overlain (see legend below).

## Legend for Regolith-Landform Unit Overlay Figures 2.8 and 2.9

**Transported Regolith**

*Alluvial Sediments*
Aap: sub- to well-rounded lithic and quartzose gravels, sands, silts and clays. Low relief and generally sloping, incised channels with some areas of minor depositional plains.

Aed: sub-rounded tro angular fragments of lithic and quartzose gravels with minor sands and silts. Widespread sub-to well-rounded ferruginous material consisting of pisoidal lag < 15 mm diameter. Gently inclined slopes, aggraded by sheetwash material.

Apd: Well-sorted quartzose and lithic sands, silts and clays with minor areas of lithic gravels and ferruginous lag. Extremely low relief.

***In Situ* Regolith**

*Colluvial sediments*
Cer: Well-rounded ferruginous lag with minor lithic gravels and quartz fragments. Low angle, gently sloping rises with low relief.

CHer1: Angular to sub-angular lithic and minor quartzose gravels. Sub-angular to rounded ferruginous pisoidal lag common on surface. Sub-cropping sandstones and siltstones. Low angle, gently sloping rises with low relief.

CHer2: Angular to sub-angular lithic and quartzose gravels. Sub-angular to rounded ferruginous pisoidal lag and lithic gravel. Small areas of sub-cropping sandstones and siltstones. Gently sloping undulating rises with low relief. Minor features characteristic of sheetwash processes.

CHer3: Angular to sub-angular lithic and quartzose boulders, minor cobbles and gravels with sands and silts. Sub-cropping massive sandstone fragments up to and > 256 mm diameter, with minor sub-cropping sandstones and siltstones. Minor fraction of well-rounded lithic gravels. Very abundant sub-rounded to well-rounded pisoidal ferruginous lag. Elongated narrow landform with moderate relief forming a small plateau.

CHed: Sub-rounded to angular lithic, quartzose and ferruginous gravels, sands and minor silt and clay. Shallow open depressions, mostly with moderately inclined slopes, aggraded by by angular and sub-angular sheetwash material.

CHep: Sub-rounded to sub-angular lithic and quartzose gravels with sub-rounded ferruginous lag and minor silt and sand sheetwash. Undulating land surface of low relief.

CHpd: Sub-rounded to sub-angular lithic and quartzose fragments with minor angular gravel. Large quantities of ferruginous lag predominantly consisting of well- to sub-rounded pisoidal fragments varying is size up to 10 mm diameter. Slightly undulating landform of low relief commonly located opposite the eroding channel bank of hill slope.

Regolith-landform mapping by Dougal Munro, University of Canberra, 2002.
Map Grid based on Map Grid of Australia 1994 using Geodetic Datum of Australia 1994.

# Site 3: Truncated Weathering Profile at McKinnons

**Site 3: McKinnons Open Pit (GR 0376300 6482700)**
Neil Rutherford

The field stop at McKinnons Pit will examine aspects of the rock profile in relation to weathering, profile erosion and effects of leaching by low pH groundwater resulting from oxidation of pyritic ores. Also discussed will be the cause and nature of colours in the weathered profile, effects of changes in redox profiles. Road sections near McKinnons will be used to illustrate some aspects of recent duricrust development. Unfortunately we are unable to access the exposure of the weathered profile north of McKinnons.

The McKinnons area and the McKinnons pit illustrate a number of regolith features that characterise the Cobar terrain. These include examples of:

- The Late Cretaceous-Early Tertiary deep weathering during a humid period with saturated ground conditions.
- Effects of increasing aridity from late Tertiary (Miocene) to Quaternary with falling groundwater tables giving rise to overprint of earlier weathered zones and deep oxidation.
- Effects of oxidation of pyritic mineralisation, supergene enrichment and rock degradation under low pH conditions.
- Tectonic warping of the landscape, particularly along the Cobar trough margins with consequential erosion of the deeply weathered landscape and infill of the eroded profile with weathered materials. Some 40+ metres locally of pre-infill relief is present.
- Erosion and redistribution of eroded ferruginous material (pisolites) from mottled zone of weathering and its implications for geochemistry and geophysics.
- Deposition of silcrete and ferricrete, (±calcrete) as a duricrusts in recent erosional depressions and capping of red earths derived to a large extent from aeolian sources.

The exposed ground surface from a few kilometres north northwest of McKinnons to a few kilometres south southwest shows progressively deeper levels of exposure through the Late Cretaceous-Early Tertiary weathered profile. In the north, remnants of upper levels show erosion of the mottled zone and “release” of pisolites from the soil profile onto the land surface. This can be seen by driving north up the track along the boundary fence dividing the Bluff and Lerida properties from the sharp turn near the end of the bitumen just north of McKinnons near the gate into the Bluff Homestead. This section also includes upper saprolite units and to the east is capped by recent silcrete and ferricrete duricrust.

In the McKinnons Pit there is a truncated lateritic profile exposed. The mottled zone has been largely removed along with some parts of the upper saprolite. Superimposed on this profile are the effects of weathering and oxidation of the quartz-pyrite mineralisation. This gave rise to the supergene enrichment of Au mineralisation that was mined. It is characterised by a leach zone, the white “halo” about the primary sulphide ores (see Fig. 3.1). This has been extensively leached by low pH groundwater generated by oxidation of pyrite. Acid weathering is also believed to be responsible for preventing the formation of kaolinite and chlorite in the mineralised sections of the profile (Fig.3.2). Where pyritic ores oxidise in weathered profiles they will produce a “geochemical hole” often devoid of most metal elements, with the exception of Au and frequently Pb. Carbonate (Lerida Limestone equivalent) units in the sediments have neutralised the low pH groundwater in the northern end of the pit.

With increasing aridity from the Late Miocene-Pliocene and fall of the watertable the redox front has also been reset. This can be seen as an overprint of the older weathered hematite bearing materials by younger goethitic material particularly along fracture zones and along vein margins (groundwater pathways). Different palaeo-magnetic dates (e.g. Early Palaeocene and Mid Miocene) from Fe-oxides in the McKinnons Pit and elsewhere in the Cobar District attest to these changing conditions in the rock profile (see Fig. 3.1). The present redox front and base of weathering closely reflect the present ground water table, (they need not do so however in other areas, weathering can be much deeper than the depth of the redox front).

South of McKinnons the older weathered profile has been entirely removed exposing a deeply oxidised moderately weathered profile formed under more arid conditions. Recent erosion (last 100 years) has stripped up to 0.5 metres of soil from the landscape.


**Figure 3.1** View to southern end of McKinnons Pit showing white leached host rocks of ore zone surrounded by older weathered saprolite. Ages are palaeo-magnetic ages for Fe-oxides. Weathered zone has been truncated by erosion at about the base of the mottle zone and upper saprolite (photo K. McQueen).

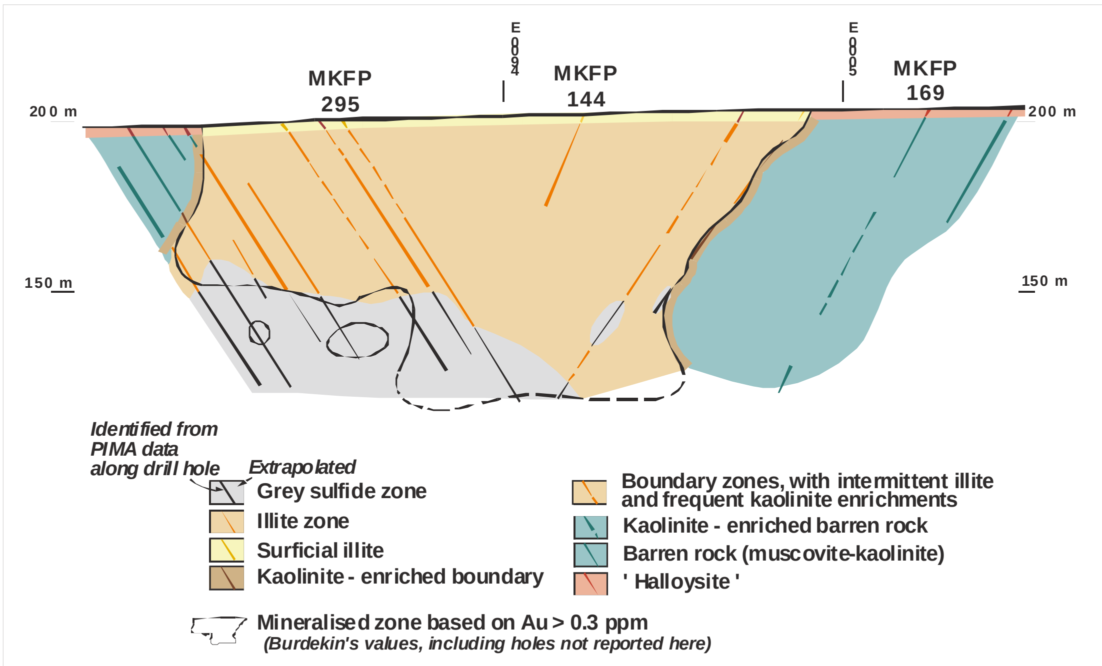



**Figure 3.2**. Cross section through the weathering zone of the McKinnons gold deposit showing the mineralogical variation, in particular the distribution of illite and kaolinite (from Marshall *et al*., 1996).

**NOTES**

## FIELD TRIP 2 COBAR-COOLABAH-BYROCK

## Introduction to Day 2

This full day field trip will follow the route of two of the aircore drilling traverses undertaken as part of the joint CRC LEME - NSW DMR Girilambone Project. The area is extensively covered by both *in situ* and transported regolith, much of the latter in mid to late Tertiary palaeochannels and colluvial plains and more recent alluvial plains and channels. Many of the palaeochannels, as well as the present drainages, contain maghemite-bearing clasts and gravels. These channels are well expressed in the aeromagnetic imagery (1.5 VD). The present drainage channels tend to have a broader more diffuse pattern than the palaeochannels. Drilling has also revealed extensive and deep, non-magnetic palaeochannels. Two electromagnetic surveys (using the NanoTEM method) were conducted across examples of these two different types of palaeochannels with the aim of testing the method for detecting non-magnetic channels. The present drainage in the field trip area is dominated by two major north-trending catchments, Yanda Creek on the western edge, and Mulga Creek through the centre. The thickness and extent of transported regolith increases from south to north (off the Cobar Spur).

The route will traverse a terrain mostly underlain by Girilambone Group rocks with infaulted slices of probable Early Devonian rocks, intruding granites and some Late Devonian outliers or downfaulted blocks. The Girilambone Group has previously been used as a "grab bag" to cover a wide range of rock types generally very poorly exposed between the eastern margin of the Cobar Basin and the edge of the Bogan River flood plain. The group is considered to be Ordovician in age (Gilligan *et al*, 1994). Rock types included are massive quartzites, micaceous quartz sandstones, siltstones, slates, cherts, mafic volcanic rocks, quartz-sericite schists, chloritic schists and phyllites, granule-cobble conglomerate and serpentinite.

The two traverses also illustrate different vegetation associations related to the regional transition from winter-dominant to summer-dominant rainfall climatic conditions, combined with a local change from shallow regolith cover in the south to deeper and more extensive transported (alluvial) regolith in the north. In the south vegetation is dominated by Bimble Box (*E. Populnea*) and White Cypress Pine (*Callitris glaucophylla*) with scattered Wilga (*Geijera parviflora*) and some Belah (*Casuarina cristata*). To the north Mulga (*Acacia aneura*) becomes increasingly abundant. The regional climatic change occurs across 30º-32º latitude and this zone also marks the boundary between some different regolith features, notably the widespread development of pedogenic calcrete to the south. In Western Australia this zone is referred to as the Menzies Line (see Hill *et al*. 1999; McQueen *et al*. 1999).

**Historical Note**

The bedrock and regolith geology of the Coolabah-Byrock area, including a number of the sites examined on this field trip, were briefly described by Geological Surveyor William Anderson in 1887 (Anderson, 1888). His description of the landscape, and particularly the vegetation distribution, is interesting given what we see today.

*"Most of this country appears to any one passing over it to be perfectly flat, but this is not actually the case, for although much of it consists of approximately level plains, there are in reality great numbers of small ridges and rising grounds, while at wide intervals a few isolated hills rise to a considerable height above the plains."*

*"The country is thinly timbered, and the timber is, as a rule, of small size; this no doubt being due to the former prevalence of bush fires, together with the natural dryness of the climate. The most common trees are the mulga, box, beefwood and ironwood. The scrub is only locally dense, and never impenetrable. Frequently wide open patches occur altogether free from timber, while everywhere the luxuriant growth of grass tells of the fertility of the soil."*

Anderson also made some remarkably perceptive comments about the landscape history of the region. He alluded to extensive palaeochannel systems and the backfilling of an older landscape.

*"In this part of the Colony there is little evidence to indicate the presence of former drainage channels, in the drift of which it might be expected that gold would occur wherever these channels had passed over auriferous reefs or lodes. Almost all the physical features which existed during late Tertiary and early Pleistocene times have been well nigh obliterated, not so much by local denudation as in other parts of the Colony, but by a very general levelling of the whole country, due to the distribution of the red soil. There can be little doubt that during the very moist Tertiary and Pleistocene Periods this large district was drained by a system of rivers and creeks, which must have worn channels for themselves, in some parts of their course through the Silurian rocks, and in others through the cretaceous-tertiary deposits. Such channels have, however, since then, been altogether obliterated by the universal distribution of the red soil and in consequence of the gradual drying of the climate."*

## Site 4: Deeply Weathered "Girilambone Group" Rocks

**Site4: Small pit south of Cobar-Coolabah Road (GR 0411991 6556676)**
Ken McQueen and Mike Hicks

This small pit exposes deeply weathered "Girilambone Group" sandstones and siltstones, now consisting of saprolite with well developed ferruginous mottling (typical of the upper parts of many weathering profiles in the Girilambone-Cobar region). Ferruginisation is generally better developed in the sandier (more permeable) lithologies and along fractures. Calcrete is developed at the soil-saprolite interface as thin coatings. An analysis of the calcrete here revealed 15.4% Ca, 1.6% Mg, 2.12% Fe, 0.52% K, 370 ppm Ba, 650 ppm Sr, 6 ppm As, 10 ppm Cu, 6 ppm Pb, 22 ppm Zn and 5 ppb Au.

A small Cu-Zn(Au) occurrence (Emu Tank prospect) is located about 2.5 km southeast of this site.

Starting just west of this site (0411259 6556289 to 0412876 6557211) is one of the NanoTEM survey lines (Line 2). This one was conducted across a magnetic channel to test the ability of this geophysical technique to profile this type of channels and measure its thickness (Fig. 4.1).

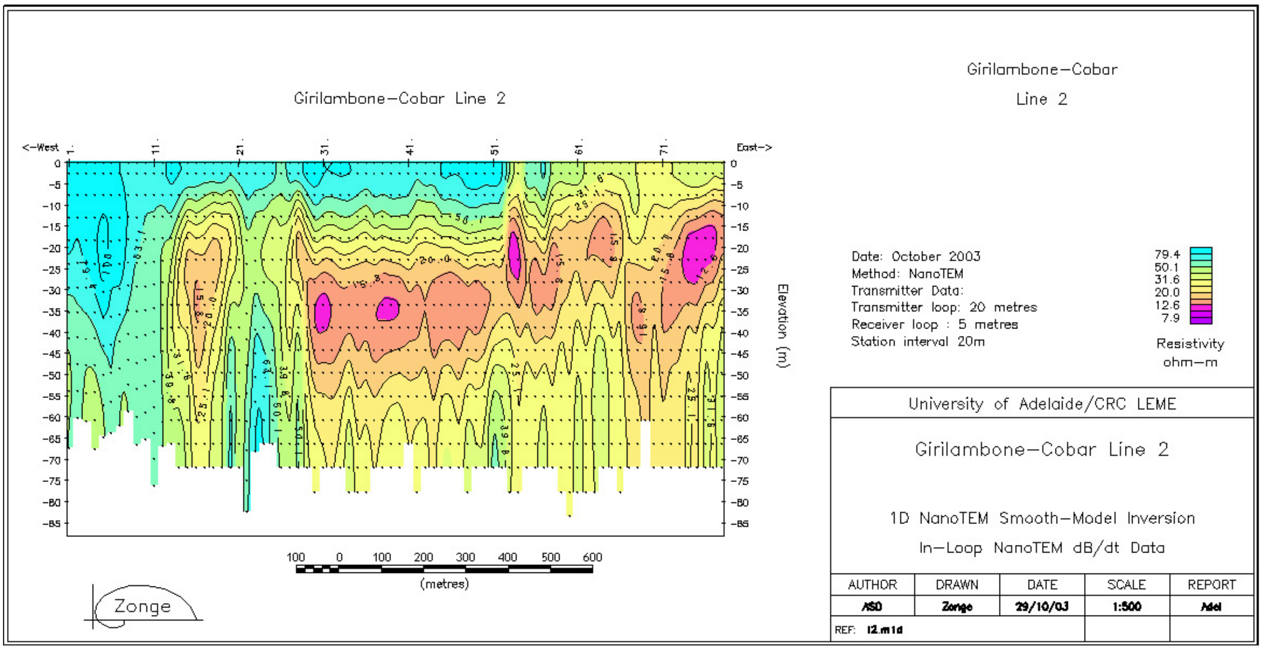



**Figure 4.2**. Depth-resistivity profile across a well-defined, shallow magnetic palaeochannel east of site 4 (from Davey & Joseph, 2004).

The profile shows that the subsurface is highly resistive (50-100 Ohm-m) beneath the first 11 stations (probably over shallow bedrock). Further east and up to the end of survey line (Station No.78) it is less resistive (5-25 Ohm-m). The low resistive region also appears to extend laterally even further east. This may indicate the palaeochannel is wider than it appears from the airborne magnetics or alternatively a channel with low resistivity overlying deeply weathered clay-rich saprolite. It is also worth noting the presence of a shallow but thicker (~10 m) resistive layer right over the western section (between stations 11 and 52). This could the sheet flow of resistive basement materials from the western flank of the palaeochannel. Abundant maghemite-bearing ferruginous lag was also noted in this area.

# Site 5: Basement Structures and Deformed Conglomerates

**Site 5: Drouin Peak northern end of Tooram Hills (GR 0426638 6566918)**
Mike Hicks and Ken McQueen

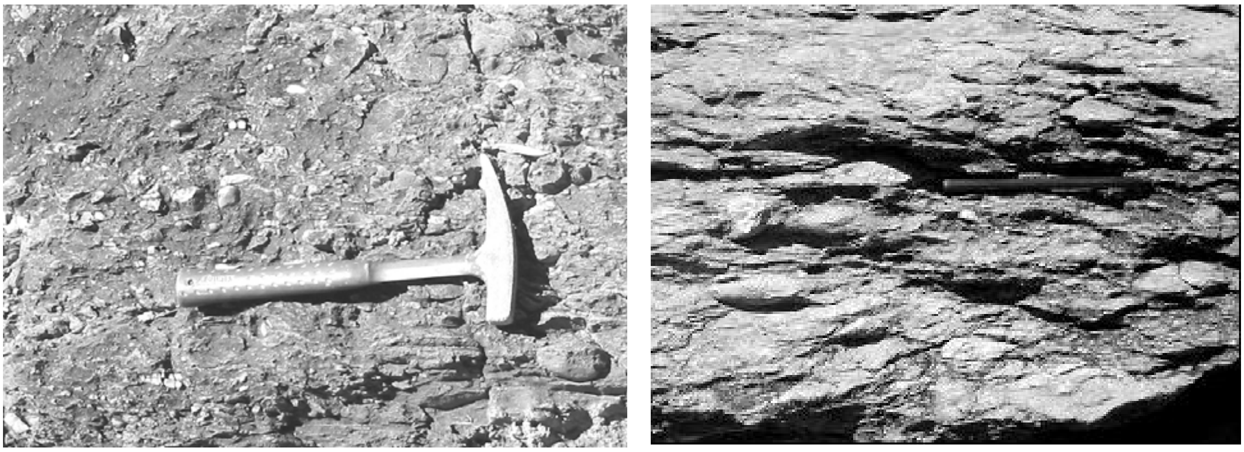
Just west of this site the road crosses a major north-northwest trending magnetic feature. In the aeromagnetic imagery this feature appears as a strong magnetic low and extends up to 35 km, mostly south of the Coolabah Road. It has been interpreted as part of the northern extension of the Gilmore Suture, which trends NNW from south of Canbelego until it is truncated by a major east trending structure on the lower part of the Bourke 1:250, 000 sheet. Air core drilling to shallow depth over this zone during the traverse drilling did not reveal any particularly unusual features. Fine-grained mafic lithologies, siliceous cherty rocks and minor ironstone occur as float in the area.

The rocks exposed on the ridge consist of a strongly deformed, matrix supported, polymictic conglomerate with clasts (5 mm-50 cm in diameter) of sandstone, chert and minor quartz. The matrix is highly siliceous to cherty. Clasts show rotation and stretching in a well-developed foliation, which is oriented 352º/80ºNE. Quartz veining is also developed parallel to the foliation. These rocks have been previously mapped as part of the Girilambone Group. They are very similar to deformed conglomerates that occur at Mount Merrere 17 km to the northwest, also previously mapped as Ordovician Girilambone Group (Fig. 5.1).

Petrographic investigation of pebbles collected from outcropping conglomerates at a number of sites suggest a different story (NSW DMR staff). Pebble lithologies include radiolarian cherts, crenulated phyllites and siltstones. These clast types together with the presence of volcanic quartz within both the matrix and some sandstone pebbles suggest a much younger age for the conglomerates. Analysis of pebbles collected from conglomerates at Mount Boppy, compared with that for Drouin Peak suggests the provenance for both conglomerates includes the Ordovician Girilambone beds and Early Silurian Chesney Formation. It is therefore likely that these conglomerates are Late Silurian or Devonian in age.

To the east of the ridge pebbles are less abundant in this unit and the rocks show greater strain, with greatly elongated pebbles in a very strongly foliated fine-grained matrix. The reduced abundance of pebbles could indicate an upward fining sequence and hence a facing direction to the east.

A number of small shafts and prospecting pits (presumably for gold) occur in quartz veins along the edge of these hills to the south.



A B

**Figure 5.1**. Deformed and strongly foliated conglomerates from Drouin Peak (A) and Mount Merrere (B).

## Site 6: Quartz-rich Gravels

**Site 6: Gravel pit north of Coolabah (GR 0471712 6568083)**
Ken McQueen

Quartz-rich gravels with minor interbedded grits and sandstones are exposed at this gravel pit, near the junction of the Cobar-Coolabah and Bourke roads. These sediments are partly consolidated and contain abundant quartz clasts, mostly 2 mm to 5 cm in diameter. There are also minor clasts of quartz-rich sandstone, chert and rare conglomerate. Bedding is near horizontal and clast orientations at one site indicate a possible palaeocurrent direction of 025º. There is some ferruginisation of the top of the gravels indicating post-depositional weathering or downward movement and oxidation of iron from the overlying soil profile. These gravels cover a large area around Coolabah and they are well exposed in a railway cutting south of the village. They are up to 35 m thick. Traces of gold have been reported from the base of the gravels in a shaft near Coolabah (Anderson, 1888). The gravels show cross bedding in some sections.

The gravels at this site are likely to be Early Tertiary in age (possibly Cretaceous). The almost pure quartz composition of the sediments suggests that they were derived from a very intensely, chemically weathered source from which most of the clay was removed during transport and reworking. Very similar grits and gravels have been found beneath a leucitite lava flow near Wilga Tank (56 km to the southwest). These can be dated from the age of the leucitite (17 Ma) as being pre Early Miocene. At the Wilga Tank locality the gravels overly a bleached, deep weathering profile.

**BBQ Lunch at Mulga Creek Hotel, Byrock**

The village of Byrock has an interesting history, including pre-European use of the granite rock holes west of the village by visiting aboriginal tribes. The first hotel was built and licensed in 1879 on Mulga Creek, some distance to the west of the present village site. It operated as a Cobb and Co. staging point. In 1884 the railway line to Bourke reached Byrock and Byrock became the rail-head for the period of construction of the final Bourke section. This was Byrock's boom time. There were five hotels, numerous stores and a school with an enrolment of seventy five students. Once the railway was completed the population soon dwindled.

Following his famous trip to Bourke by train in 1892 Henry Lawson wrote of Byrock:

*"About along Byrock we saw the first shearers. They dress like the unemployed but differ from that body in their looks of independence. They sat on trucks and wool-bales and the fence, watching the train, and hailed Bill, and Jim, and Tom, and asked how these individuals were getting on. Here we came across soft felt hats with straps round the crowns, and full-bearded faces under them. Also a splendid-looking black-tracker in a masher uniform and a pair of Wellington boots."*

"*About Byrock we met the bush liar in all his glory. He was dressed like – like a bush larrikin. His name was Jim.*" (Henry Lawson, 1896).

In the tourist brochures Byrock is also referred to as the "village of heroes" (possibly village of "mad bastards" if you read what they did – see inside the pub). In WWI and WWII volunteers from Byrock were awarded 1 Victoria Cross, 1 Military Cross, 3 Military Medals and a Distinguished Flying Cross. This was from a very small population (e.g. in WWI, 13 men enlisted from Byrock).

Byrock's main problem as a town has always been the lack of a sufficient water supply (hence the permanent need for a pub).

# Site 7: Byrock Granite

**Site 7: Byrock Rock Holes just west of Byrock**
Mel Jones and Phil Blevin

At the Byrock rock holes a flat granite exposure with weathering cavities along a prominent joint direction has produced a natural water catchment and storage system. This was used by the local aborigines as a water source (in an otherwise pretty dry terrain). A description of the nature and history of the site from the aboriginal perspective is well documented by the signage at the site.

The exposed Byrock Granite is a coarse-grained biotite granite with minor hornblende. It is felsic (73 –74 % $SiO_2$), high-K, and compositionally evolved and fractionated with elevated Th (34 ppm), U (6 ppm) and Nb (38 ppm). Most granites of the region are similarly $SiO_2$ rich, compositionally evolved and I-type, and are usually non-magnetic (like here at Byrock) or rarely less felsic but still only modestly magnetic (Compton Downs).

Enclaves are variably distributed around the waterhole reserve and locally form swarms. Magmatic enclaves are abundant in low outcrops towards the back (southern end) of the reserve near the rock dumps. Here, rounded and bulbous masses of more mafic material suggest that the dyke magma was injected into the felsic granite magma and then spalled off into pillows and bulbous masses and froze to form the "enclaves". This is an example of magma "mingling" rather than "mixing". Back-veining of granite magma into the enclaves is present in places. Enclaves (xenoliths) of metamorphosed country rock are also present nearer the main road.

**Figure 7.1** The Byrock rock holes, developed in outcropping Byrock Granite, 0.8 km west of Byrock.

## Site 8: Byrock Leucitite Lava Mound

**Site 8a: Byrock aggregate quarry**
Ian Roach and Phil Blevin

The Byrock aggregate quarry, presently operated by Boral, provides a unique cross-section through the Byrock leucitite lava mound. Leucitite was first identified here in 1885 by the Rev. J.M. Curran (Curran 1887) and the location, physical attributes, mineralogy and geochemical features have been described by Anderson (1888), David and Anderson (1889-1890), Adamson (1963), Brunker (1968) and Cundari (1973, 1989). Glanville conducted 1:25,000 regolith-landform mapping around the Byrock leucitite in 2003 as part of an honours project. Some results of this work, including morphology, a landscape evolution model and a volcanological interpretation have been published (Glanville *et al.*, 2003, 2004). The Byrock leucitite is believed to have erupted at ca. 16.8 ± 0.2 Ma (Sutherland 1983, based on a "biotite" crystal and using the revised decay constants of Harland *et al.*, 1982) into a landscape more-or-less similar to that which we see today.

The Byrock leucitite forms an erosional rise, ca. 35 m high on its western side. Lavas were erupted onto an undulating surface of weathered Palaeozoic basement rocks including granite and Girilambone group metasediments and alluvial sediments of the Mulga Creek. The form is of a NE-SW-elongated mound of ca. 5 $km^2$ with two lower satellite mounds on the western side. The total extent and volume of the lava mound are difficult to estimate because on-lapping sediments from the Mulga Creek alluvial system appear to cover a large proportion. The leucitite is believed to subcrop extensively beneath this blanket to the west and north. A 15 m thickness is known under alluvium on the western side of the quarry from drilling in that area (Boral Quarry Master *pers. comm.* 2003) and additional leucitite float occurs to the north of the main outcrop. The leucitite is pervasively weathered; the upper surface consists of a thin stony lithosol, 1-2 m thick in the quarry faces, grading into more coherent columnar leucitite with depth. Weathering has penetrated joint faces in the rock mass, coating the edges with carbonate/zeolite, and altering some primary minerals, particularly olivine, into secondary products. Vegetation on and around the lava pile is noticeably different from the surrounding area and consists largely of grasses and forbs with scattered Bimble Box (*E. Populnea*), Beefwood (*Grevillea striata*), Kurrajong (*Brachychiton populneus*) and Wilga (*Geijera parviflora*).

The lavas are fine- to medium-grained, holocrystalline, columnar olivine leucitite, which is a mafic, silica-undersaturated basalt typically rich in Ti, K, Mg, P, Ni, Cr and Zr. Leucitites represent high-pressure mantle liquids that were probably formed from mantle (>100 km depth) sources metasomatised by subduction-derived fluids prior to fusion. The Byrock occurrence is the northern-most of a belt of flows and necks extending through El Capitan (NE of Cobar), Lake Cargelligo, Bygalorie and Griffith to Cosgrove in northern Victoria. Mineralogy consists of abundant euhedral to subhedral leucite, clinopyroxene, olivine, euhedral and skeletal spinels (magnetite-ulvöspinel-ilmenite) and poikilitic phlogopite, which gives the rocks a spotted appearance on weathered surfaces and causes the fresh surfaces to "wink" in sunlight. The leucitite also contains rare micropegmatoid veinlets, normally < 5 cm width. These are filled with abundant coarse leucite, phlogopite, acicular amphibole, spinel and clinopyroxene, and are interpreted to be crystallised late-stage "filter-pressed" fluids derived from the flow cores. Xenoliths and phlogopite megacrysts are found scattered throughout the fresh rocks in the quarry floor and faces, but xenoliths are entirely absent on weathered surfaces. Xenoliths consist primarily of upper crustal rocks including granite, mudstone (now contact metamorphosed and partially recrystallised containing acicular amphiboles) and some quartzite. Lower crustal and upper mantle xenoliths occur infrequently, consisting primarily of pyroxenite and peridotite. The area has previously been explored for diamonds based on the indicator xenolith types present (Weber, 1984). Rare pink/white-coloured inclusions occur low in the quarry face, consisting of baked clay-rich alluvial sediments. These have irregular contacts with the enclosing leucitite and are interpreted to be porcelainite, contact-metamorphosed moist clay-rich lacustrine sediment which has been incorporated into the lava during eruption.

**Site 8b: Byrock Hill dust trap**
Susan Tate

Byrock Hill stands approximately 20 m above the relatively flat Girilambone landscape and represents one of three Natural Dust Traps (NDT) used to identify aeolian materials in the region. These Tertiary leucitite outcrops were formed by lava flow inflation and mounding and have been positive landscape features since the Miocene. (McQueen pers. com., 2003). The NDT now exist as detached hills in a generally flat landscape and provide potential traps for wind blown material. They are lithologically distinct from the surrounding bedrock and wind blown material. These leucitite lavas are rich in K and Ti, and the main mineral constituents include leucite, pyroxene, amphibole, phlogopite, perovskite, apatite, and opaque oxides and minor accessory zircon (Gonzalez, 2001). They do not contain crystalline quartz.

Soils on the leucitites are skeletal with a maximum depth of approximately 0.1m. Sampling sites were chosen towards the top of these topographic highs to avoid any possibility of alluvial or colluvial contamination, thus ensuring that leucitite or aeolian additions could be the possible sources for the soils. Bulk soil samples were analysed by particle size analysis (laser detection, Malvern Mastersizer 2000), major mineralogical analysis (X-ray diffractometry), geochemical analysis (X-ray fluorescence) and micromorphological analysis (scanning electron microscopy and thin section micromopholoy).

The soil veneer over Byrock Hill is composed of fine materials, has a silty clay texture, and a rough faced ped fabric. The solum is whole coloured, has a value/chroma rating of 5, a red hue, a pH of 6.5, and is relatively stable as indicated by the Emerson test. Particle size analysis revealed a tri-modal, well-sorted pattern with a dominant size fraction peak at 70 µm (Fig. The distribution curve also shows smaller, less defined peaks at the 600µm and 4µm particle size fractions, similar to the other NDTs. Determination of major mineral composition and investigations of micromorphological characteristics using SEM and thin section microscopy reveal the Byrock Hill soil contained both aeolian quartz and *in situ* mafic-derived clays, some of which evenly coated the quartz. These techniques confirm that the dominant 70 µm particle size fraction is represented by well-abraded quartz particles, consistent with aeolian transport. Selected geochemistry confirms this and highlights the *in situ* contamination by the leucitite, for example elevated Cr, Nb and Ti/Zr.

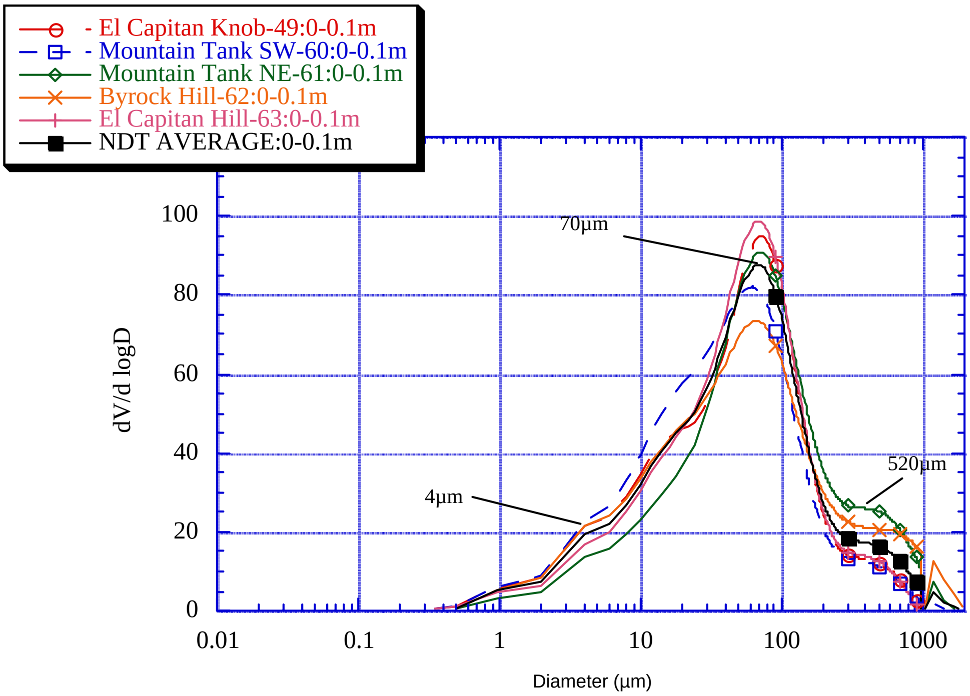
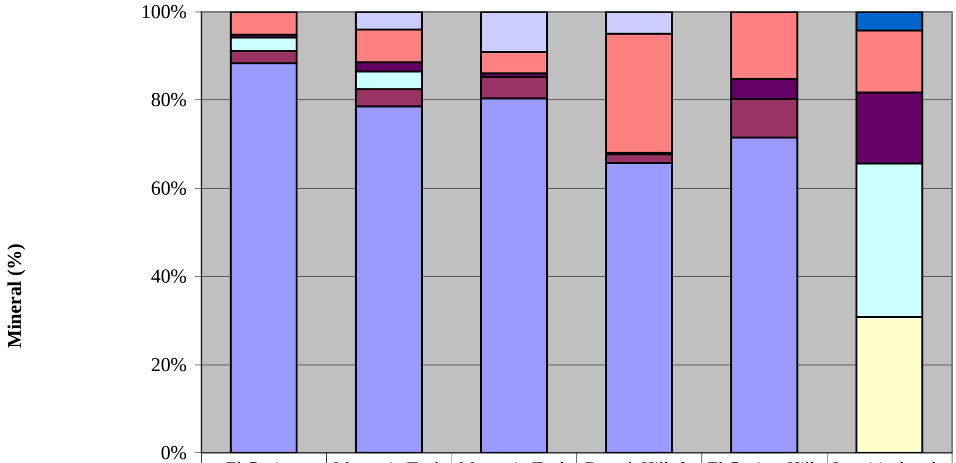



**Figure 8.1**. The particle size distribution of all NDT 0-0.1 m bulk soil samples, plus their calculated average.




| | El Capitan Knob: 0-0.1m | Mountain Tank SW: 0-0.1m | Mountain Tank NE: 0-0.1m | Byrock Hill: 0-0.1m | El Capitan Hill: 0-0.1m | Leucitite basalt: El Capitan Hill |
|---|---|---|---|---|---|---|
| Other Minor Phases (Wt%) | 0 | 4 | 9 | 5 | 0 | 0 |
| Amphibole | 0 | 0 | 0 | 0 | 0 | 4 |
| Mica + (including muscovite, biotite) | 5 | 7 | 5 | 27 | 15 | 14 |
| Fe, Ti Oxides (including hematite, rutile) | 1 | 2 | 1 | 0 | 5 | 16 |
| Pyroxene | 3 | 4 | 0 | 0 | 0 | 35 |
| Leucite | 0 | 0 | 0 | 0 | 0 | 31 |
| Kaolin | 3 | 4 | 5 | 2 | 9 | 0 |
| Quartz | 88 | 79 | 80 | 66 | 71 | 0 |

**Figure 8.2**. Major mineralogical analysis (wt%) on all NDT soil bulk samples, as determined by quantitative XRD (SIROQUANT).

**Table 8.1**. Selected geochemical analyses for the soils overlying NDTs at Mountain Tank, Byrock Hill and El Capitan for 0-0.1 m: bulk sample, and also *selected geochemistry for three leucitite samples (Gonzalez 2001).

| **Sample** | **$SiO_2$ (%)** | **$Al_2O_3$ (%)** | **Cr ppm** | **Nb ppm** | **Ti (%)** | **Zr ppm** | **Ti/Zr** |
|---|---|---|---|---|---|---|---|
| Mountain Tank bulk sample | 58.6 | 10.6 | 263 | 126 | 2.57 | 777 | 33 |
| ***Byrock Hill bulk sample*** | ***58.7*** | ***9.8*** | ***204*** | ***130*** | ***2.79*** | ***735*** | ***38*** |
| El Capitan bulk sample | 66.0 | 9.7 | 228 | 120 | 2.19 | 770 | 28 |
| Leucitite sample: WT6* | **42.1** | **7.8** | **348** | **179** | **3.24** | **883** | **37** |
| Leucitite sample: WT7/8* | **41.6** | **7.7** | **360** | **184** | **3.34** | **862** | **39** |
| Leucitite sample: MT28* | 42.8 | 7.8 | 438 | 174 | 3.08 | 762 | 40 |

# Site 9: Geochemical Variations in the Regolith

**Site 9: Drill hole and quarry at Pine Tree Tank (GR 0416088 6589563)**
Ken McQueen

The regional aircore drilling program has provided a large data base of background geochemical compositions. It has also provided an opportunity to assess the level of background variation and establish element associations related to normal regolith-forming processes and different regolith host minerals.

An aircore hole (CBAC215) drilled at this site illustrates a number of background-related geochemical features. Multi-element analyses of bulk aircore samples for a range of elements (ICP AES following multi acid digest) are presented in Table 9.1.

Features of note include an association of elevated As with Fe in several intervals, particularly in the upper 3 m, high Pb in a deeper Fe- and As-enriched zone, and an association of Co, Ni, Cu and Mn at around 60 m depth. Chromium and V are also enriched in the high-Fe zones, particularly in the upper 3 m. Calcium and Mg are enriched at around 3-4 m depth.

The adjacent quarry exposes the upper part of the profile *in situ*. The top 2-3 m consists of palaeochannel sediments. These contain clasts of ferruginous pisoids and well-rounded quartz in a clay-rich matrix (Fig. 9.1). They also show post-depositional ferruginous mottling and development of flakey, laminated calcrete in their upper part. Regionally these palaeochannel sediments now form a slightly inverted bench on the northern margin of a low bedrock rise. The surface here is covered in well-rounded pisoidal lag, largely reworked from the underlying palaeochannel. The aircore hole was collared in the palaeochannel sediments. An analysis of the bulk lag is shown in Table 9.2.

**Table 9.2** Analysis of bulk lag sample collected at the collar position of CBAC215 near Pine Tank quarry (multi acid digest ICP OES/MS & aqua regia digest solvent extraction GF AAS for Au, ALS Chemex).

| Sample No. | Al % | K % | Ca % | Mg % | Fe % | Au ppm | As ppm | Ba ppm | Cu ppm | Mn ppm | Ni ppm | Pb ppm | Sb ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BY-9 | 4.26 | 0.85 | 0.07 | 0.15 | 28.7 | 0.018 | 41 | 430 | 14 | 103 | 12 | 49 | 13 | 9 |

The paleochannel sediments overlie deeply weathered bedrock, originally of steeply dipping, interbedded siltstones and fine-grained sandstones. This is now saprolite/saprock with ferruginous mottling and coatings of calcrete at the unconformity with the overlying palaeochannel sediments. The elevated Ca and Mg contents at around 3-4 m in the drill hole correspond to this zone of calcrete development at the unconformity. In the drill hole the interval from 4-13 m appears to be a very bleached clay-rich zone, possibly an older lacustrine clay or highly leached and collapsed saprolite. It is distinguished geochemically by higher Ca, Mg and S and lower K, Cu and Zn than the underlying saprolite.

Separate samples were collected of the bleached saprolite and the ferruginous mottles exposed in the southwestern part of the quarry. These reveal different geochemical features, mainly related to the concentration of particular elements with hematite and possibly some goethite in the mottles (Table 9.3).

**Table 9.3.** Analyses of ferruginous mottled and non-mottled saprolite/saprock from the Pine Tree Tank quarry. (multi acid digest ICP OES/MS & aqua regia digest solvent extraction GF AAS for Au, ALS Chemex).

| Sample | Al % | K % | Ca % | Mg % | Fe % | Au ppm | As ppm | Ba ppm | Cu ppm | Mn ppm | Ni ppm | P ppm | Pb ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mottled | 9.15 | 2.60 | 0.06 | 0.42 | 24.2 | 0.011 | 33 | 750 | 120 | 744 | 24 | 560 | 92 | 101 |
| Non - mottled | 6.65 | 2.08 | 2.32 | 1.39 | 1.72 | 0.024 | <5 | 490 | 116 | 137 | 14 | 50 | 68 | 61 |

Two samples of calcrete were collected at this site. One sample from on the bedrock and another from within the upper part of the palaeochannel sediments. The palaeochannel calcrete has elevated Au and Ag, whereas in the bedrock calcrete these elements are at or below detection (Table 9.4). The palaeochannel sediments appear to have been sourced from the southwest.

**Table 9.4**. Analyses of calcrete samples from Pine Tree Tank quarry (multi acid digest ICP OES/MS and aqua regia digest solvent extraction GF AAS for Au, Amdel)

| Sample No. | Ca % | Mg % | Al % | Fe % | S % | Au ppb | Ag ppm | As ppm | Ba ppm | Cu ppm | Pb ppm | Sr ppm | V ppm | Zn ppm |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CC167 | 19.8 | 9.25 | 1.12 | 0.28 | 0.16 | <1 | 1.1 | <0.5 | 1150 | 23 | <5 | 650 | 7 | <2 |
| CC168 | 12.7 | 1.33 | 6.01 | 2.66 | 0.12 | 5 | 6 | 5.5 | 320 | 33 | 18 | 650 | 54 | 23 |

Sample CC167 is nodular calcrete above bedrock.
Sample CC168 is flakey calcrete from upper part of palaeochannel sediments.

**Discussion**

The association of Fe and As in the upper part of the drill hole is related to concentration in hematite in pisoidal lag in the palaeochannel sediments. Chromium and V, other elements hosted in hematite, are also relatively enriched in this material. An evaporitic association of Ca-Mg-Sr in some cases with Ba and Au, related to calcrete development is a common regolith controlled association throughout the region. Deeper in the profile Pb and As are enriched in association with hematite-rich ferruginous mottles. The association of Co and to a lesser extent Ni, Cu and Zn with Mn at depth in the drill hole appears to relate to a zone of concentration of Mn, probably as Mn oxides (commonly lithiophorite) developed at a redox boundary. At this position it probably correlates with the present or a fossil water table level. This association of Co-Ni-Zn and in some cases Cu and Au, with zones of Mn enrichment at about 30-60 m is a common feature of the regolith of the region.

The importance of a multi-element approach and good logging of aircore and drill cuttings is clear from the example of this site.

This site further demonstrates the potential complexities of carrying out geochemical sampling in areas of transported regolith, particularly related to palaeochannels. The profile through drill hole CBAC215 also demonstrated the difficulty of knowing how deep to drill and where to sample in an aircore drilling program. Put yourself to the test – where would **you** sample in this particular hole ?

**Figure 9.1**. Mottled palaeochannel sediments with ferruginous pisoidal and quartz clasts at Pine Tree Tank quarry.

**Table 9.1 Geochemical analyses of bulk aircore samples from CBAC215. Multi acid digest and ICP OES/MS (ALS-Chemex).**

| Depth | m | Al | K | Ca | Mg | Fe | Au | As | Ba | Co | Cr | Cu | Mn | Ni | P | Pb | S | Sr | Ti | V | Zn | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **from** | **to** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **wt %** | **ppm** | **wt%** | **ppm** | **ppm** | |
| 0 | 1 | 4.97 | 0.67 | 0.09 | 0.32 | 14.26 | 0.002 | 21 | 1600 | 5 | 217 | 12 | 172 | 37 | 230 | 34 | 0.05 | 80 | 0.24 | 262 | 21 | |
| 1 | 2 | 6.09 | 0.85 | 0.48 | 0.66 | 16.8 | 0.002 | 31 | 697 | -1 | 234 | 10 | 161 | 19 | 138 | 41 | 0.03 | 95 | 0.2 | 294 | 19 | **Apc** |
| 2 | 3 | 5.39 | 0.73 | 0.94 | 0.84 | 14.01 | 0.002 | 27 | 890 | -1 | 189 | 7 | 185 | 19 | 121 | 37 | 0.03 | 91 | 0.28 | 228 | 16 | |
| 3 | 4 | 6.6 | 0.78 | 4.45 | 2.98 | 6.63 | 0.001 | 14 | 318 | 4 | 109 | 7 | 488 | 18 | 57 | 22 | 0.02 | 186 | 0.25 | 122 | 14 | |
| 4 | 5 | 5.12 | 0.68 | 0.05 | 0.35 | 5.83 | 0.001 | 12 | 314 | 3 | 93 | 13 | 404 | 13 | 45 | 28 | 0.02 | 30 | 0.16 | 103 | 14 | |
| 5 | 6 | 5.79 | 0.56 | 0.83 | 0.78 | 8.1 | -0.001 | 13 | 224 | 1 | 146 | 10 | 395 | 26 | 54 | 44 | 0.02 | 59 | 0.17 | 162 | 14 | |
| 6 | 7 | 5.53 | 0.46 | 0.09 | 0.29 | **13.37** | 0.002 | **33** | 716 | 1 | 167 | 9 | 355 | 14 | 66 | **131** | 0.04 | 37 | 0.19 | 291 | 14 | **SB/A** |
| 7 | 8 | 8.44 | 0.43 | 0.74 | 0.76 | 4.16 | -0.001 | 11 | 152 | 2 | 120 | 11 | 463 | 34 | 67 | 21 | 0.03 | 61 | 0.33 | 89 | 10 | |
| 8 | 9 | 7.93 | 0.43 | 0.96 | 0.84 | 3.74 | -0.001 | 15 | 191 | 1 | 101 | 13 | 316 | 15 | 82 | 33 | 0.02 | 71 | 0.37 | 91 | 8 | |
| 9 | 10 | 11.1 | 0.7 | 0.17 | 0.44 | 4.12 | -0.001 | 6 | 400 | -1 | 126 | 13 | 191 | 36 | 124 | 52 | 0.03 | 46 | 0.53 | 93 | 19 | |
| 12 | 13 | 7.62 | 1.37 | 2.58 | 1.7 | 2.19 | -0.001 | 8 | 446 | -1 | 115 | 8 | 48 | 22 | 78 | 21 | 0.03 | 188 | 0.32 | 93 | 13 | |
| 13 | 19 | 17.19 | 1.83 | 0.89 | 0.95 | 4.6 | -0.001 | 9 | 681 | -1 | 132 | 13 | 79 | 21 | 135 | 12 | 0.03 | 77 | 0.7 | 98 | 28 | |
| 19 | 25 | 9.22 | 1.3 | 0.11 | 0.43 | 4.8 | -0.001 | 13 | 523 | -1 | 90 | 23 | 51 | 17 | 181 | 6 | -0.01 | 19 | 0.22 | 97 | 42 | |
| 25 | 31 | 6.68 | 1.16 | -0.01 | 0.28 | 4.74 | -0.001 | 6 | 391 | -1 | 109 | 28 | 328 | 73 | 240 | 12 | 0.01 | 11 | 0.12 | 78 | 51 | **S** |
| 31 | 37 | 8.42 | 1.51 | -0.01 | 0.39 | 3.3 | -0.001 | 5 | 563 | 2 | 105 | 30 | 151 | 54 | 215 | 23 | -0.01 | 25 | 0.19 | 97 | 64 | |
| 37 | 43 | 8.58 | 1.65 | -0.01 | 0.41 | 4.32 | -0.001 | 10 | 591 | 2 | 107 | 27 | 203 | 32 | 411 | 24 | 0.01 | 23 | 0.16 | 101 | 60 | |
| 43 | 49 | 7.74 | 1.4 | -0.01 | 0.32 | 4.39 | -0.001 | 12 | 455 | 1 | 100 | 28 | 219 | 21 | 358 | 21 | 0.01 | 19 | 0.16 | 81 | 47 | |
| 49 | 55 | 7.11 | 1.74 | -0.01 | 0.31 | 3.82 | -0.001 | 12 | 480 | 2 | 94 | 22 | 401 | 36 | 414 | 36 | -0.01 | 27 | 0.12 | 79 | 63 | |
| 55 | 56 | 5.28 | 1.57 | 0.01 | 0.22 | 3.2 | 0.005 | -5 | 300 | -1 | 52 | 20 | 104 | 21 | 340 | 21 | 0.01 | 7 | 0.16 | 56 | 53 | |
| 56 | 57 | 4.93 | 1.71 | 0.01 | 0.23 | 2.93 | 0.003 | -5 | 310 | 1 | 49 | 16 | 101 | 18 | 330 | 14 | 0.01 | 3 | 0.18 | 58 | 47 | |
| 57 | 58 | 3.16 | 1.21 | 0.01 | 0.16 | 2.27 | 0.003 | -5 | 390 | **144** | 24 | **46** | **3080** | **63** | 280 | 60 | 0.01 | 10 | 0.11 | 41 | **75** | |
| 58 | 59 | 4.01 | 1.88 | 0.01 | 0.23 | 2.14 | -0.001 | -5 | 420 | **90** | 27 | **41** | **1600** | **43** | 260 | 40 | 0.01 | 11 | 0.09 | 54 | **52** | |
| 59 | 60 | 5.7 | 1.86 | 0.01 | 0.25 | 3.33 | 0.001 | -5 | 480 | **160** | 43 | **57** | **2960** | **81** | 390 | 43 | -0.01 | 15 | 0.16 | 70 | **94** | |

# Site 10: Mineralisation at Bald Hills – Mt Dijou

**Site 10: Drill hole CBAC201, South of Bald Hills (GR 0408366 6579436)**
Ken McQueen

This site is south of Bald Hills, an area of historic small-scale gold mining. Deposits in the Bald Hills – Mt Dijou area are associated with deformed mafic volcanic rocks (including pillow lavas) and associated metasediments. Mineralisation appears to be structurally controlled occurring in fault breccias and quartz veins and lodes with associated silicification and minor sulfides. Lodes are reported to be up to 300 m long and 5 m wide. Magnetite and sulfides (mainly pyrite) occur as disseminations, stringers and bands in the mafic volcanic rocks and interpillow material. Early descriptions of the deposits refer to mineralisation occurring in vughy horizons or jasper-ironstone lodes, probably reflecting near surface oxidised portions of the mineralisation.

Aircore holes CBAC198-204 intersected anomalous gold values, in some cases with associated copper. Some of these holes have intersected thin mafic units, possibly dykes. There is thin cover in this area, but the surface is littered with highly ferruginous quartz and "ironstone" float and lag. Some of the latter consists of specular hematite with magnetite, of interest given the description of magnetite-bearing jasper with some of the known Bald Hills - Mt Dijou mineralisation.

Geochemical analyses of bulk aircore samples from hole CBAC201 indicate significant features in the weathering profile (Table 10.1).

The upper 2 m of the profile consists of soil and shallow colluvium. From 2-8 m there is a zone enriched in Ca and Mg, probably in regolith carbonates, and depleted in K and Fe relative to the underlying saprolite.

At around 20-30 m there is a zone of Mn concentration (old redox boundary) with associated enrichment in Co and Ni and to a lesser extent Cu and possibly Au. Areas of higher Mg, Fe, Ti, V and P contents near the base of the hole reflect mafic units in the section (dykes or interbedded volcanics).

Low-level Au anomalies occur in a number of intervals, probably related to quartz veining, and Au appears to be weakly anomalous in the surface soil. This may be an example of a stripped *in situ* profile.

A bulk sample of specular ironstone lag from this site was found to contain 0.04 ppm Au, 145 ppm Cu, 15 ppm As, 61 ppm Pb and 95 ppm Zn. Analysed ferruginous quartz lag contained 0.04 ppm Au, 36 ppm Cu, 36 ppm As, 18 ppm Pb and 46 ppm Zn.

**Figure 10.1**. The Rocky Ned gold mine at Bald Hills, view southeast to Coronga Peak.

**Table 10.1 Geochemical analyses of bulk aircore samples from CBAC201. Mulit acid digest and ICP OES/MS (ALS-CHEMEX).**

| **Depth** | **m** | **Al** | **K** | **Ca** | **Mg** | **Fe** | **Au** | **As** | **Ba** | **Co** | **Cr** | **Cu** | **Mn** | **Mo** | **Ni** | **P** | **Pb** | **S** | **Sr** | **Ti** | **V** | **Zn** | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **from** | **to** | **wt%** | **wt%** | **wt%** | **wt%** | **wt%** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **ppm** | **wt%** | **ppm** | **%** | **ppm** | **ppm** | |
| 0 | 1 | 8.02 | 1.08 | 0.23 | 0.33 | 5.25 | **0.006** | 7 | 287 | 18 | 79 | 27 | 383 | 4 | 31 | 526 | 44 | 0.01 | 66 | 0.46 | 122 | 59 | |
| 1 | 2 | 8.69 | 1.18 | 0.18 | 0.43 | 4.8 | **0.006** | 8 | 423 | 14 | 78 | 25 | 301 | 4 | 29 | 363 | 27 | 0.01 | 73 | 0.44 | 117 | 53 | **CH** |
| 2 | 3 | 8.44 | 1.85 | 7.47 | 1.46 | 1.12 | 0.004 | -5 | 881 | 3 | 79 | 7 | 188 | 3 | 12 | 238 | 21 | 0.03 | 255 | 0.41 | 92 | 22 | |
| 3 | 4 | 6.34 | 1.54 | 10.22 | 6.05 | 0.61 | 0.002 | -5 | 703 | -1 | 64 | 6 | 154 | 2 | 9 | 125 | 16 | 0.03 | 621 | 0.28 | 63 | 14 | |
| 4 | 5 | 8.8 | 1.71 | 6.07 | 3.5 | 1.99 | 0.003 | 7 | 738 | -1 | 88 | 8 | 119 | 1 | 8 | 655 | 45 | 0.02 | 511 | 0.36 | 103 | 29 | **SL** |
| 5 | 6 | 5.95 | 0.9 | 8.52 | 5.15 | 0.75 | 0.005 | -5 | 480 | -1 | 56 | 8 | 93 | 2 | 9 | 129 | 13 | 0.02 | 649 | 0.22 | 56 | 13 | |
| 6 | 7 | 5.92 | 1.46 | 8.56 | 4.97 | 0.54 | 0.004 | -5 | 418 | -1 | 56 | 3 | 91 | 3 | 6 | 121 | 16 | 0.01 | 638 | 0.23 | 52 | 12 | |
| 7 | 8 | 6.46 | 1.63 | 6.75 | 3.84 | 6.45 | 0.005 | 25 | 360 | -1 | 66 | 29 | 131 | 3 | 17 | 851 | 22 | 0.02 | 452 | 0.28 | 93 | 89 | |
| 8 | 9 | 10.6 | 2.24 | 1.5 | 0.66 | 5.79 | 0.005 | 19 | 547 | -1 | 92 | 30 | 77 | 3 | 24 | 820 | 44 | 0.02 | 164 | 0.39 | 107 | 78 | |
| 9 | 15 | 8.01 | 2.1 | 0.37 | 0.36 | 4.02 | 0.004 | 12 | 471 | -1 | 75 | 30 | 49 | 2 | 15 | 650 | 29 | 0.01 | 75 | 0.33 | 89 | 60 | |
| 15 | 21 | 4.67 | 2.2 | 0.02 | 0.26 | 4.28 | **0.007** | 15 | 751 | **139** | 103 | 55 | **2810** | 6 | **70** | 681 | 28 | -0.01 | 40 | 0.32 | 103 | 109 | |
| 21 | 27 | 7.52 | 2.6 | 0.03 | 0.36 | 4.57 | 0.003 | 13 | 734 | **72** | 108 | 62 | **2210** | 4 | **69** | 758 | 37 | 0.01 | 47 | 0.23 | 114 | 123 | **S** |
| 27 | 33 | 7.53 | 2.21 | 0.05 | 0.32 | 4.44 | 0.002 | 11 | 689 | **57** | 108 | 64 | **3380** | 14 | **161** | 828 | 34 | -0.01 | 41 | 0.26 | 99 | 152 | |
| 33 | 39 | 8.34 | 2.05 | 0.02 | 0.33 | 4.15 | 0.002 | 14 | 474 | 11 | 69 | 38 | 579 | 3 | 47 | 666 | 29 | -0.01 | 43 | 0.26 | 83 | 110 | |
| 39 | 45 | 8.4 | 2.41 | 0.02 | 0.39 | 4.57 | **0.006** | 11 | 535 | 14 | 92 | 37 | 445 | 4 | 54 | 825 | 24 | -0.01 | 37 | 0.29 | 104 | 124 | |
| 45 | 46 | 6.93 | 2.44 | 0.03 | 0.3 | 3.99 | **0.009** | 8 | 420 | 11 | 63 | 25 | 501 | 1 | 47 | 670 | 16 | -0.01 | 22 | 0.16 | 75 | 104 | |
| 46 | 47 | 6.57 | 2.39 | 0.02 | 0.3 | 3.71 | 0.005 | 8 | 450 | 17 | 64 | 28 | 934 | 1 | 59 | 620 | 25 | -0.01 | 18 | 0.18 | 77 | 111 | |
| 47 | 48 | 7.51 | 2.9 | 0.02 | 0.36 | 4.15 | 0.004 | 10 | 550 | 13 | 84 | 31 | 476 | 1 | 49 | 690 | 32 | -0.01 | 23 | 0.16 | 101 | 129 | |
| 48 | 49 | 11.3 | 2.94 | 0.04 | 0.55 | 4.73 | **0.011** | 8 | 710 | 6 | 98 | 34 | 428 | -1 | 45 | 760 | 36 | -0.01 | 45 | 0.31 | 113 | 128 | |
| 49 | 50 | 7.93 | 3.07 | 0.02 | 0.38 | 4.36 | **0.007** | 10 | 570 | 14 | 88 | 34 | 388 | -1 | 36 | 690 | 30 | -0.01 | 21 | 0.21 | 108 | 125 | |
| 50 | 51 | 7.69 | 2.92 | 0.03 | 0.36 | 4.48 | **0.012** | 13 | 540 | 25 | 84 | 34 | 897 | -1 | 63 | 660 | 28 | -0.01 | 20 | 0.15 | 98 | 131 | |
| 51 | 57 | 8.48 | 1.52 | 0.74 | 0.56 | 7.85 | 0.003 | 7 | 592 | 23 | 35 | 20 | 1700 | 19 | 14 | 3740 | 32 | -0.01 | 62 | 1.29 | 92 | 175 | |
| 51 | 52 | 11.3 | 1.95 | 0.04 | 0.51 | 4.56 | 0.002 | 7 | 570 | 7 | 70 | 30 | 608 | 1 | 32 | 660 | 26 | -0.01 | 26 | 0.33 | 87 | 103 | |
| 57 | 63 | 9.45 | 2.1 | 1.07 | **0.89** | **9.9** | 0.002 | -5 | 801 | 37 | 9 | 18 | 1770 | 3 | 6 | **4980** | 26 | -0.01 | 83 | **1.76** | **144** | 210 | **Mafic** |
| 63 | 69 | 9.65 | 2.22 | 0.91 | **1.04** | **8.79** | -0.001 | -5 | 761 | 34 | 6 | 22 | 1040 | 2 | 10 | **3860** | 14 | -0.01 | 90 | **1.68** | **198** | 160 | **units** |
| 69 | 72 | 8.06 | 2.39 | 0.82 | **0.86** | **7.32** | -0.001 | 6 | 598 | 46 | 6 | 43 | 1670 | 3 | 14 | **4000** | 26 | -0.01 | 70 | **1.99** | **243** | 164 | |

## **Site 11**: **Girilambone Beds near Mount Merrere** (Optional Stop)

**Site 11: Road cuttings on Cobar-Bourke road west of Mt Merrere (GR 0394836 6573228)**
Ken McQueen

Several road cuttings at this site expose relatively fresh sericite-chlorite phyllites considered to be part of the Girilambone Group. These show a well-developed cleavage, trending 013º with near vertical dip. The prominent peak to the northeast is Mount Merrere, which consists of strongly deformed polymicitic conglomerate, similar to that at Drouin Peak in the Tooram Hills. This conglomerate shows stretched pebbles in a strong foliation with orientation 036º/85ºSE. It may well be equivalent to the conglomerates at Drouin Peak. Possible evidence for a Late Silurian or Devonian age should be investigated at this site.

A number of small gold workings occur at the southern end of the line of hills to the east. They are poorly recorded but were apparently developed in quartz veins unrelated to the conglomerate (Byrnes, 1993).

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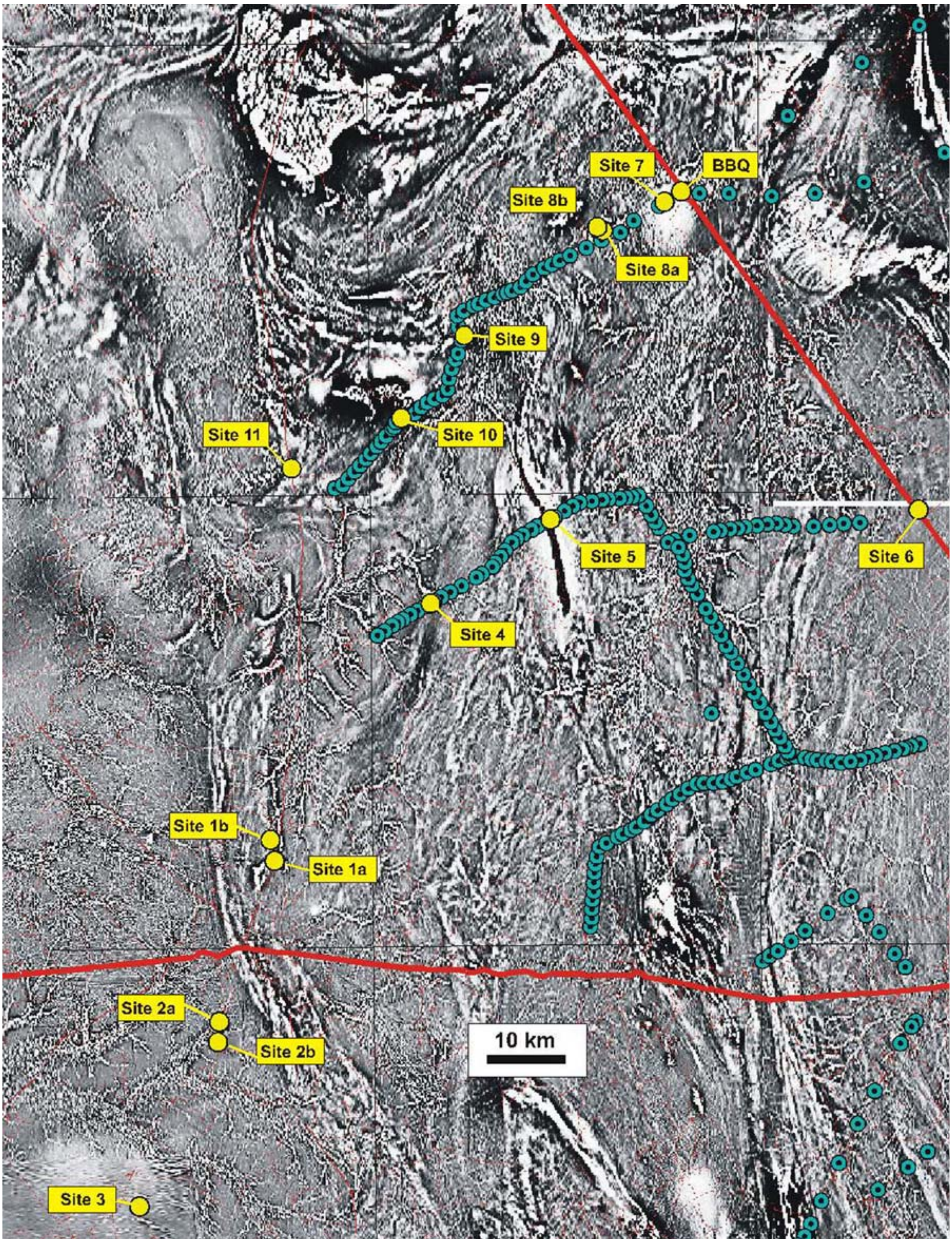
**NOTES**




**Field Trips 1 and 2 Site Locations.**
**Exploration Field Workshop Cobar Region 2004**