Southern Curnamona Province, regolith tour guide

Adrian J Fabris (compiler)

Report Book 2008/9

Government of South Australia
Primary Industries and Resources SA

080708

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Geological Survey

August 2008

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Preferred way to cite this publication
Fabris, A.J., 2008. Southern Curnamona Province, regolith tour guide. *South Australia. Department of Primary Industries and Resources. Report Book* 2008/9.

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Southern Curnamona Province, Regolith Tour Guide

Adrian J Fabris (compiler)

INTRODUCTION

This tour guide presents fourteen sites of interest within the southern Curnamona Province (Olary and Barrier Ranges) (Fig. 1). Sites demonstrate a variety of regolith materials, profiles and landforms. Together, these represent a useful educational aid to understanding the regolith and landscape evolution of the region and provide reference sites for comparisons elsewhere. Regolith materials representing potential sample media are visited and discussed.

Permission to visit these sites prior to entering them should be sought from the respective pastoral lease holders and/or their on-site managers.

LOCALITIES

BARRIER RANGES

Central western Barrier Ranges transect (after Hill and Roach, 2008)

This half day field excursion is a field transect through the Umberumberka Creek drainage basin from the central Barrier Ranges, across the Mundi Mundi range-front and onto the Mundi Mundi Plain (Fig. 2). Either refreshments at the Silverton Pub or a view of the sunset from the Mundi Mundi Lookout provide fitting finales to this trip.

LIMESTONE STATION

Introduction

A series of pits dug into the alluvium of the Umberumberka Creek system expose thick profiles of 'regolith carbonate accumulations' (RCA), containing a range of RCA morphologies and changes in major and trace element chemistry and mineralogy.

Location

West of Limestone Homestead, in between the Silverton Road and Umberumberka Creek. Approximate coordinates are 531715 mE, 6469753 mN (GDA94, MGA54).

Description

The carbonate profile is exposed within a pit originally excavated to obtain flux for smelting at Broken Hill and later to obtain road base aggregate. The pit is dug into alluvial depositional plain sediments associated with Umberumberka Creek, with some mixed aeolian and sheetflow sediments. These sediments consist of quartzose and lithic sands, silts and gravels. The lower parts of the pit intersect an irregular bedrock interface consisting of slightly to moderately weathered micaceous schist. Bedrock in the area is very poorly exposed but mostly consists of micaceous schists, K feldspar-rich pegmatite, amphibolite and minor quartz-gahnite rock.

The profile here is up to 3 m deep. The uppermost parts consist of a zone of nodular RCA's with nodules up to 20 mm in diameter. This overlies several discontinuous laminar hardpans and then an underlying nodular zone with a weakly indurated matrix. The lowermost parts of the profile consist of friable powdery RCA's with ‘pods’ of massive, tabular RCA's in many places resting upon

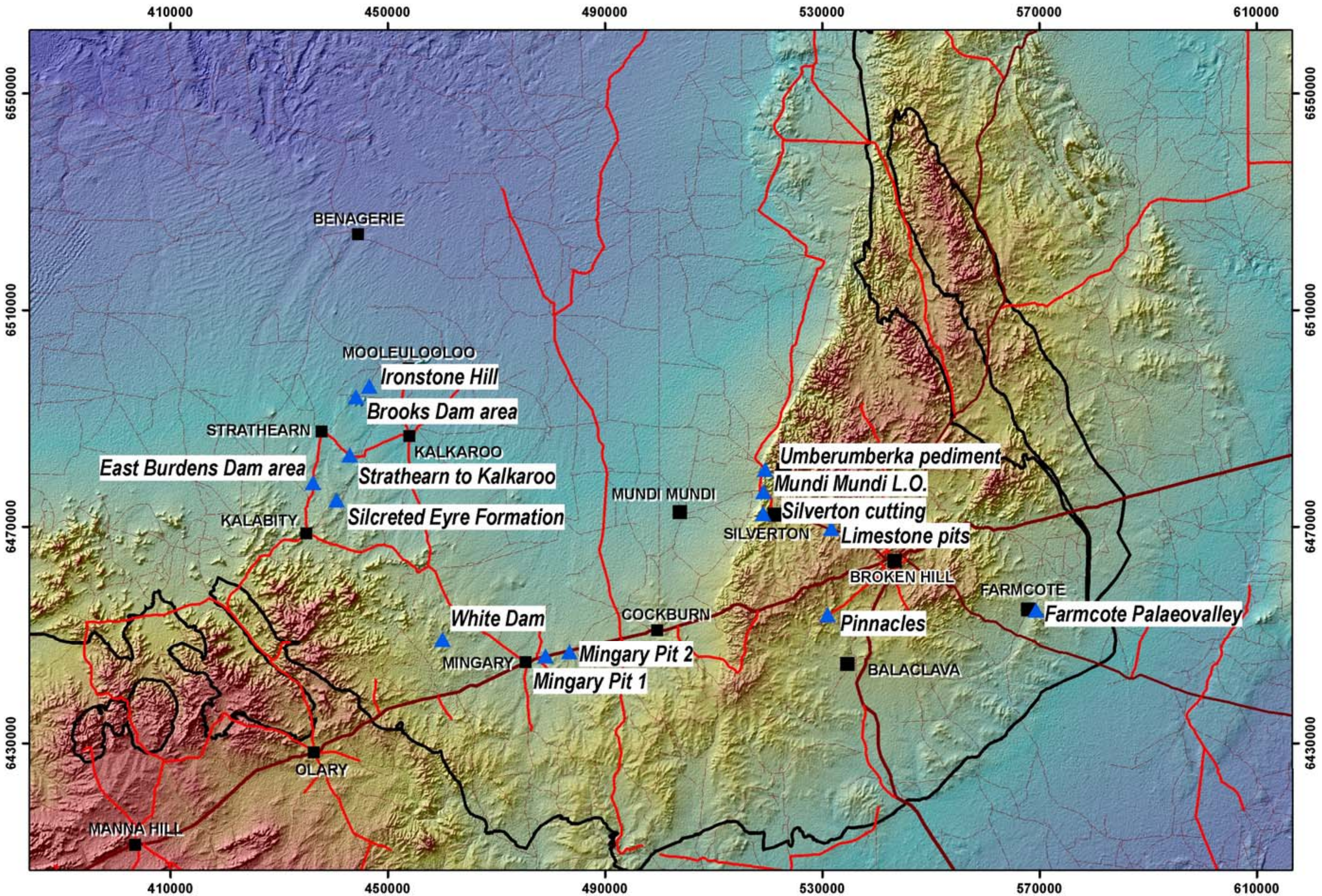


Figure 1. Regional location plan and field sites with an elevation model as a base

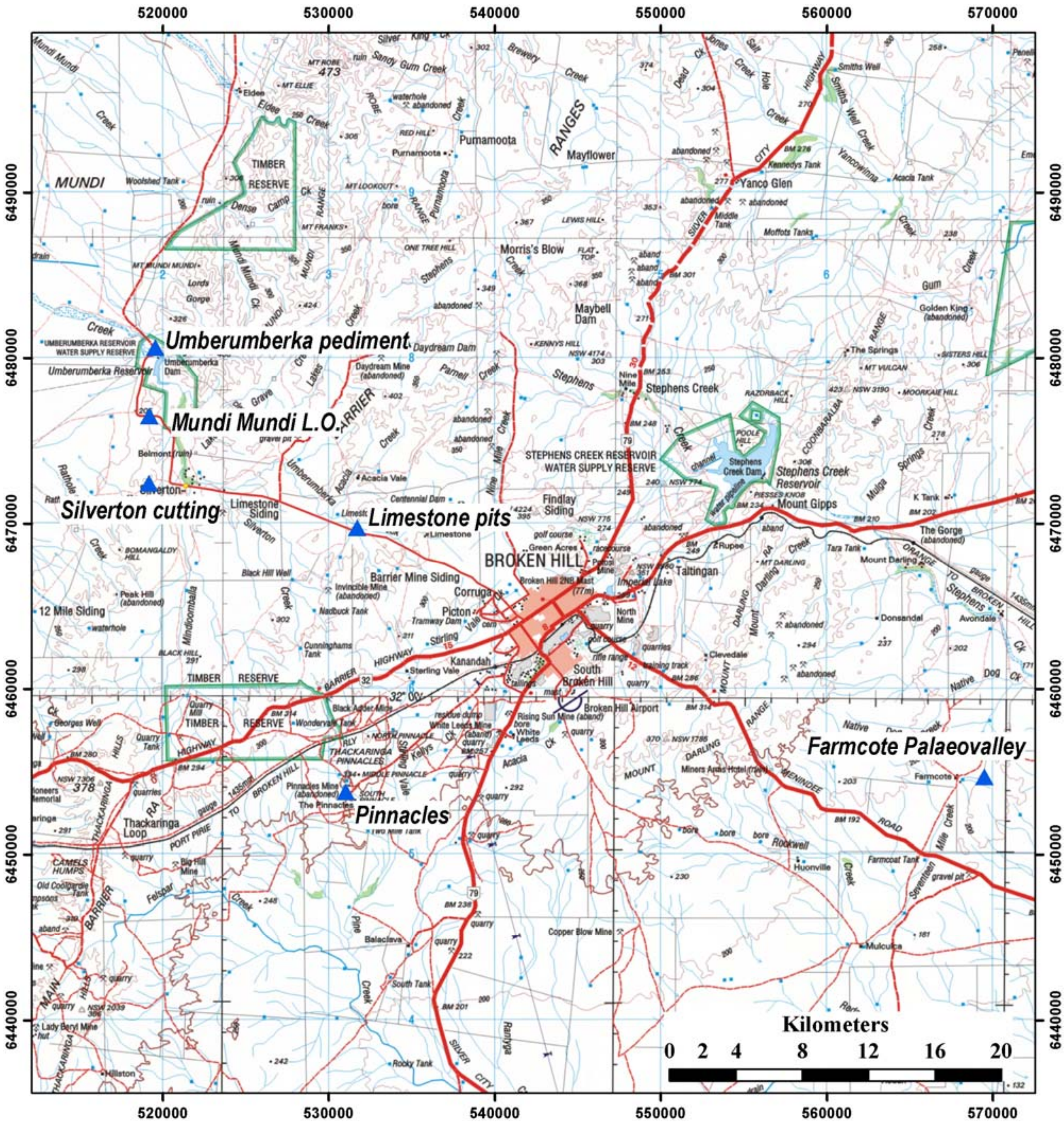


Figure 2. Location map of field sites within New South Wales

the bedrock interface and penetrating joints within the bedrock (these indurated forms are common at permeability barriers).

Carbonate mineralogy within the profile shows a systematic variation with depth from calcite-rich to dolomite-rich. This is also reflected by an increase in Mg content and a decrease in Ca:Mg with depth (Fig. 3). The Au content in the profile shows a close association with Ca and calcite and is greatest in the upper high Ca:Mg nodular zone. The differences in Au content within the carbonate profile is typical of many others having a decreasing Ca:Mg and increasing Mg content with depth.

There is considerable variation in Au content within this single vertical profile and although there are Au values typically worthy of greater examination, the profile also contains “background” result. The way that samples from this profile may be expressed in regional sampling programs depends upon which part of the profile is considered and then compared with other samples from different parts of similar profiles. It suggests that the chemical, mineralogical and morphological facies changes observed with changes in depth of this profile may also be important to consider when

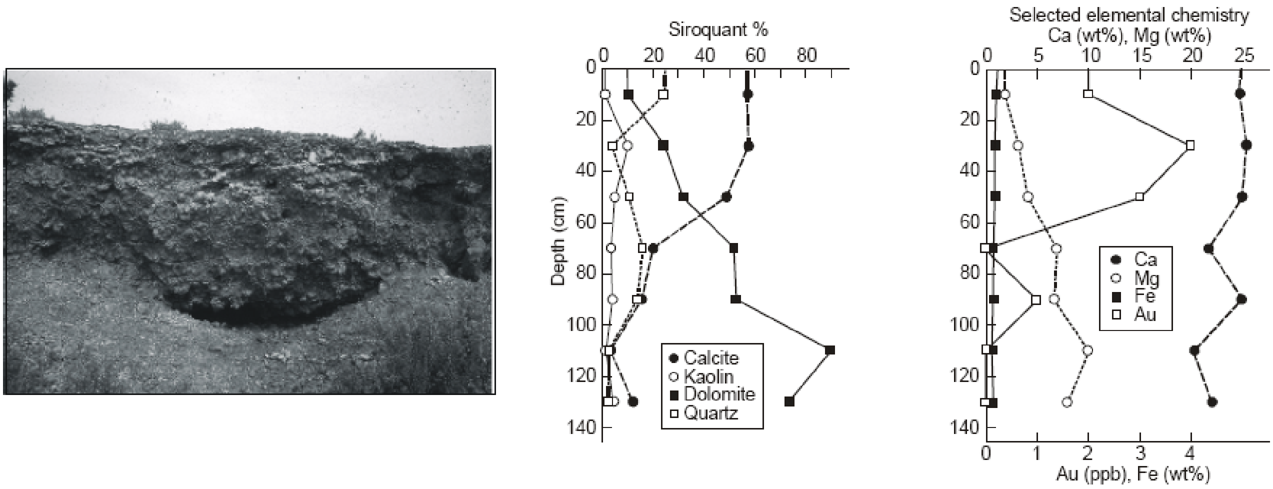


Figure 3. Limestone Station RCA profile, selected chemistry and mineralogy (Hill, 2000)

comparing Au contents in a variety of RCA samples across an area. These associations may or may not be significant in a regional sense, but should be considered during orientation sampling.

As well as showing systematic changes in Ca and Mg contents with depth, the RCA's here show systematic catenary change across the landscape. From the valley margins towards the valley axis there is a gradual change from calcite to dolomite to gypsum to halite induration. Some of this lateral transition is shown in Figure 4.

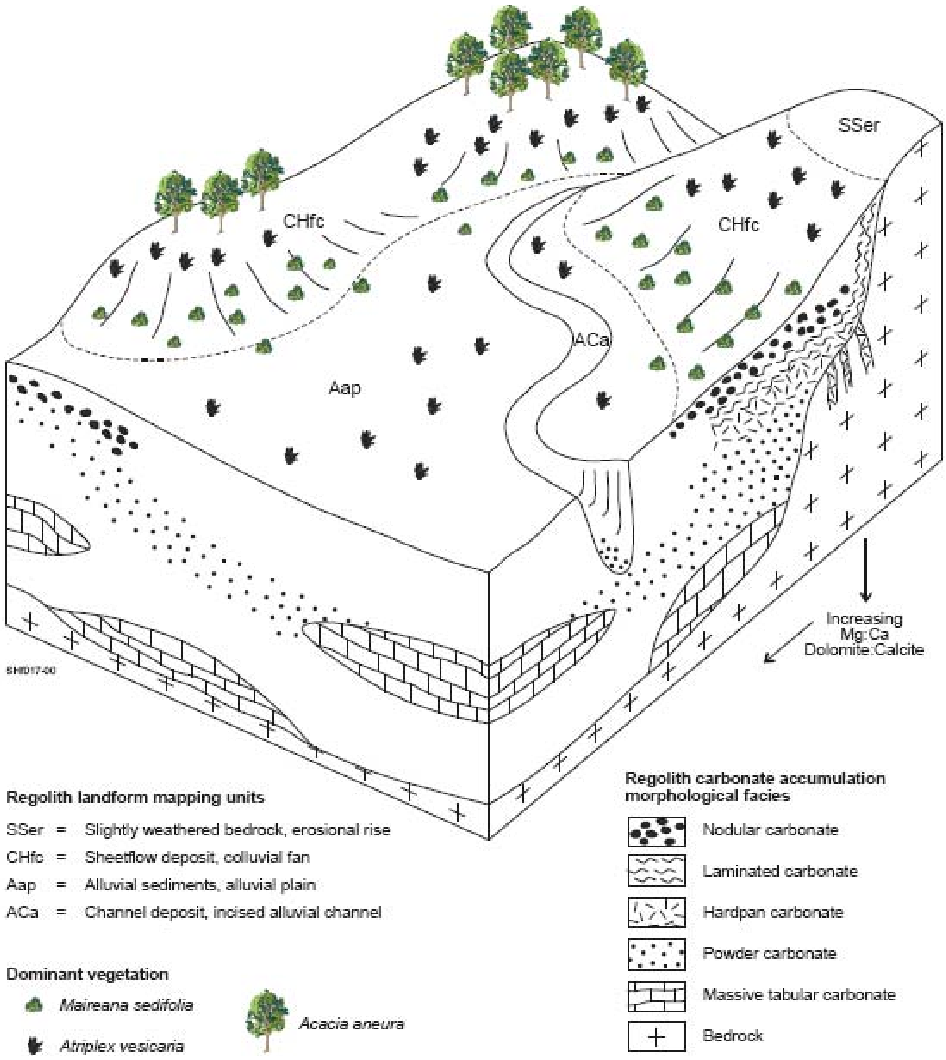


Figure 4. A 3D toposequence for RCAs in the Limestone Station area (Hill, 2000)

SILVERTON – UMBERUMBERKA MINE RAILWAY CUTTING

Introduction

At this site a section of the regolith is exposed in the railway cutting between Silverton and the Umberumberka Mine (Fig. 2). The cutting passes through moderately weathered, micaceous schists and granite of the Umberumberka Shear Zone.

Location

Railway cutting between Silverton and the Umberumberka Mine. Approximate coordinates are 519170 mE, 6472450 mN (GDA94, MGA54).

Description

Overlying the bedrock is a cover of sediment consisting of poorly-sorted and matrix supported sediment, with angular bedrock boulders (Fig. 5). This sediment is up to 10 m thick on the southern wall of the cutting, however it is less than 2 m thick on the north wall. This suggests that there were considerably greater slope gradients in this area at the time of sedimentation, compared with the contemporary landscape. These sediments have been interpreted as mostly of debris flow origins deposited within a palaeo-depression trending towards the southeast. The age of the sediments is not known with any certainty, however their poor surface landscape expression suggest some antiquity, although the slightly-moderately weathered nature of bedrock clasts and overall unconsolidated nature suggests that this unit is not exceedingly old.

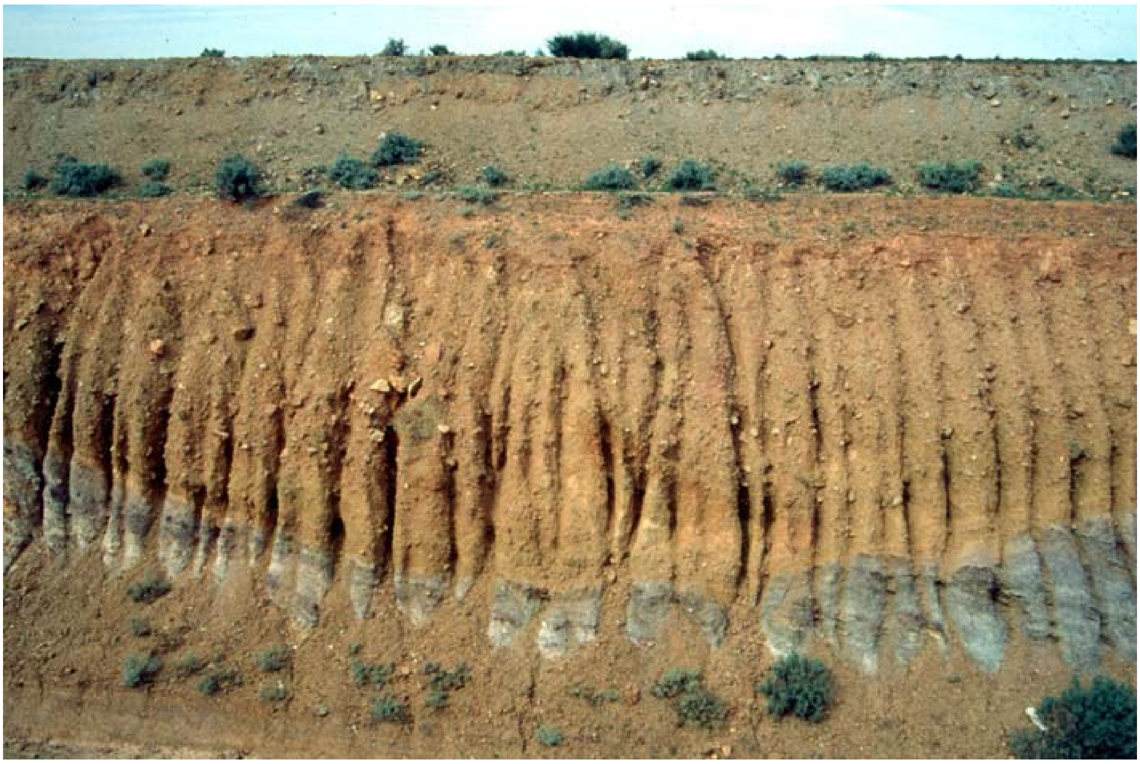


Figure 5. Southern face of the old railway cutting between Silverton and the Umberumberka Mine (Hill and Roach, 2008)

MUNDI MUNDI LOOKOUT

Introduction

From the hill crest there is an impressive view to the west across the Mundi Mundi Plain, while to the north and south there are views along the Mundi Mundi range-front.

Location

Just off the road between Silverton and Eldee Homestead. Approximate location is 519200 mE, 6476480 mN (GDA94, MGA54).

Description

In this area, the range-front is some 250 m east of the Mundi Mundi Fault. To the immediate west of the fault, the sedimentary cover is over 200 m thick (Figs 6, 7). The range-front is of particularly low sinuosity where the range-front trends northeast-southwest.

To the northwest of here a line of river red gums defines the channel of Umberumberka Creek as it incises its way through the large Umberumberka fan. The next stop is just on the other side of this channel.

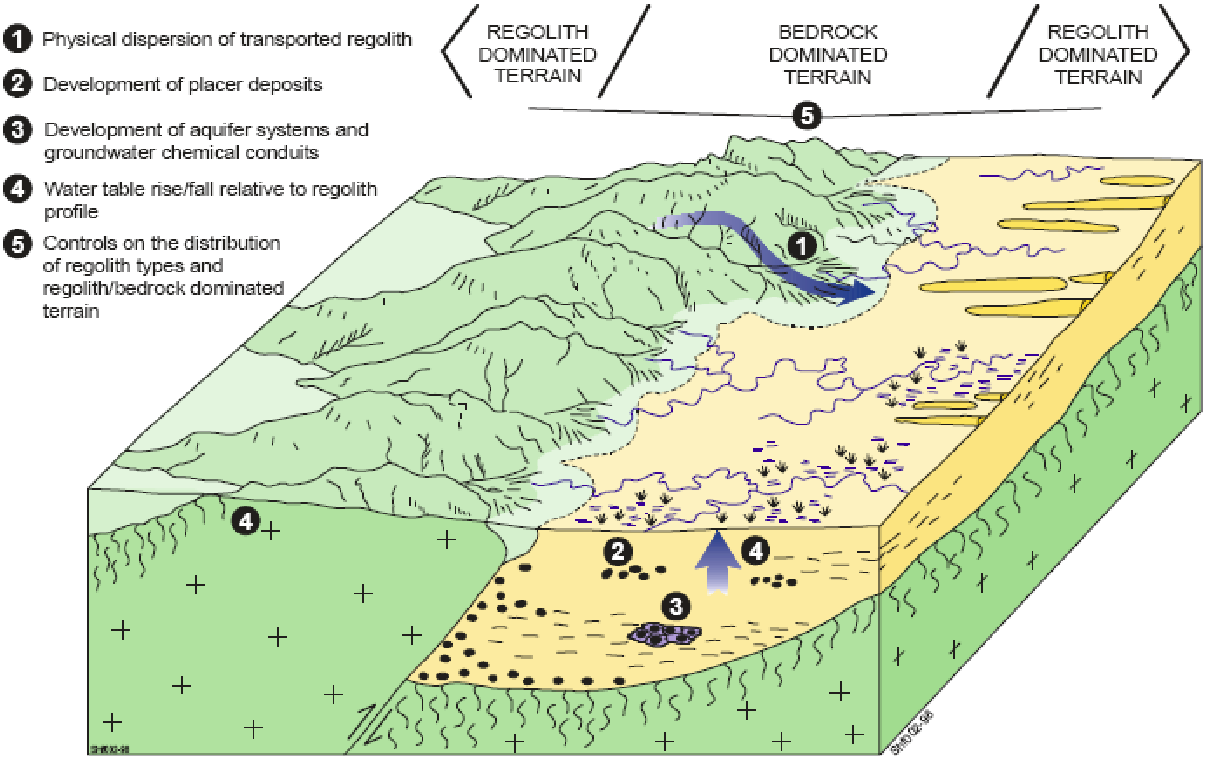


Figure 6. Some morphotectonic controls on regolith-landform processes associated with the Mundi Mundi range-front (Hill and Kohn, 1999)

UMBERUMBERKA FANS – MUNDI MUNDI RANGE-FRONT

Introduction

Alluvial fan sediment forms several flat-topped rises on the western side of the Mundi Mundi range-front (Fig. 8). These rises are perched at a higher level than the fan sediments further west that make up fans such as that associated with Umberumberka Creek. The western margins of these high-level fans typically terminate some 250 m west of the range-front and very closely correspond with the position of the Mundi Mundi Fault. Further north, similar fan sediments rest upon a pediment of slightly to moderately weathered bedrock.

Location

Just north of where the road crosses Umberumberka Creek. Approximate coordinates are 519550 mE, 6480650 mN (GDA94, MGA54).

Description

The Umberumberka fans are interpreted as having been uplifted by relatively young fault movement along the Mundi Mundi Fault. The upper surface of these high-level fans can be followed upstream in some of the smaller creeks where they coalesce with valley terraces. Approximately four alluvial fan surfaces can be seen in this area between these high-level fans and the Umberumberka Creek channel.

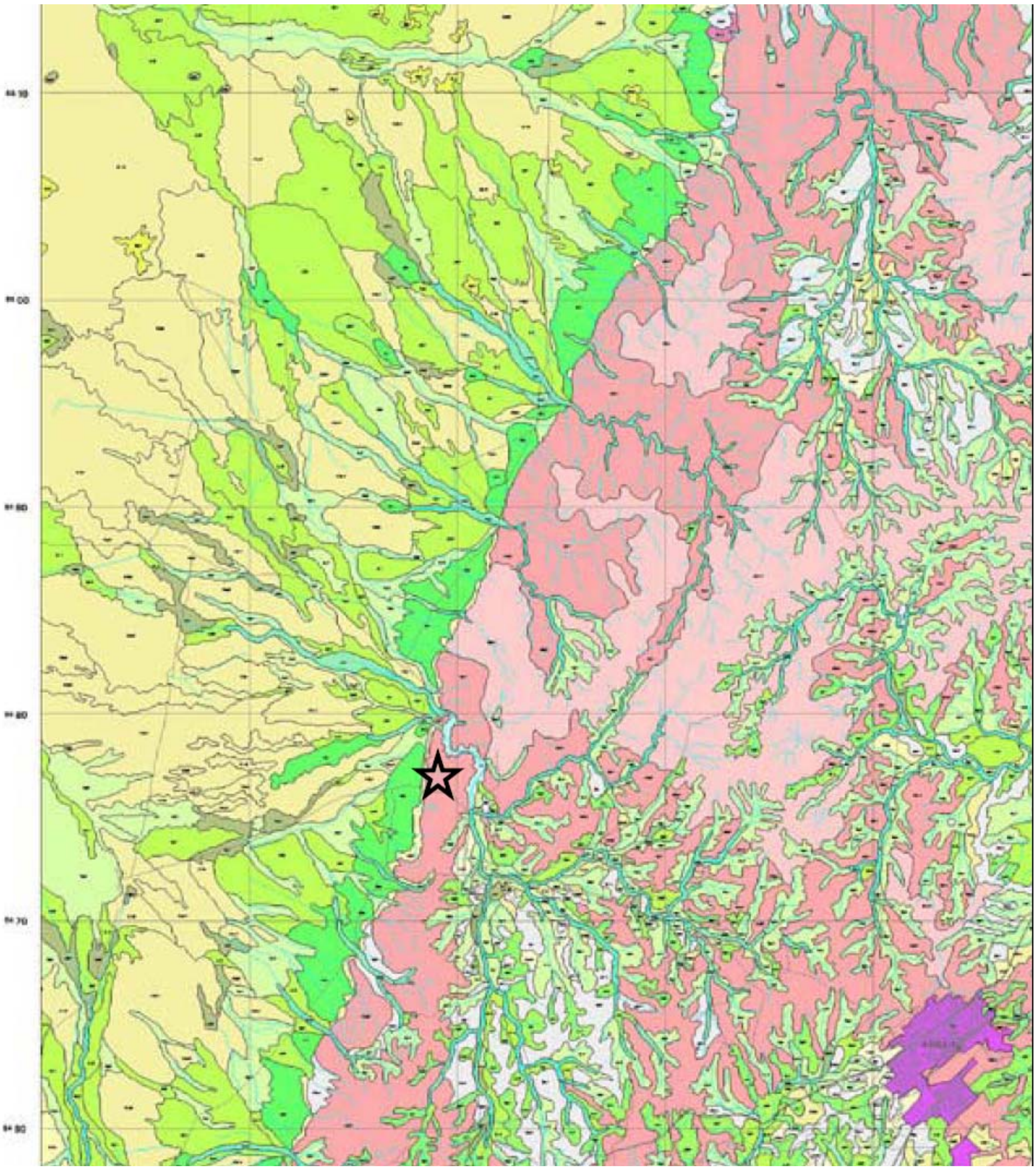


Figure 7. A portion of the Broken Hill Domain 1:100k regolith-landform map (Hill, 2000) showing the Umberumberka Creek catchment and large alluvial fan. The star indicates the approximate location of the Mundi Mundi Lookout. Sedimentary cover west of the Mundi Mundi Fault and approximately 250 m west of the range-front increases rapidly to more than 200 m. Grid square interval is 10 km (Hill and Roach, 2008).

Wasson (1979), developed a Quaternary stratigraphic framework for the fan sediments, which was largely motivated by episodic, climatically driven sedimentation, incision and pedogenesis (Table 1). A more recent study by Hill (2000) suggests that instead, fan evolution is related to the intrinsic fan processes that have approximated continual operation throughout their development (Fig. 9). This is supported by the irregular distribution of numerous palaeosols in the fan sequences, and the spatial mosaic of sedimentation, erosion and pedogenesis operating in the contemporary landscape.

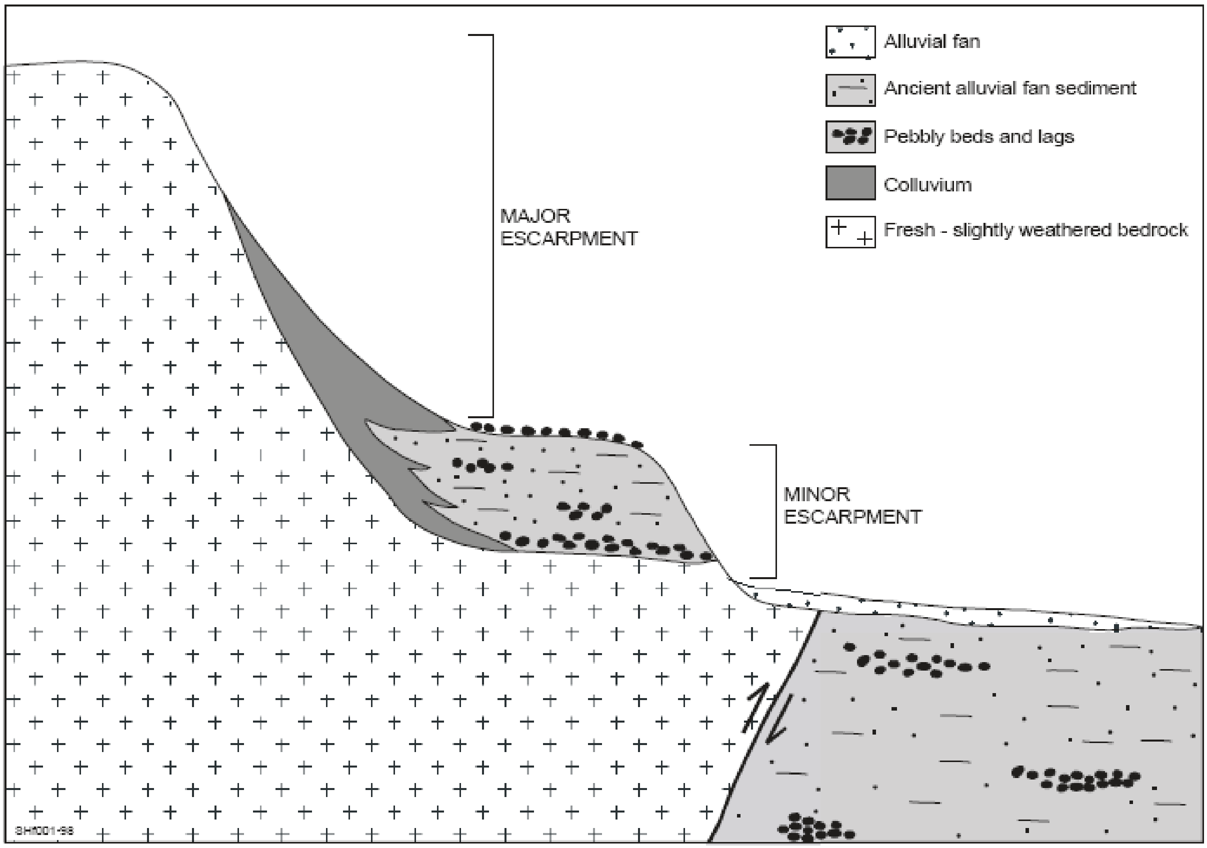


Figure 8. Generalised section across the Mundi Mundi range-front showing major and minor escarpments (Hill and Kohn, 1999)

Table 1. Late Quaternary stratigraphy of the Mundi Mundi Alluvial Fans (after Wasson, 1979; Wasson and Galloway, 1986)

Lithostratigraphic unit	Age	Characteristics	Depositional environment
Modern channel sediments	500 BP to modern	Bedload of sand and gravel, small suspension load in floodouts	Entrenched channel flow and dispersed flow on floodouts
Thackaringa Unit	1000 to 500 BP	Coarse sands and fine gravels in terraces	Entrenched channel flow and presumed floodout flow
Mundi Mundi Unit	6000 to 3000 BP	Bedload sands and gravels; unsorted sands in matrix of clay and silt (typically 143 cm thick)	Braided streams and slurry flows
Korkora Unit	c. 13 000 BP	Slightly gravely sandy loam with some sorted bedload sands and gravels (typically 50 cm thick)	Slurry flows and very shallow braided streams
Belmont Palaeosol	c.16 000 to 13 000 BP	Angular polyhedral peds with pedogenic carbonate, manganese and gypsum accumulations (typically 10 cm thick).	Pedogensis associated with a palaeosurface
Umberumberka Unit	15 000 BP	Gravelly loam, well sorted cosets of gravel and sand plus unsorted sands in matrix of clayed silt (>4 m thick)	Braided channels and slurry flows

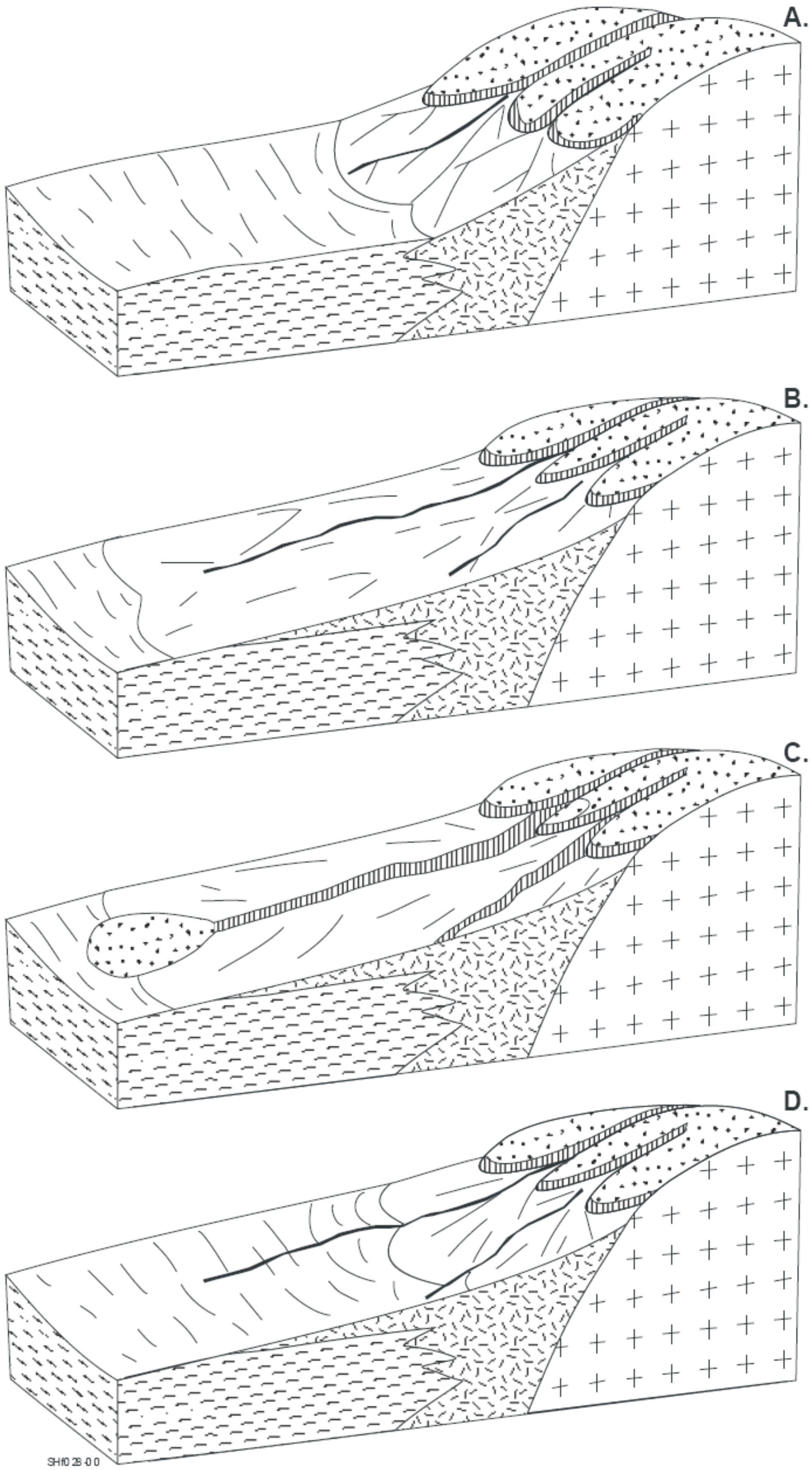


Figure 9. Evolution model for Mundi Mundi alluvial fans. A. Fan aggradation, B. Continued aggradation until a smooth concave profile develops, C. Reduced sediment flux and fanhead trenching with sediment bypassing upper fan and prograding lobes develop at lower fan, D. channel backfilling and reworking of fan surface (Hill, 2000).

PINNACLES (AFTER BARRATT AND HILL, 2003)

Introduction

The regolith-landforms of this area are covered on the Pinnacles 1:25k map sheet (Senior et al., 2002), and described within Senior and Hill (2002), with more specific accounts of the regolith carbonate accumulations (RCAs) in Hill et al. (1999), McQueen et al. (1999), Senior (2000).

This site displays a well-developed regolith carbonate profile and is used herein as a discussion point for regolith carbonate, soil and vegetation sampling in mineral exploration.

Location

The Pinnacles is located ~15 km south-west of Broken Hill (Fig. 2) at 531030 mE, 6453750 mN (GDA94, MGA54).

Description

The regolith-landforms here consist of prominent low hills with the upper slopes composed of slightly weathered quartz-magnetite rock, this is relatively resistant to erosion. These prominent bedrock exposures are immediately flanked by colluvial rock-fall talus deposits, consisting of large clasts of quartz-magnetite rock. The lower slopes and adjacent erosional rises consist of slightly to moderately weathered bedrock with flanking sheetflow sediments covering erosional rises and forming depositional plains. Low-lying parts of the landscape consist of alluvial sediments within alluvial plains (containing a mixture of alluvial landforms), depositional plains (dominated by depositional features), channels and smaller drainage depressions. Regolith carbonate is widely distributed within most of these regolith-landform units, with thin hardpan morphologies mostly on upper slopes at the transported regolith-saprock hydromorphic boundary; and well-developed carbonate profiles with nodular, powder and occasional hardpan morphologies on lower slopes. Regolith carbonates are less well developed or occur deeper in the regolith profile within many of the alluvial units, where greater volumes of water through-flow may account for greater leaching and mobilisation of carbonate components (Fig. 10). There also appears to be a very close association between weathered amphibolites and well-developed carbonate profiles in this area, as can be seen in the pits dug into regolith carbonates overlying amphibolites south-east of the Middle Pinnacle (note also the abundance of pearl bluebush [*Maireana sedifolia*] in this area). The vegetation at this site is mostly a chenopod shrubland, dominated by bladder saltbush (*Atriplex vesicaria*) and black bluebush (*Maireana pyramidata*), with an open river red gum (*Eucalyptus camaldulensis*) woodland along Pine Creek.

Marnpi RCA costean

At the base of the western slopes of Middle Pinnacle (531300 mE, 6453750 mN AGD66, Z54) an old E-W trending costean provides a section up to 1.5 m deep through the regolith units including a well-developed RCA profile. This profile is developed within sediments associated with an alluvial depositional plain related to Pine Creek in the west, and a sheetflow depositional plain and erosional rise to the east, with further contributions from aeolian sediments. The regolith host lithology mostly consists of red-brown, quartzose silty-sand, with some lithic and quartzose, coarse sand and pebbles. The upper 200 mm of this profile consists of a light brown-red, fine sand with occasional lithic pebbles, and is interpreted as a post-settlement sediment (post 1880's). Disseminated gypsum occurs in the lower parts of the profile.

The main RCA morphological facies represented in the profile is nodular RCAs. It is best developed between about 200–800 mm depth, where below this, nodules are mostly restricted to scattered occurrences within a powder RCA. In the main nodular zone, individual nodules are between 5–30 mm diameter, and show a weak trend of increasing nodule diameter upwards in the profile. Some of the nodules have coalesced to form laterally discontinuous hardpan pods. The micro-morphological internal structures of nodules include coated lithic or quartzose clasts, or coatings on an older RCA fragment, or else a series of concentric coatings around a central irregular void (resembling a desiccation crack). There is a grey outer coating on many nodules, particularly within a zone at about 200–400 mm depth. This has been interpreted as a biological (algal/cryptogam) overprint within the profile (Hill et al., 1999; Hill, 2000).

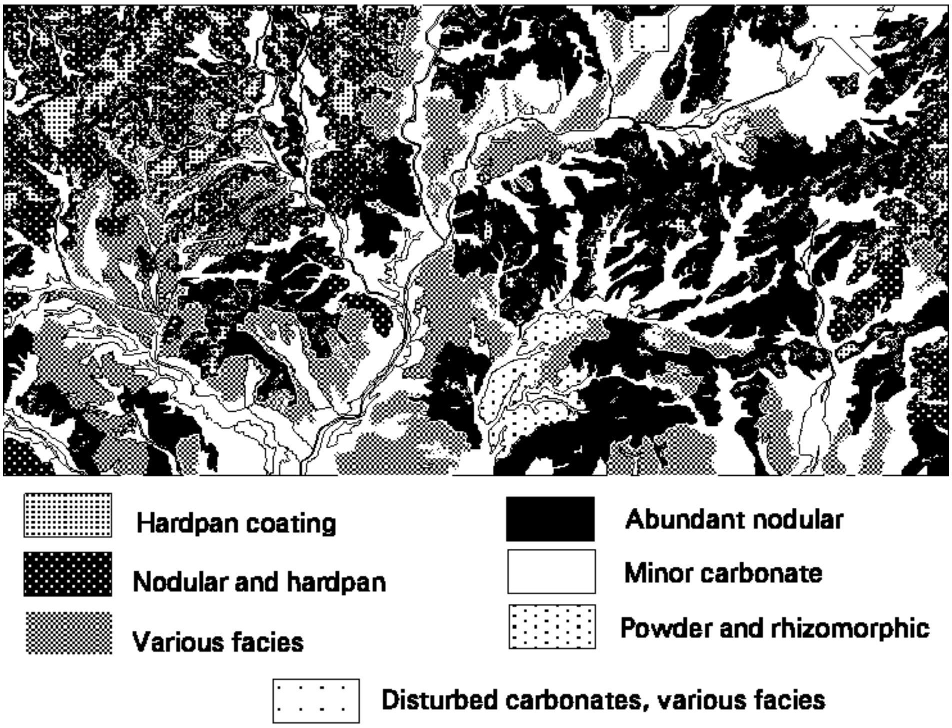


Figure 10. Distribution of RCAs and their predominant morphologies on the Pinnacles 1:25k map sheet. Regolith carbonate is less well developed or occur deeper in the regolith profile along alluvial units due to leaching and mobilisation (from Senior et al. 2002)

Geochemistry within the profile features a close association between Ca and Au, typical of many of the profiles first used in Western Australia and South Australia to support the use of RCAs as a regolith sampling medium for Au exploration (e.g. Lintern, 1997, 2002). The Au content closely correlates with changes in Ca content and does not appear to be closely associated with Fe throughout the profile (Fig. 11). There is a slight association between Mg and Au accounted for by the accommodation of small amounts of Mg within calcite (hence a strong association between Ca and Mg). In summary, this profile is a calcite-dominated, nodular and powder, high Ca:Mg RCA profile with low Mg contents. The mineralogy of the profile is dominated by quartz with minor feldspars, muscovite, and hematite associated with the alluvial sediment host. The dominant carbonate mineral throughout the profile is calcite.

An important feature that relates to the use of these materials as an exploration sampling medium is that there is as much variation in the Au content within this profile as numerous mineral explorers use to distinguish between anomalous and background RCA assays across many regions. This means that depending on what part of this profile is sampled in a regional survey, a single RCA sample from this point could either show a high or low value. An orientation study prior to large-scale sampling would help identify this for specific tenements, however, the profile chemistry here shows that particular care needs to be taken to ensure that equivalent parts of RCA profiles are consistently sampled across a region. In areas hosting this type of profile, the preferred RCA sampling media would be distinguished in the field as the nodular morphology (preferentially with nodules of the same diameter) and this could be further discriminated after geochemical or mineralogical analysis to target the Ca-rich (also calcite-rich) RCAs. This type of RCA would also be the most easily obtained by shallow augering, shallow pit digging, or opportunistic exposure in burrows, gullies and existing pits. Areas with this type of profile have typically been where RCA-based exploration programs have been the most successful. Results from a sub-catchment 3D chemical mapping project south of Staurolite Ridge, and from more Mg-rich (dolomitic) RCA profiles in the region, such as at Limestone Station (Hill et al., 1999; Hill, 2000), show that RCA sampling consistency is even more important than shown here. In contrast, at least in an exploration sense, Lintern (2002) concluded that RCA morphology does not critically affect Au geochemistry.

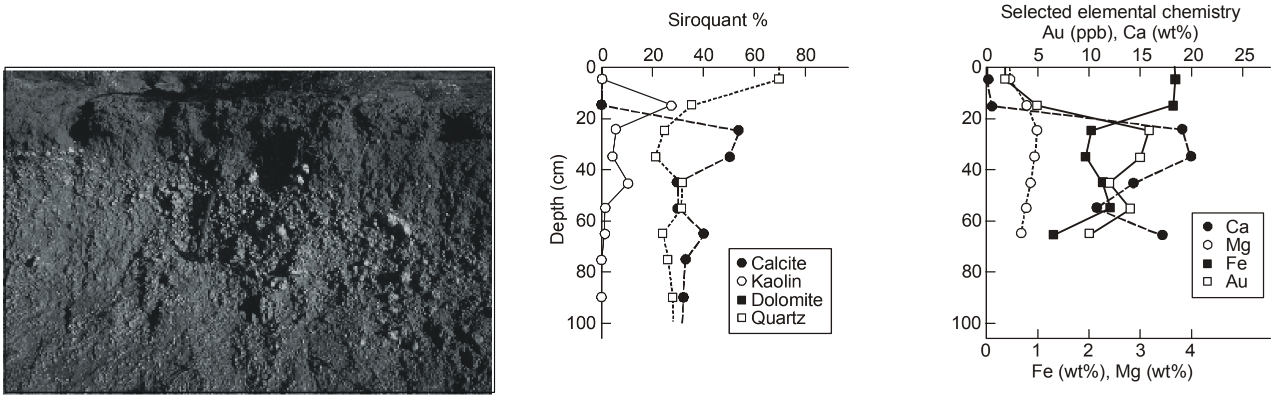


Figure 11. Part of the RCA profile exposed in the costean between Middle Pinnacle and Pine Creek (Hill and Roach, 2008)

It should also be noted that the part of the profile with the highest Au contents also corresponds to the part with the greatest amount of possible cryptogam coatings on nodules, consistent with a possible link between biological processes and regolith chemistry.

Sub-catchment 3D chemical mapping

To the south of the Pinnacles, between Staurolite Ridge and North Tank, a detailed 3D regolith geochemistry and biogeochemical study has been conducted over a quartz-gahnite lode within a small first order drainage catchment (Senior, 2000; Senior and Hill, 2002). Regolith samples collected comprised lower-level soils (darker, more clay-rich, superficially resembling a B-horizon), RCAs, saprolite-soil interface and black bluebush (*Maireana pyramidata*) leaves. A grid was laid out across the catchment at 50 m spacing and each of the four different media were collected.

As part of the study, a series of chemical maps of the different sampling media in this area were produced, some of which are shown in Figures 12 and 13. It is interesting to note that the Cu in regolith carbonate assay results closely correspond to those from alluvial plains, and therefore may represent transported (redistributed) chemical signatures from further north. Once the regolith-landform features and characteristics were mapped, a context for the multi-element assays revealed

- relatively high assay results towards the base of the catchment for some trace metals (e.g. Zn, Pb, Au) representing a transported (redeposited) reflection of mineralisation further upslope. This demonstrates the value of integrating the chemistry results with a regolith-landform map showing landscape dispersion pathways
- in some cases, RCA trace metal assay results besides Au, defined mineralisation (e.g. Co, Pb), suggesting that a multi-element approach to RCA surveys is useful
- in some cases other regolith sampling media such as soils and black bluebush (*Maireana pyramidata*) defined the area of mineralisation.

In other words, the consideration of these points provides a means to interpret and rank RCA assay results in this area, and thereby improve the recognition of associations between this chemistry and mineralisation.

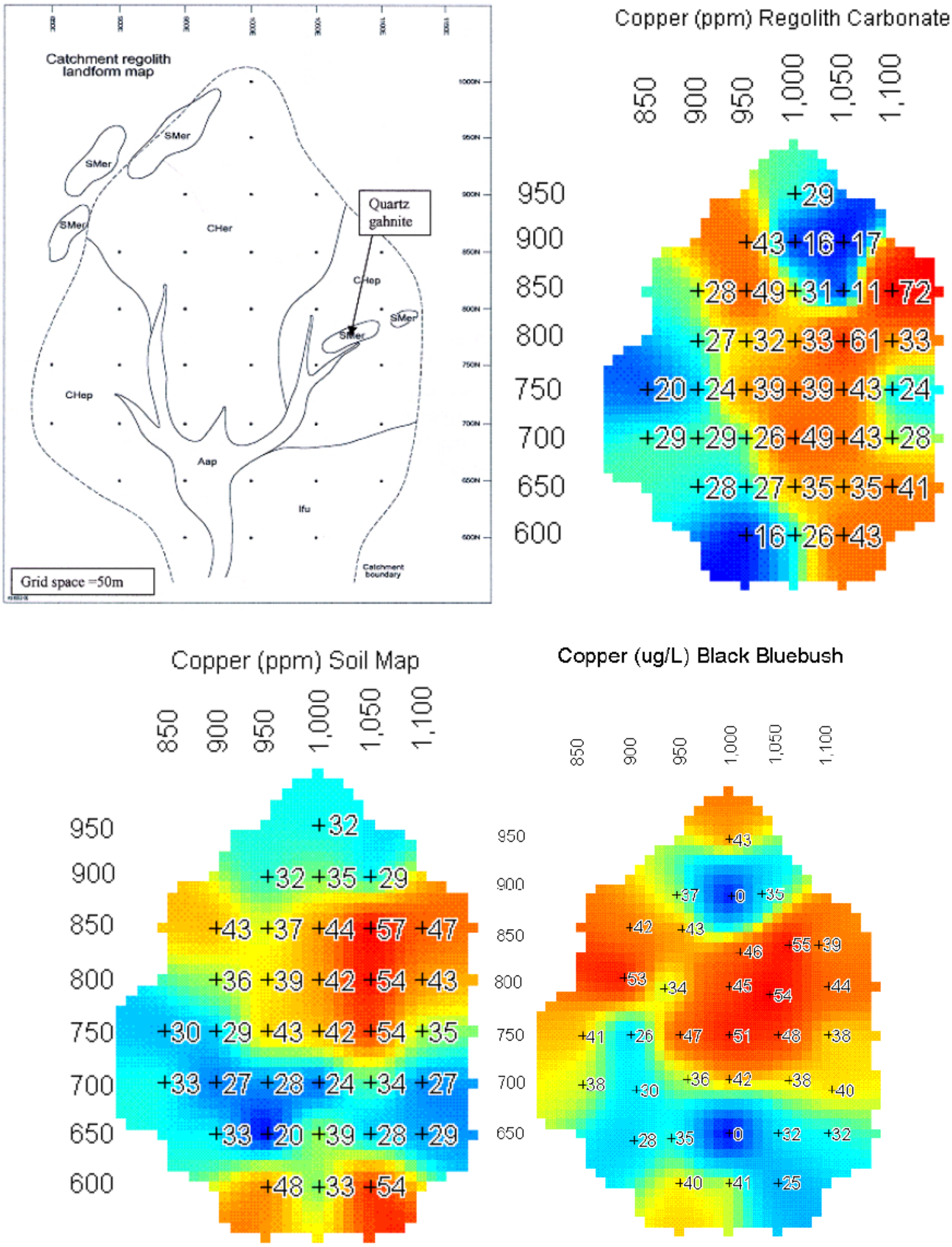


Figure 12. Regolith-landform map of the sub-catchment between Staurolite Ridge and North Tank with Cu dispersion results for calcrete, soil and vegetation. SMer = moderately weathered bedrock on an erosional rise, CHer = colluvial material on an erosional rise, CHep = colluvial material on an erosional plain, Aap = alluvial material on an alluvial plain (Hill and Roach, 2008)

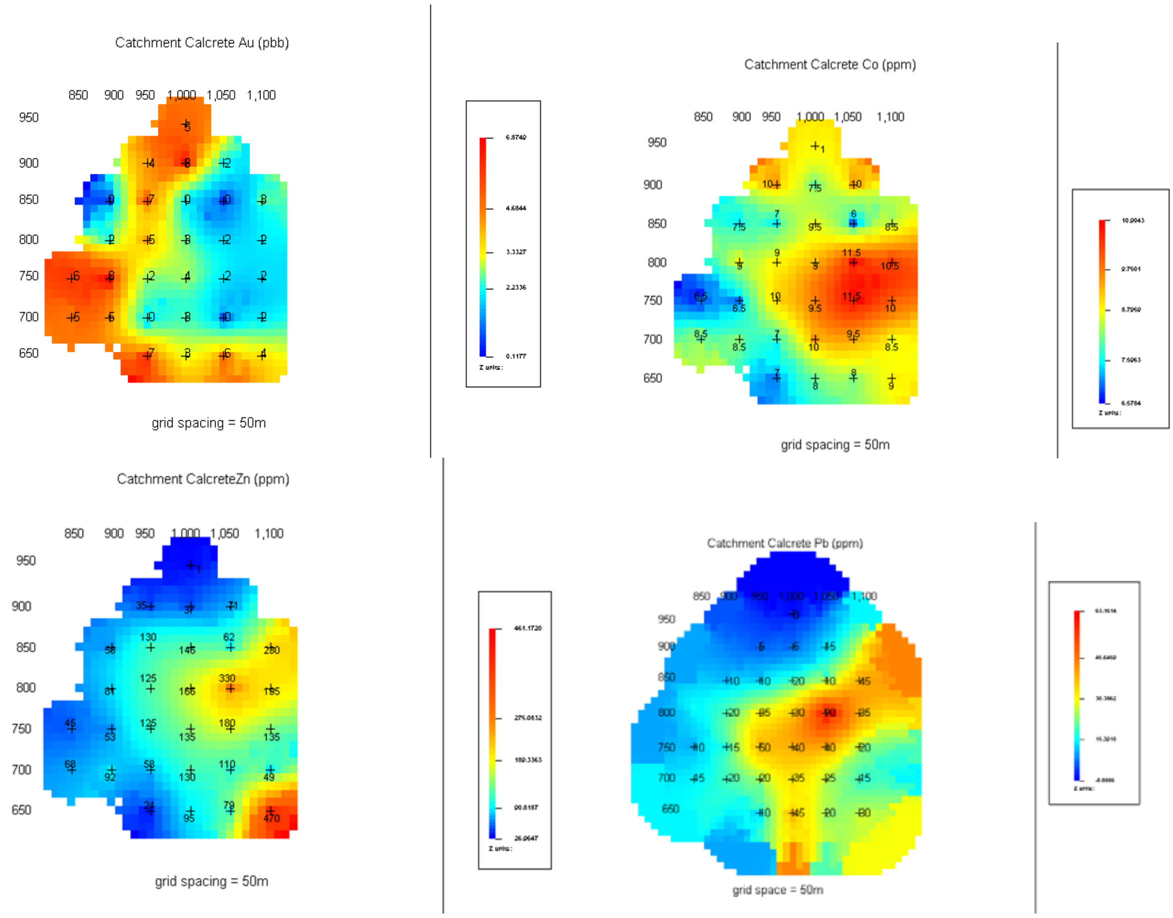


Figure 13. Geochemical maps of selected assay results (Au, Co, Zn, Pb) from the sub-catchment between Staurolite Ridge and North Tank (Senior, 2000). Regolith map shown in Figure 12.

Farmcote Palaeovalley (after Barratt and Hill, 2003)

Introduction

This site examines a large variety of regolith materials on the east side of the Mulculca range-front including a silicified palaeovalley that now forms areas of elevated relief due to its increased resistance to erosion (inverted relief). Silicification and ferruginisation of bedrock, that in part underlay the palaeovalley, can be observed.

Location

Key field observations can be made along a series of rises and low hills in close proximity to the Farmcote Homestead ?near Battery Tank track, starting from ~1.5 km east of Farmcote Homestead. A regolith-landform and location map of this area is shown in Figure 14.

Description

An erosional rise at 569750 mE, 6453450 mN (AGD66, Zone 54) is capped with silicified, rounded and angular quartzose sands and pebbles (Fig. 15). The silicification of these sediments largely occurs within massive ‘pods’ with some areas displaying columnar and nodular morphologies (pedogenic silcrete). Silicification here is mostly in the form of microcrystalline quartz with minor microcrystalline anatase and hematite. The flanking slopes of this rise are covered in colluvial sediments with a surface lag of boulders and pebbles (gibber) of silicified sediment derived from further upslope.

These sediments are interpreted as being alluvial, from an ancient palaeovalley system (Fig. 16). Equivalent silicified sediments occur about 5 km west-north-west of Farmcote Homestead however, their topographic elevation is some 20 m less than those exposed here. It is further interpreted that these remnants represent a southeast flowing palaeovalley system that crossed

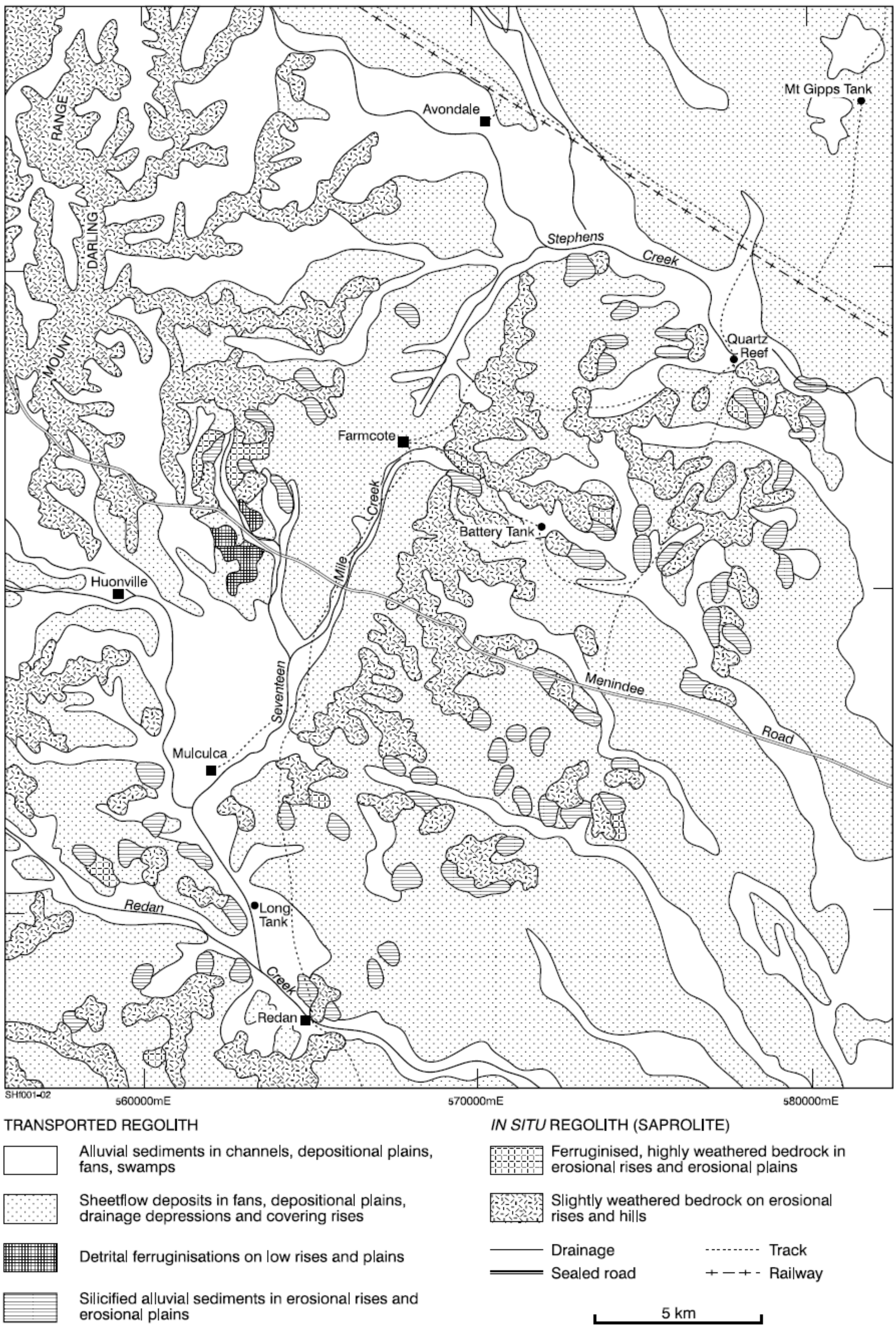


Figure 14. Regolith–landform map of the Mulculca range-front area (AGD66, Zone 54; Hill and Roach, 2008)

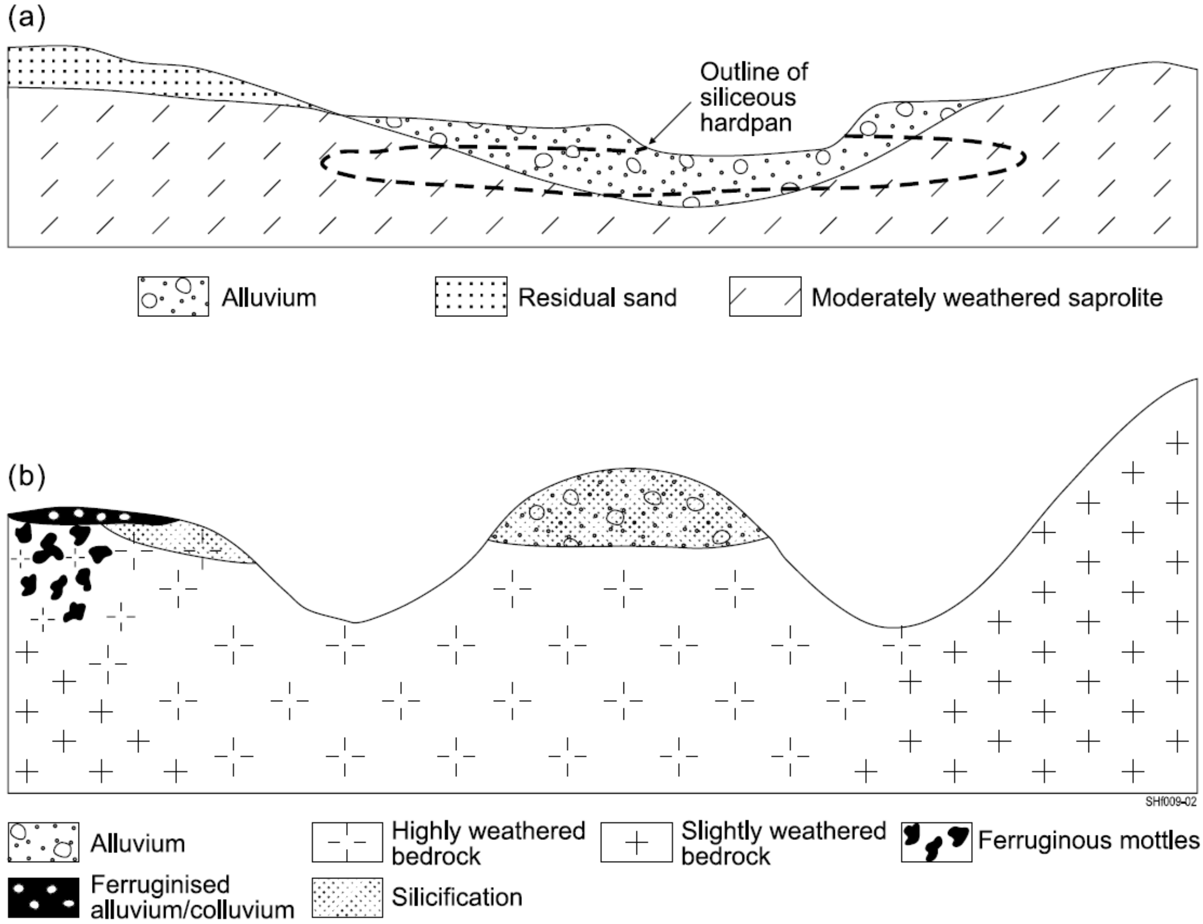


Figure 15. Interpreted palaeo-landscape context of regolith materials a) in a modern analogue landscape from the Cape York Peninsula (after Pain et al., 1999); and, b) as observed at the Farmcote Palaeovalley site (Hill et al., 2003)

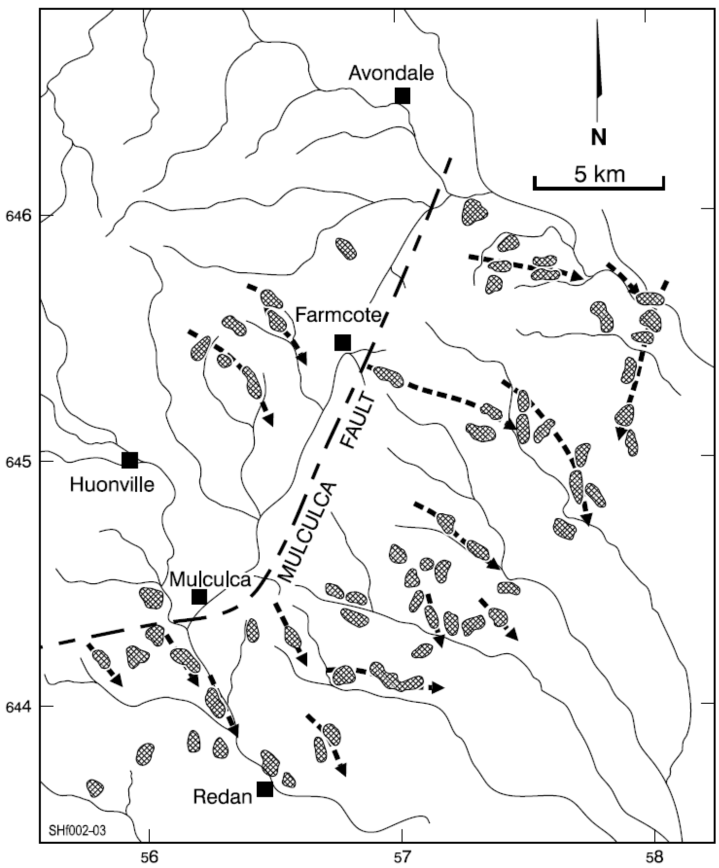


Figure 16. Mapped distribution of silicified palaeo-valley sediments (hatched pattern) with interpreted palaeo-valley systems (doted arrows) crossing the Mulculca Fault (Hill et al. 2003)

the Mulculca range-front between this rise and Farmcote Homestead (Fig. 17). From this rise crest the view to the southeast runs further along the axis of this palaeo-valley system, and the bedrock rises that once confined the palaeo-valley still stand proud in the landscape (inverted relief). Tectonism along the Mulculca Fault has since displaced (vertically by about 20 m) the palaeovalley system. This would have also lead to the gradual defeat or senescence of comparable palaeovalley systems, leading to the deposition of about 20 m of lacustrine—wetland sediments within the fault-angle depression (observable in the creek gully sections south of Farmcote). Erosion of the weathered materials flanking the silicified palaeo-valley has since led to relief inversion of the palaeo-valley sediments at this site so that they are now preserved mostly on rise crests.

The interpreted southeast flow of these palaeo-valleys suggests that they are most likely to have been associated with the Murray Basin sedimentary fill. They maybe equivalent to the early to mid Cenozoic Renmark Group sediments, or the late Cenozoic Callivil Formation sediments (Brown and Stephenson, 1991), although there has been little research linking the Murray Basin sedimentary fill with areas outside of the Eastern Highlands.

Several hundred metres to the north (569550 mE, 6453850 mN AGD66, Zone 54), some cavernous rises are mostly composed of variably silicified saprolite. These exposures display parent bedrock features such as pseudomorphs of feldspars, primary jointing and quartz vein fabrics. The cavernous nature of the exposures reflects the variably silicified, case-hardening of the exposures. These materials would have once underlain and flanked the palaeovalley system in this area. Some of the saprolite here has also been variably ferruginised to form hematitic and goethitic mottles. These indurated mottles are now being eroded from the weathering profile and dispersing down slope to contribute to detrital ferruginous lag, such as seen in the creek cutting south of Farmcote. Near the crest of the rise there is a transition from ferruginised saprolite to ferruginised sediments, representing the margins of the palaeovalley in this area.

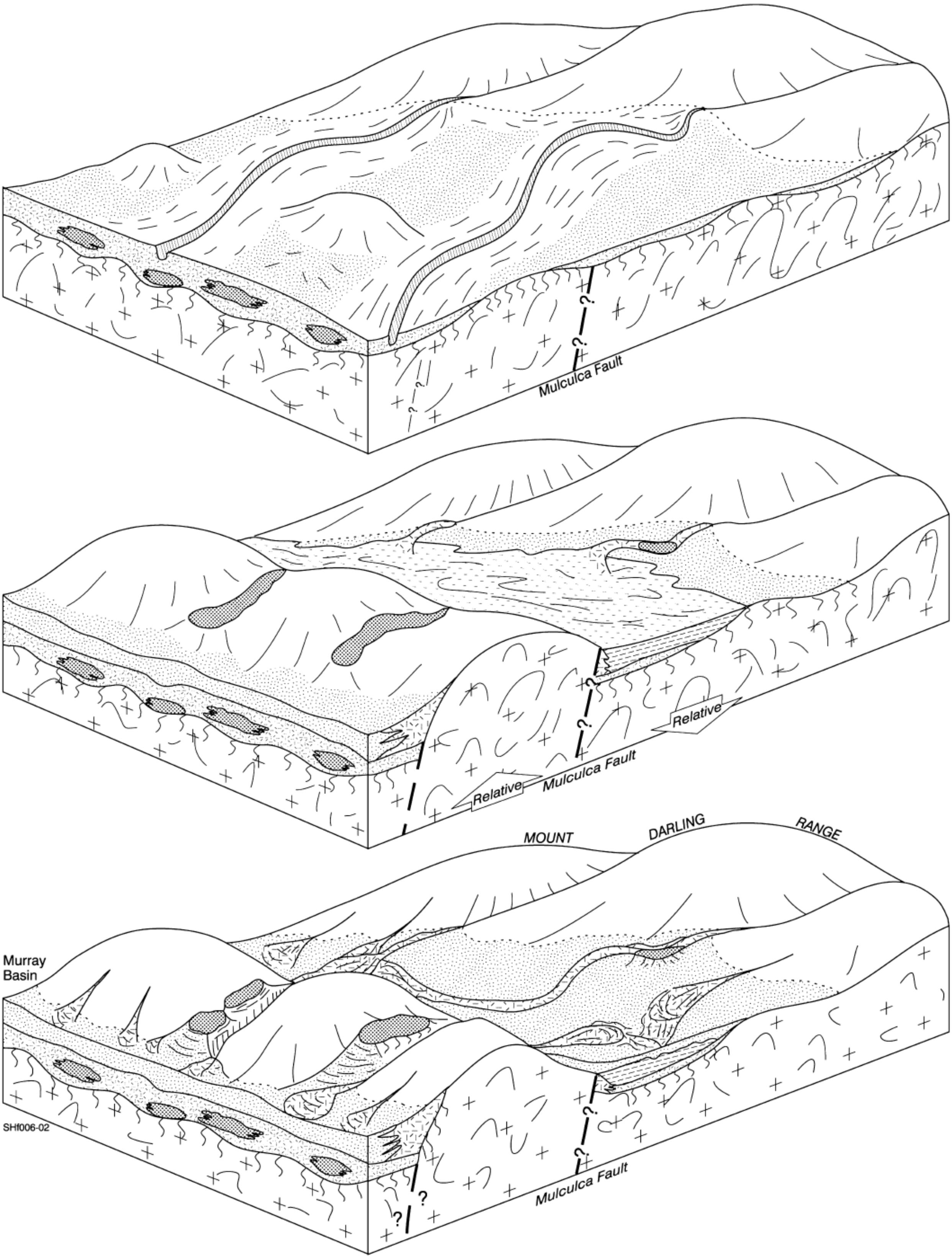


Figure 17. Interpreted sequence of events for the major regolith and landscape evolution events along the Mulculca range-front (Hill et al., 2003)

OLARY RANGES

Mingary Pits (Fig. 18; after Crooks, 2002a,b)

Introduction

Climate during the early Cenozoic or earlier, resulted in deep weathering of basement and Neoproterozoic rocks in the Mingary area, and the formation of extensive iron-oxide-rich regolith materials. The deeply weathered rocks formed a more prominent topographic high that separated the Callabonna Sub-basin of the Lake Eyre Basin from the Murray Basin, and this is preserved as the modern, more subdued topographic high of the Barrier Ranges. Later in the Cenozoic, a significant change in base level of the region caused a reactivation of the river systems draining those highlands. During subsequent erosion episodes, much of the weathering profile was stripped from the higher parts of the ranges leaving relatively fresh basement exposed (Fig. 19).

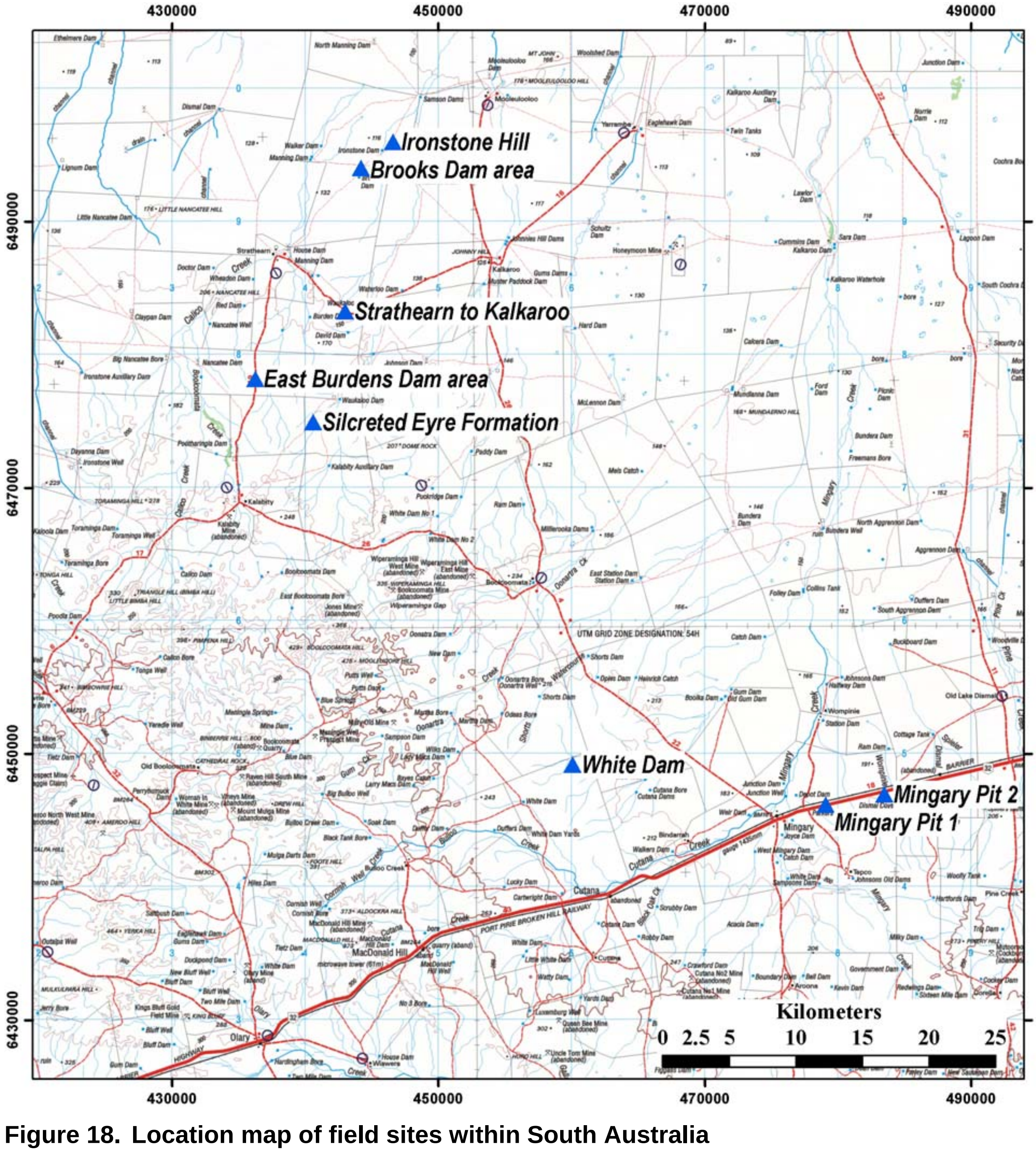


Figure 18. Location map of field sites within South Australia

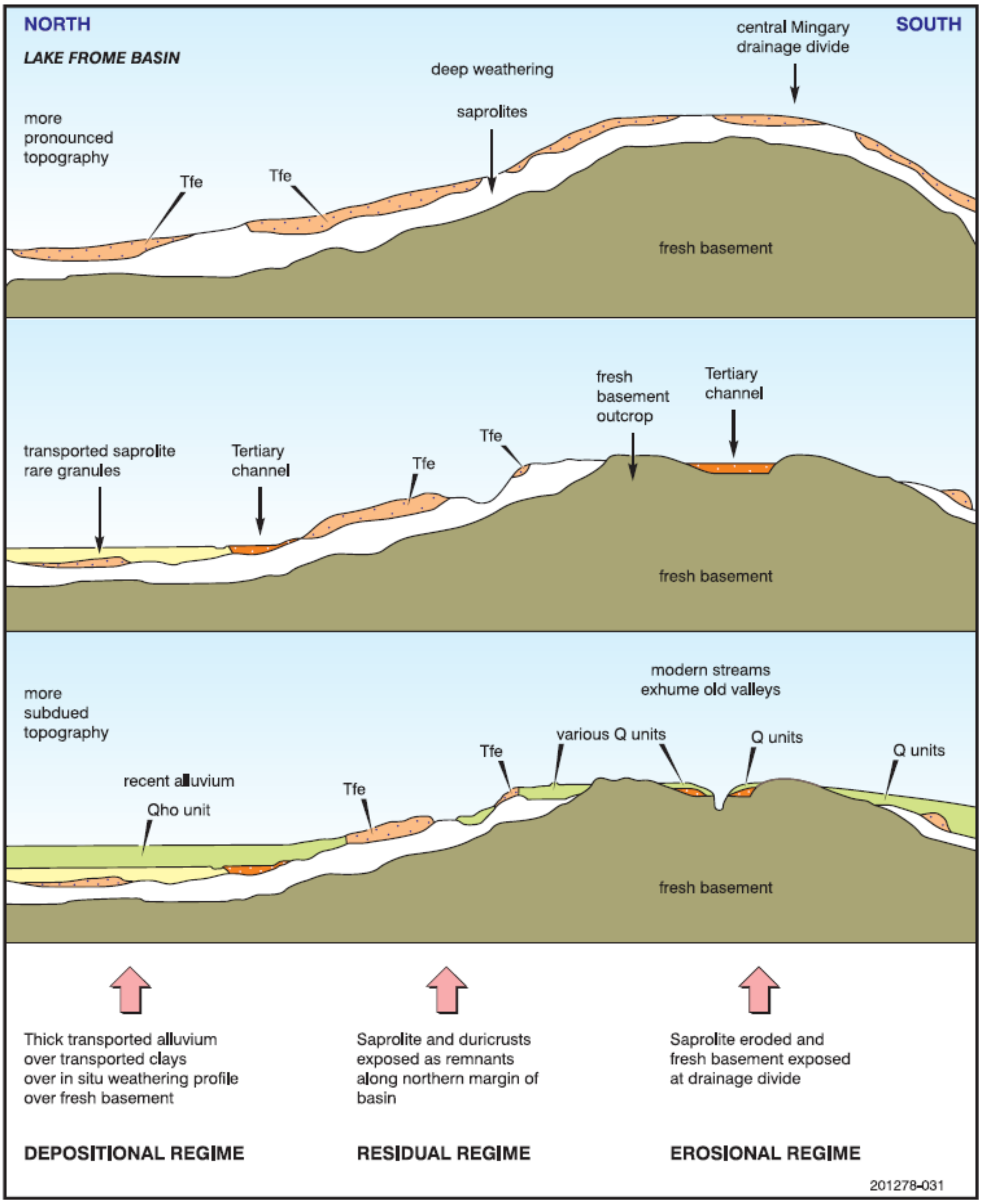


Figure 19. Evolution of the regional regolith profile across the Olary Ranges over time (Crooks, 2002b)

The thick weathering profile is preserved along the northern margin of the ranges where erosion of the profile is incomplete. Saprolite to upper mottle zone, exposed within borrow pits, is the focus of this site. Both sites are within erosional plains where a thin veneer of Neogene sediments cover weathered bedrock.

Location

The Mingary Pits are located just off the Barrier Highway on Tepco Station (Fig. 18; ph. 8091 1677). Approximate coordinates for Mingary Pit 1 are 479076 mE, 6446177 mN (WGS84, MGA54) and for Mingary Pit 2, 483503 mE, 6446955 mN (WGS84, MGA54).

Description

Mingary Pit 1

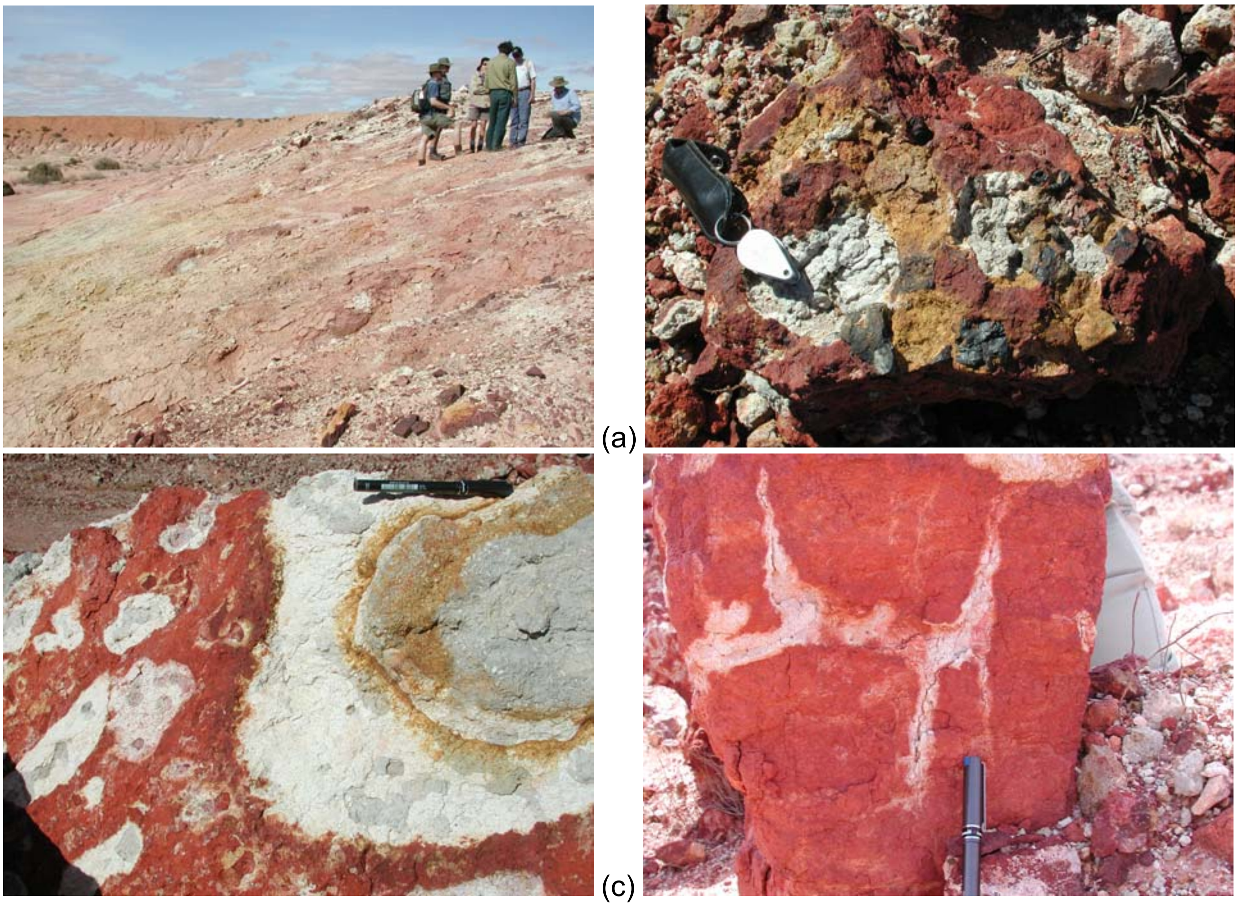
The borrow pit exposes highly weathered saprolite and overlying mottle zone. Pit walls contain basement fabrics including quartz veining. Excavated boulders of mottle zone display typical segregation of iron-rich and bleached regolith (Fig. 20). A dense blocky ferruginous lag covers the surface around the pit.

Figure 20. Mottled zone developed in Willyama Supergroup rocks. From quarry on Barrier Highway near the turn off to 'Tepco' (~479070 mE, 6446180 mN WGS84, MGA54). Field notebook scale is 200 mm long.

Mingary Pit 2

The borrow pit exposes highly weathered saprolite and overlying mottle zone (Fig. 21). The mottle zone is formed by iron segregation—precipitation within a relict kaolin- and quartz-rich matrix. Mottles range in size and shape and may have sharp, distinct or diffuse boundaries. Mottles broader than 200 mm are termed megamottles (Eggleton, 2001). A complex relationship between mottles can be observed and suggest a varied and evolving origin.

Several interesting features from this locality are displayed in Figure 21b–d. Large, randomly aligned hematite crystals are evidence for original basement mineralogy (Fig. 21b). Porcellanite developed in mottles is interpreted as being evidence for tree-root remnants, where tree roots have exploited porous, kaolin-rich mottles and then are replaced by porcellanite after the organic matter decays. Goethite rims represent iron precipitation at redox boundaries (Fig.21c).



(a) (b) (c) (d)

Figure 21. Borrow pit on the Barrier Highway (~483500 mE, 6446955 mN WGS84, MGA 54), (a) exposed saprolite and mottle zone developed in Willyama Supergroup rocks, (b) mottle zone with relict hematite, (c) porcellanite mottling within pallid mottles, (d) root-like shapes within the mottle zone suggest that roots may influence iron mobilisation

White Dam (after Brown and Hill, 2004; Brown and Hill, 2007; Dart et al., 2006; Lau, 2004)

Introduction

This site gives an introduction to the range of regolith-landform units in the vicinity of the White Dam Deposit and the control that regolith landscape and associated materials can have on the expression of mineralisation in geochemical and biogeochemical assays at a prospect scale. Exploration costeans provide the opportunity to look at the regolith in profile (at the time of writing). Gold chemistry down-profile from two of these costeans is discussed.

Location

The White Dam Deposit is located within the Olary Domain on Bullo Creek Station (ph. 08 8091 1522), ~30 km northeast of Olary in South Australia and 80 km west of Broken Hill in New South Wales. The approximate coordinates are 460100 mE, 6449200 mN (Fig. 18; GDA94, MGA54).

Background

White Dam was discovered after the detection of anomalous Au assays of soil samples during a regional soil survey by Aberfoyle Resources (McGeough and Anderson, 1998). However, drilling delineated a substantially larger mineralised zone than indicated by surface geochemical methods. As little as 1 m of transported regolith masks significant bedrock mineralisation. This is in-part attributed to varying regolith across the prospect. High Au assays were related to a sub-cropping, weakly mineralised 'tail' of the mineralisation sub-crop. Other high Cu and Au assays from soils within the area were drilled but found to be unrelated to underlying mineralisation. This poses the question as to why White Dam doesn't have a better geochemical dispersion signature and footprint.

Mineralisation setting

The mineralisation is hosted by biotite-quartzofeldspathic gneiss of the Wiperaminga Subgroup within the Palaeoproterozoic Willyama Supergroup. The primary Au resource is contained within an extensive stockwork of pyrite and chalcopyrite veins (Cooke, 2003). Sulphide minerals are oxidised above an asymmetric weathering profile which increases up to 50 m in depth towards a major north-south trending fault on the west side of mineralisation. Within the oxide zone, Au is concentrated in biotite-rich selvages and leucocratic bands and veins within the gneiss (Cordon, 1998. Cooke, 2003). Compared with other Au-Cu prospects in the district, White Dam has a relatively low Fe content and does not show elevated levels of As, Ag, Ni, Cd, Sb or Pb (Cordon, 1998).

Description

Regolith-landform setting

The White Dam mineralisation occurs within a landscape with subdued topography and limited bedrock exposure. This area is within the upper Mingary Creek catchment, which is a part of the Lake Eyre Basin. Alluvial and sheetflow depositional plains and low rises occur across much of the mineralisation, which is bounded to the north and west by an alluvial channel flowing to the north and north-west. Transport of surface materials in the area has beed dominated by shallow overland flow (sheetflow), which occurs across much of the current landscape. Alluvial sediments are most significant along the creek channel and associated alluvial plains, while aeolian sediments are at least a widespread component of most regolith materials in this region. Limited exposure of weathered bedrock flanked by mixed sheetflow and aeolian sediments occur within low hills to the north, and low erosional rises to the south.

Vegetation at this site consists of a chenopod shrubland dominated by bladder saltbush (Atriplex vesicaria) with black bluebush (Maireana pyramidata), and some pearl bluebush (Maireana sedifolia). Occasional rosewood trees (Alectryon oleifolius) occur near bedrock exposures and regolith carbonate accumulations (RCA's), while beelah (Casuarina pauper) occurs on some alluvial plains and fans.

Surface regolith

Regolith materials vary across the mineralised area, and include:

- skeletal soils associated with slightly weathered bedrock (saprock) exposures in the south
- up to 4 m thick, red-brown alluvial silts and clays in the north-east
- quartzose and lithic, red-brown, colluvial silts and clays across remainder of the area.

Multiple generations of RCA's occur as pallid powdery mottles and rhizomorphs underlying the alluvial plains and depositional plains flanking the creek, and nodular and/or fragmented hardpan RCA's within the thinner cover on the erosional rises to the south.

Surface regolith materials were determined by 1:2000 scale regolith-landform mapping (Fig. 22). Field mapping at 1:2000 scale requires careful attention to variation in the regolith materials, landscape position, vegetation present, and changes in the nature of surface lags or veneers. In some cases, changes in elevation between units is in the order of tens of cm. This scale of mapping was required to delineate subtle, yet significant changes in the regolith and landforms to adequately evaluate the distribution of elements at White Dam. Although more time consuming, the level of detail (>6 m wide polygons) gives improved confidence in defining the landscape context for existing geochemical data and the reinterpretation and subsequent ranking of surface geochemical anomalies.

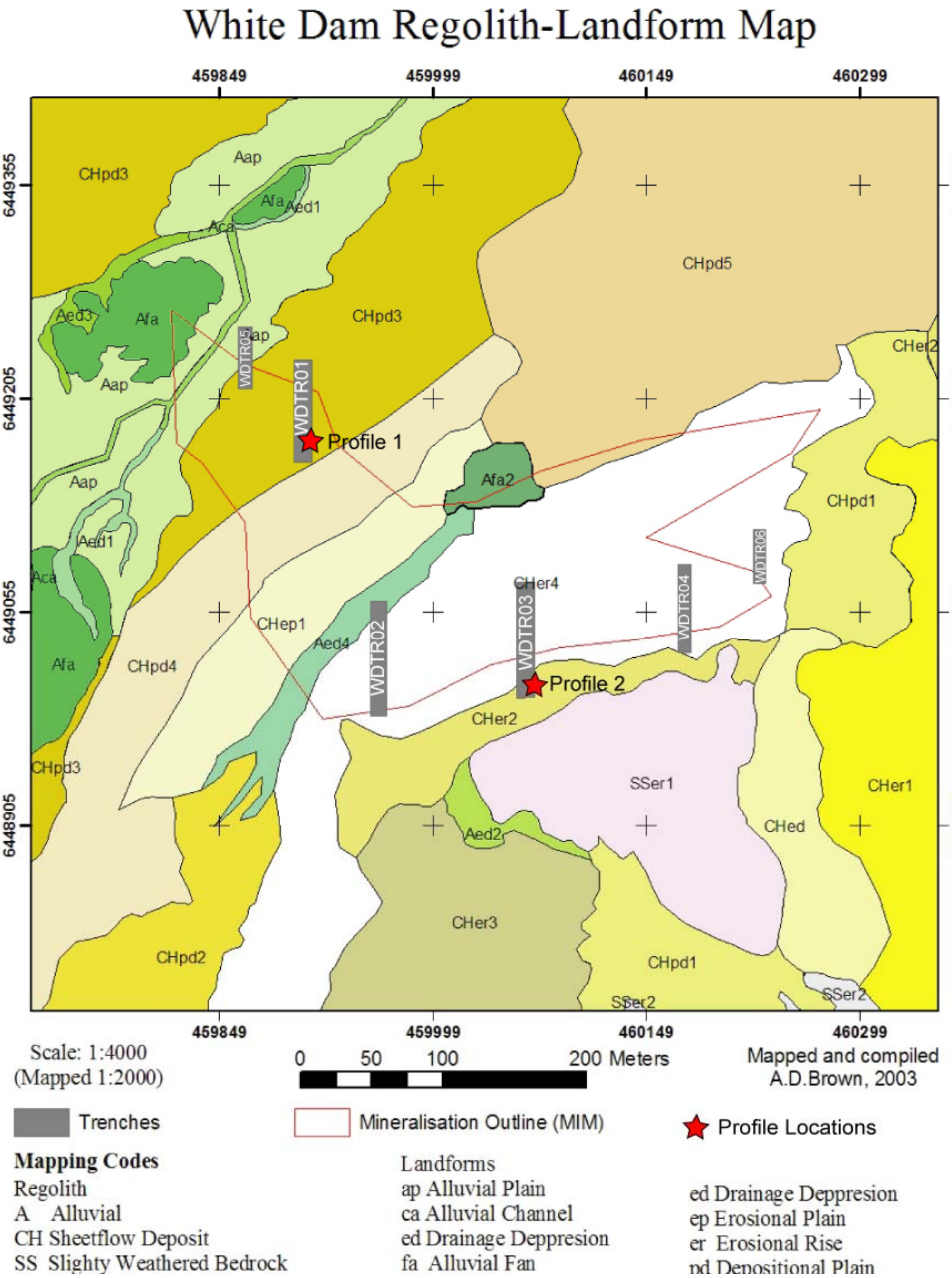


Figure 22. White Dam regolith-landform map with the outline of the mineralised zone and costean locations. Refer to Table 2 for an explanation of mapping codes.

Sub-surface regolith

The regolith profile has been described from two profiles exposed in exploration costeans above mineralisation (Dart et al., 2006). Profile 1 (Fig. 23) is directly above mineralisation and is ~3.5 m deep. It consists of a thin coarse-textured A1 horizon, a clay rich B1 horizon and a calcareous B2 horizon (BCa horizon) that gradually changes to a black horizon with carbonate nodules and rhizomorphs. Below this the sequence is repeated with another clay horizon (2B2) and calcareous horizon (2Bk). This has been interpreted as a palaeosol where the A1 horizon as been eroded. Below this is the saprolith (C horizon) consisting of a weathered pegmatite that intrudes a weathered biotite gneiss.

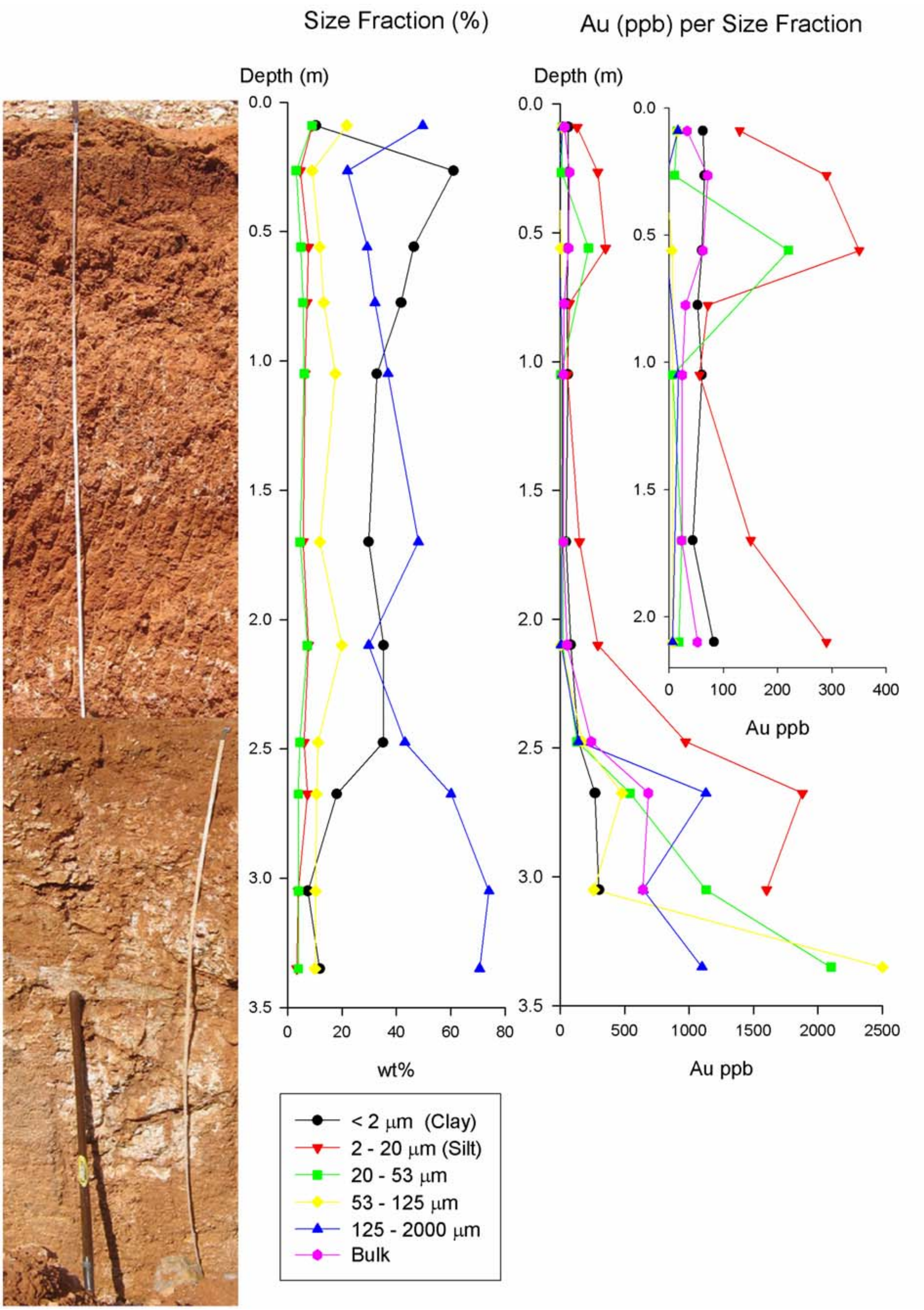


Figure 23. Profile 1 – costean located directly over mineralisation (Dart et al., 2006). See Figure 22 for geographic location.

Table 2. Extended legend for White Dam regolith-landform map (Fig. 22)

Transported regolith

Alluvial sediments

Aed Sub-rounded to sub-angular quartzose to lithic sands with occasional gravels, within elongated depressions containing minor channels. Surface materials consisted of quartzose sands and lithic gravels. Minor powdery and hardpan regolith carbonate with fine brown sands. Colonised by chenopod scrublands, dominated by dense communities of Atriplex vesicaria.

Afa Sub-rounded to angular quartzose sands, silts and gravels with outwash fans and braided distribution channels. Surface materials consist of quartzose and lithic sands and gravels. Colonised dominantly by chenopod shrubland, dominantly Maireana pyramidata with minor Condonocarpus cotinifolius and Xanthium spp.

Aap Sub-rounded to sub-angular quartzose and lithic sands and gravels within meandering and minor braided ephemeral, incised channels in low relief areas flanking sheetwash dominated systems. Surface lag dominated by quartzose and lithic sands and red-brown sands. Colonised by dense scrublands of Atriplex vesicaria, minor Atriplex holocarpa and Acacia victoriae trees.

ACa Quartzose and lithic sands and gravels within broad meandering and minor braided ephemeral, incised channels. Surface lag is mostly imbricated lithic gravels and quartzose and lithic sands. Colonised by occasional Eucalyptus Camaldulensis (riparian woodland) and Acacia victoriae.

Colluvial sediments Sheetflow deposits

CHpd Sub rounded to sub-angular, mixed lithic, and quartzose gravels with minor red-brown quartzose sands, associated with areas of low topographic relief, characterised by irregular contour-band surface patterns. Colonised by a chenopod shrubland dominated by Maireana spp. and minor Atriplex vesicaria forming discrete communities.

CHep Sub-rounded to sub-angular quartzose sands and red-brown silts, associated with areas of low topographic relief. Surface lags consist of red-brown quartzose sands and gravels. Colonised by a sparse chenopod scrubland, dominated by Atriplex vesicaria.

CHer Sub-angular lithic and quartzose gravels with minor red-brown quartzose sands flanking areas of low topographic relief, and locally shedding material into lower topographic areas. Minor channel incision and riling perpendicular to the contour of slope, causing possible erosional hazards. Surface lags consist of quartzose gravels and red-brown quartzose sands with minor lithic gravels, forming patchy contour banding pattern. Colonised by a sparse chenopod shrubland dominated by Atriplex vesicaria and Casuarina pauper trees.

In situ regolith

Saprock - Slightly weathered bedrock

SSer Exposures of bedrock with thin surficial weathering in areas of slight topographic relief (9-20 m). Surface lags consist of red-brown quartzose sands of varying thickness mantle the saprolite. Minor hardpan and powdery RCA's are locally developed. Localised gully erosion. Colonised by open woodlands dominated by Acacia aneura and Casuarina pauper, with a mixed understorey of chenopod shrubland, locally dominated by Atriplex vesicaria and Maireana spp. as well as Sida petrophilla.

Profile 2 (Fig. 24) is located just off the main zone of mineralisation and is ~3 m deep. It consists of a thin coarse-textured A1 horizon, a sandy clay B1 horizon that becomes calcareous with depth and gradually changes to a Bk horizon with increasing coarse grains and lithic fragments. The Bk horizon gradually changes with depth into the saprolith, which consists of a highly weathered biotite-gneiss saprolite that overlies saprock at ~1.5 m.

The distribution of various size fractions is shown in Figures 23 and 24. The distribution of the silt and the 20–53 µm sand shows little variation (all values are <10%) throughout the profile with a slight drop at the profile base. The 53–125 µm sand fraction is also similar between the two profiles. However, this fraction has a higher content (~10–20%) and shows a slightly higher variability than the silt and 20–53 µm fractions. The clay fraction shows significant differences between the two profiles. In Profile 1 the clay content steeply rises to ~60% in the B1 horizon and gradually decreases to a slight peak at the second clay horizon before dropping off rapidly to <10% in the saprolith. In Profile 2 clay content rises to ~40% in the B2 horizon before falling to <1% at the base of the profile. The 125–2000 µm fraction is similar in both profiles with an almost inverse relationship to the clay fraction.

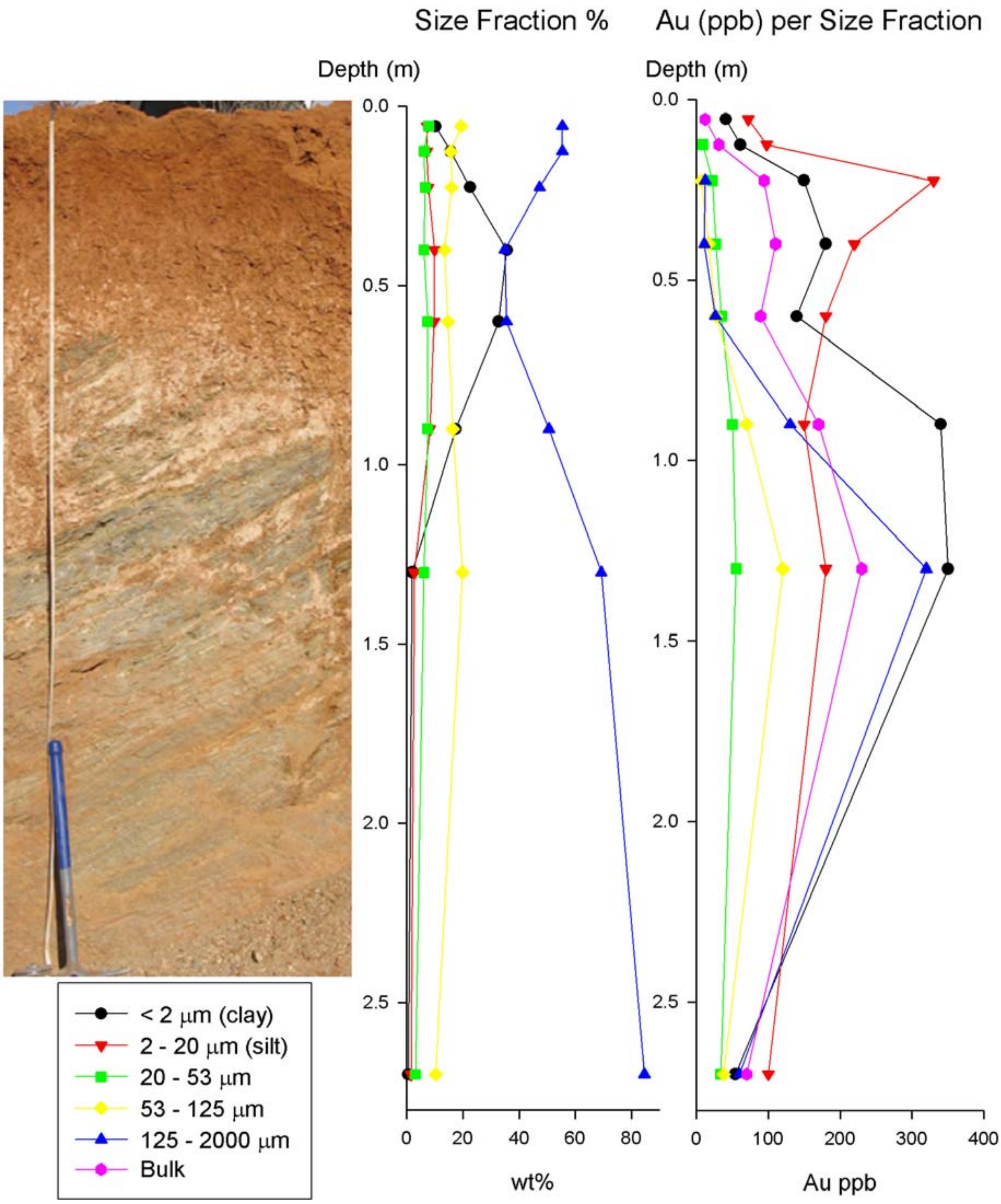


Figure 24. Profile 2 – costean located just off the main zone of mineralisation (Dart et al., 2006). See Figure 22 for geographic location.

Geochemistry

Following 1:2000 scale regolith-landform mapping, the uppermost 20 mm of topsoil was sampled at 70 sites on a 50 x 50 m grid. At each site, loose vegetation litter and large lithic debris were scraped away, and a 2.5 kg sample was collected using a plastic scoop. The <75 µm fractions was selected from topsoil samples, based on an orientation survey. Gold and Cu assay results from the topsoil samples highlight the effect of the subtle topography and regolith materials on the expression of mineralisation (Fig.s 25 and 26).

Soil assay

Gold is detectable in 52 of the 70 topsoil samples, with relatively high assay results obtained from samples over sub-cropping mineralisation, including a high-grade mineralised zone that is overlain by 4 m of transported cover (CHpd3, Fig. 25). On the topographically lower landforms over the

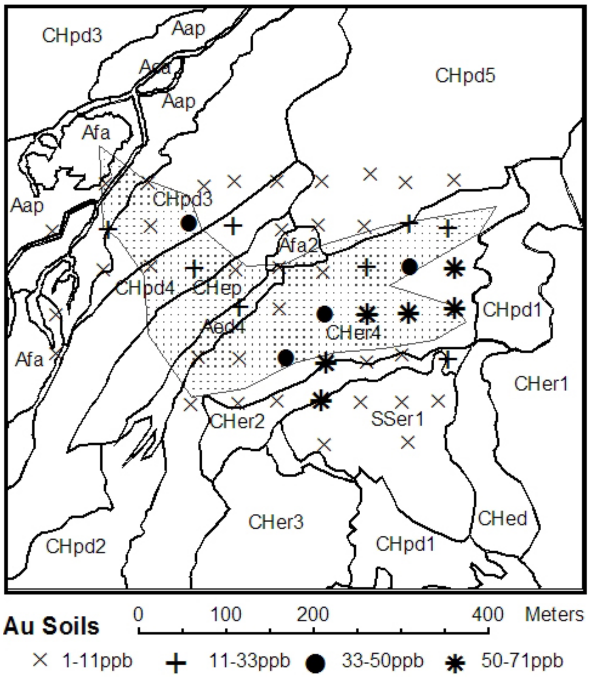


Figure 25. Au assays <75 um soil samples (Brown and Hill, 2007)

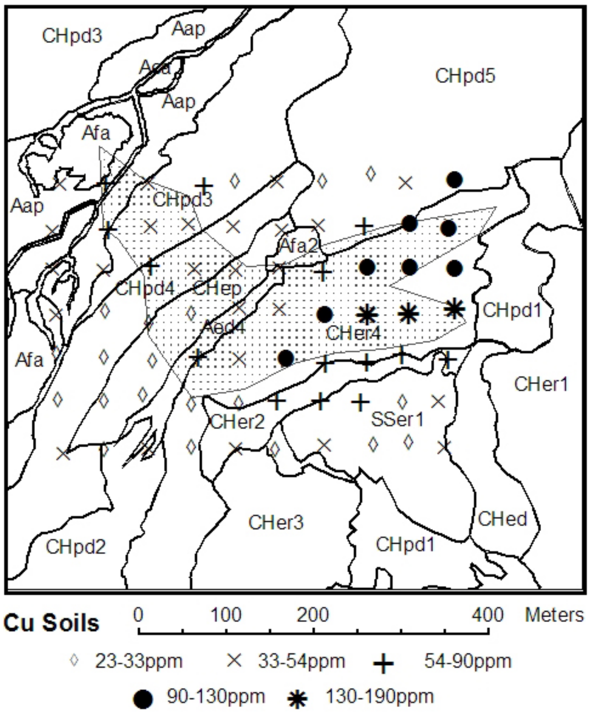


Figure 26. Cu assays <75 um soil samples (Brown and Hill, 2007)

south-west of the mineralised zone, Au was below detection limit of the assay method, with the exception of some samples along Bullo Creek and adjacent alluvial fans and plains. There is however, detectable Au in all samples to the north-east of the mineralisation. This dilution or depletion to the south-west, and the presence of detectable Au assays to the north-east, fits well with the predominantly north to north-east dispersion vectors mapped across the prospect from measurement of litter-dam orientations (Brown and Hill, 2003a; 2003b). Copper was detectable in all 70 samples, with the relatively high assay results largely restricted to the area of sub-cropping mineralisation.

Mapping of assay results reflects the downslope dispersion onto a large depositional plain to the north-east of the prospect. Copper results show a distinct dilution or depletion zone in the south-west, extending across the mineralisation along the CHep and CHpd4 regolith landform units (Fig. 26) in a similar way to the pattern of Au assays.

Biogeochemical assays

The Au and Cu assays from the bladder saltbush twig samples highlight the significance of landform effects when interpreting these biogeochemical survey results. Gold was detectable in nine of the 70 samples assayed (Fig. 27). Seven detectable Au assays were from sites overlying or immediately adjacent to the surface projection of the mineralisation. Four of these samples were adjacent to mineralisation in the south of the area, where the mineralisation is buried by ~1 m of transported regolith. The other three results were located over the high-grade zone of mineralisation, which is overlain by 4 m of transported regolith. The remaining two detectable assays were from an alluvial plain flanking Bullo Creek and another site 100 m north-east of the high-grade zone of mineralisation on a depositional plain (CHpd3 Fig. 27). These are both interpreted as transported and redeposited Au contents. The lack of detectable Au assays in the area of sub-cropping mineralisation may reflect poor bioavailability of Au in areas of skeletal soil cover. The three detectable Au assays from over the high-grade mineralised zone indicate that even where the transported regolith is at its maximum thickness, plants can incorporate Au into its tissues.

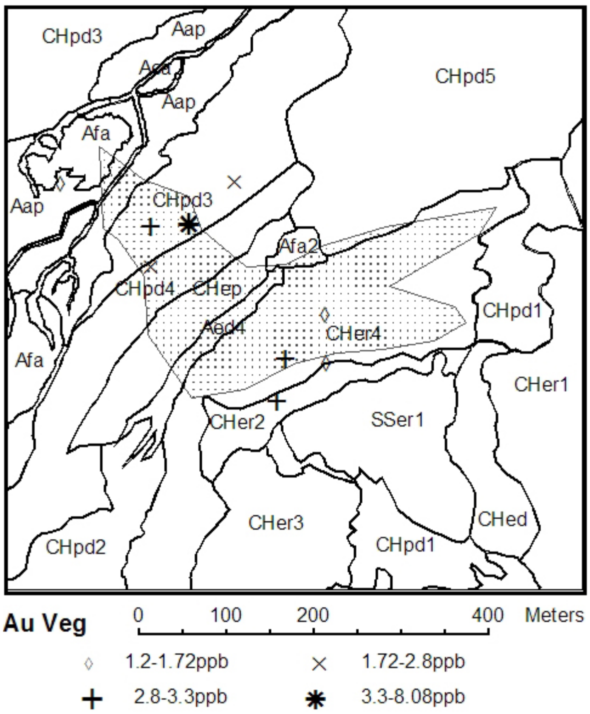


Figure 27. Au assays bladder saltbush twigs (Brown and Hill, 2007)

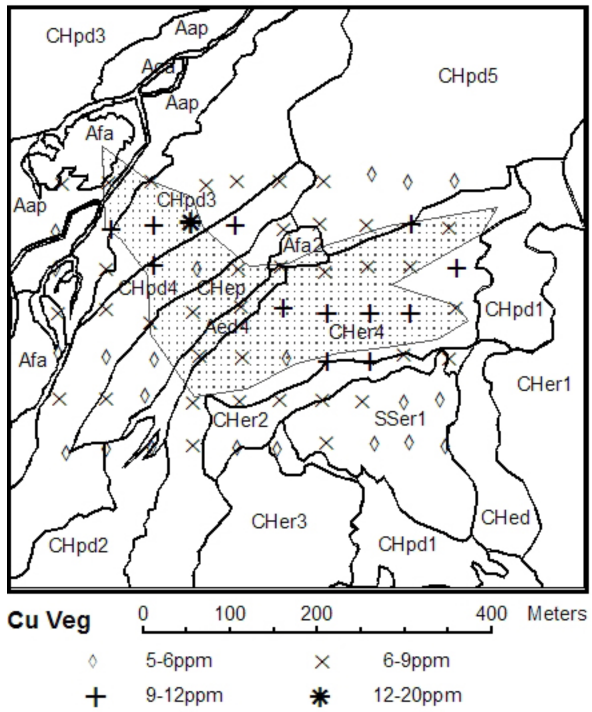


Figure 28. Cu assays bladder saltbush twigs (Brown and Hill, 2007)

Copper was detected in all 70 samples assayed, and all anomalous values are overlying or adjacent to the area of known mineralisation. The Cu results in bladder saltbush show dilution or depletion to the south-west of the mineralisation, and over the mineralisation on the erosional plain (CHep, Fig. 28) and depositional plain (CHpd4, Fig. 28). This again fits well with the interpretation of materials being transported in a north-east direction across the prospect, with non-mineralised material being carried in from the south-west. Copper assays also reflected the zone of higher grade mineralisation, through 4 m of transported cover.

Profile assay

In Profile 1, the pedolith has Au values from below detection limit (5 ppb) to ~350 ppb for the various size fractions (Fig. 23). Within the saprolith there is a significant elevation in Au content with many samples >1000 ppb. The highest concentration of Au in Profile 1 is within the silt sized fraction, which has a peak of ~350 ppb in the B2 horizon. The Au concentration in this fraction then falls back to between 50–100 ppb before rising again to ~300 ppb at the second carbonate layer. The Au concentration in the 20–53 µm fraction is the only other fraction to show any significant variation through the pedolith, which like the silt fraction, is within the B2 horizon. Of the remaining size fractions, clay has a consistent Au concentration of between 50–100 ppb and the 53–125 µm and 125–2000 µm size fractions have Au concentrations <50 ppb (with some even below detection limits). The Au values of the bulk samples are consistently lower than the clay and silt fractions through the pedolith with values around 50 ppb.

The Au concentration through Profile 2 (Fig. 24) peaks at approximately 350 ppb in the pedolith and drops to <100 ppb within the saprolith. The silt fraction has a peak within the B1 horizon, at the top of the highest carbonate content region. The Au concentration in the clay fractions has considerable variability with a small peak (~150 ppb) at the base of the B1 horizon and another larger peak (~350 ppb) in the saprolite. The Au concentrations of the remaining size fractions are all <50 ppb through the pedolith. Within the saprolite, all size fractions apart from the 20–53 µm fraction have a peak in concentration. The bulk samples follow a similar pattern to the clay fraction with a lower overall Au content.

Observations made using a field emission gun scanning electron microscope on the silt fraction revealed several Au particles within the saprolith samples and a single particle within the B2 sample of Profile 1. Considerable difference in morphology between the saprolith and the pedolith sample was observed. The Au particles within the saprolith had a smooth, rounded and almost crystalline morphology. The grain sizes were ~1 μm in diameter. The single Au particle located within the pedolith was larger (~3 μm) and had a nodule-like surface texture. No Au particles could be located within Profile 2.

The major difference between the two profiles is the Au content at the profiles base. These values highlight that Profile 1 is directly above mineralisation whereas Profile 2 is not. However, similar Au values were recorded for both profiles within the pedolith. The silt fraction consistently had the greatest Au concentration of the various size fractions throughout the pedolith.

The fact that both profiles had similar Au values in the pedolith shows that Au is very mobile within the regolith and that available Au is readily concentrated in evaporative zones within the pedolith.. The lateral migration of the Au will make target areas larger and hence, easier to locate. There seems to be a preference for Au to be accumulated within the top of the calcareous horizon. Bulk samples had anomalous Au values, however, higher Au values can be expected if analyses are performed on the finer fractions. Therefore the Au must be very finely disseminated throughout the samples (Dart et al., 2006).

Kalabity–Mooleulooloo Region

This series of sites incorporates several key regolith exposures north of the Olary Ranges. The variety of regolith materials is indicative of a complex history of sedimentation, weathering and erosion. These range from silcreted Eyre Formation, isolated remnants of once more widely distributed Adelaidean metasediments and a variety of ferruginous materials derived largely from an exposed palaeo-weathering front. An important observation in this area is the fact that even though the terrain is dominated by Neogene regolith units (largely erosional), the depth to basement is generally less than a few metres.

SILICIFIED EYRE FORMATION

Location

Silicified Eyre Formation crops out ~8 km north-east of Kalabity Homestead on the Kalabity Pastoral Lease (Fig. 29; ph. 8091 1515). Coordinates are 440600 mE, 6474950 mN (GDA94, MGA54).

Description

This site is the most prominent of a series of buttes that preserve a highly weathered basement armoured by a resistive silcrete cap. Silcrete here is interpreted as having formed within transported sediments of the Eyre Formation based on the predominance of sub-rounded quartz grains (Fig. 30).

EAST BURDENS DAM AREA (AFTER LAWIE, 2001)

Location

Within Kalabity Pastoral Station (ph. 8091 1515), ~9.5 km northwards from Kalabity Homestead, and towards Strathearn Homestead (Fig. 29). West of East Burdens Dam, centred around 436255 mE, 6478173 mN (GDA94, MGA54).

Description

This area comprises a variety of unusual surficial materials including mottles, ferruginised, manganiferous and primary hematite-bearing Ethiudna Subgroup saprock and lag. Mottles and megamottles are present within a matrix of in situ, highly crystalline kaolinite (Fig. 31). The mottles form a resistant ferruginous cap and a subsequent local topographic high. Close by, a breakaway exposes varying degrees of weathered in situ regolith (Fig. 32). Ferruginous materials exposed by the breakaway are interpreted to be ferruginised Ethiudna Subgroup rocks. In places contemporary

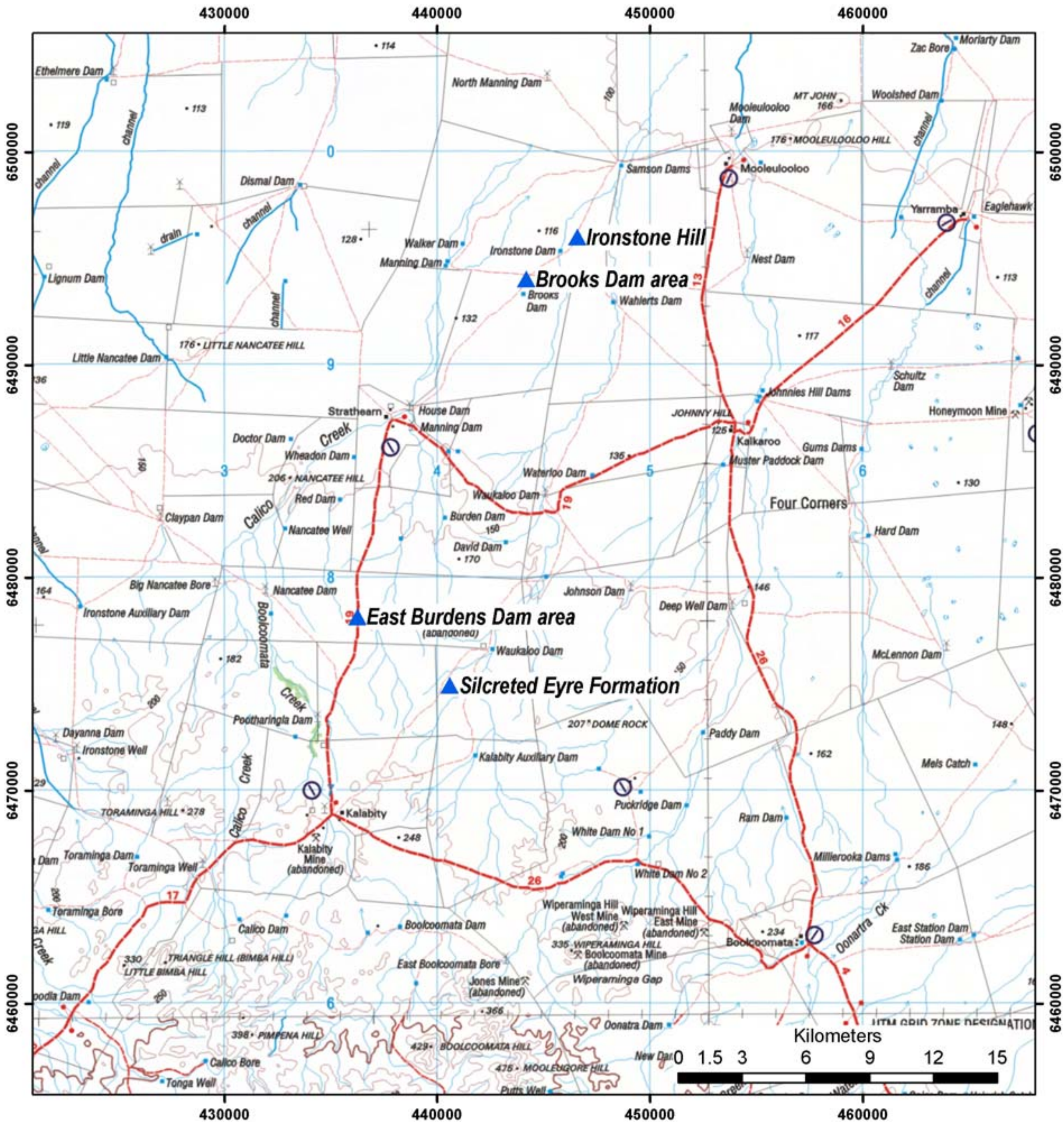


Figure 29. Location map of field sites in the Kalabity to Mooleulooloo region

Figure 30. Silcrete developed in Eyre Formation (440600 mE, 6474950 mN GDA94, MGA54). Silcrete in the left image displays a fracture surface where breakage has occurred across the enclosed larger quartz grains. The right image displays the sub-rounded quartz grain-granule character typical of Eyre Formation.

Figure 31. Degraded mottles and megamottles within highly weathered, kaolinitic matrix. Degradation and disruption of mottles has created an extensive lag (436031 mE, 6477993 mN WGS84, MGA54). The yellow area encloses a subcropping megamottle ~1 m across (after Lawie, 2001).

Figure 32. Photo from East Burdens Dam looking west (437768 mE. 6477634 mN WGS84, MGA54). Prominent black, manganiferous lag in the foreground. Breakaway in the background is covered by a ferruginous lag derived from disaggregation of mottles and Bimba Formation gossans (Lawie, 2001).

erosion has removed the weathered profile to expose relatively fresh bedrock. Although the weathering profile at East Burdens Dam is at least 10 m deep, it is surrounded by outcrops of only incipiently weathered Curnamona Group rocks. This can also been observed at West Burdens Dam, ~2.5 km to the west, where a deep weathering profile (exposed in dump material excavated from a shaft) surrounds a gossanous outcrop, yet the surrounding rocks are unweathered at the surface.

Strathearn to Kalkaroo road (after Ashley et al., 1997)

Location

Along the road between Strathearn and Kalkaroo Homestead within the Mooleulooloo Pastoral Station (Fig. 29; contact Strathearn Homestead ph 8091 1528). Dense lag occurs between 5.5–8.5 km along the Strathearn to Kalkaroo track.

Description

Extensive ferruginous lags at this location represent a dismantled pre-existing ferruginous weathering-front developed within pelitic and psammitic rocks (some of which appear to be Adelaidean). These lags are composed dominantly of rock fragments with minor pisoliths and nodules. Fragments preserve primary rock textures such as crenulated cleavage, porphyroblastic textures, graded bedding. The chemistry of the lags is nearly identical to outcropping ferruginised basement rocks (Lawie, 2001). To the south, David Dam exposes weathered Adelaidean which is known to occur in this region.

BROOKS DAM AREA (AFTER ASHLEY ET AL., 1997)

Location

Proceed north from Kalabity Pastoral Lease, through Strathearn Homestead to the Brooks Dam area (centred around 444192 mE, 6494031 mN GDA94, MGA54; Fig. 29).

Description

Adelaidean outcrop

There are several small areas of poorly outcropping Adelaidean siltstones between 2.5–5 km north-east of Strathearn Homestead. Lag becomes dominated by Bimba-derived material towards Brooks Dam. An important observation is that even though the terrain is dominated by Neogene regolith units (largely erosional), the depth to basement is generally less than a few metres.

Brooks Dam

A dense spread of degraded gossanous rubble is crossed by the road near Brooks Dam. It extends for several hundred metres and is interpreted to be representative of the Bimba Formation that crops out 500 m north-west of Brooks Dam (accessible along the track to the west towards Manning Dam). Average composition of the rubble is 47.5% Fe, 0.87 ppm Au, 1.1 ppm Ag, 816 ppm As, 1950 ppm Ba, 20 ppm Co, 276 ppm Cu, 480 ppm Mn, 80 ppm Mo, 20 ppm Ni, 2510 ppm P, 1030 ppm Pb, 5 ppm Se, 2800 ppm Zn, 13 ppm U and. lead isotope analyses of gossanous material from this site indicate a Broken Hill-type age (Lawie, 2001).

Also within the extensive ferruginous lag spreads in this region are ferruginous materials derived from pelitic rocks of the Brooks Range. The Brooks Range break an otherwise flat terrain to the east of Brooks Dam. Metamorphic grade appears to be somewhat lower here than to the south in the main outcropping part of the Olary Domain. The pelitic schists here are similar to those in other outliers in the northern part of the Olary Domain, such as Nancatee Hill and the Mooleulooloo Hills.

IRONSTONE HILL (AFTER ASHLEY ET AL., 1997)

Location

On the eastern side of the road, 12 km north-east of Strathearn Homestead towards Mooleulooloo Homestead. Coordinates are 446590 mE, 6496000 mN (GDA94, MGA54; Fig. 29).

Description

Ironstone Hill is interpreted to preserve the only recognised occurrence of in situ ferruginous pisoliths ('lateritic gravel' a pedolith component) in this region. The dense cap of pisoliths is underlain by weathered Strathearn Group and is surrounded by an erosional plain of iron-rich colluvium. The ferruginous material at this location is interpreted to have formed from and above an in situ weathered profile. A dense lag has armoured and preserved the once more widespread highly weathered basement. The average composition of ten lag samples taken from this location is 40.7% Fe, 1 ppm Ag, 43 ppm As, 1272 ppm Ba, 7 ppm Co, 161 ppm Cu, 246 ppm Mn, 6 ppm Mo, 22 ppm Ni, 911 ppm P, 40 ppm Pb, 16 ppm Se, 120 ppm Zn and 20 ppm U. These elevated values probably represent residual accumulations but there may also be a scavenged component of indeterminate magnitude.

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