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Australian Regolith Conference '94

Broken Hill, 14-17 November 1994

Field Guide and Notes on the Regolith and Landscape Features of the Broken Hill Region, Western NSW

By S M Hill, G Taylor & T Eggleton

Record 1994/57

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FIELD GUIDE AND NOTES ON THE REGOLITH AND LANDSCAPE FEATURES OF THE BROKEN HILL REGION, WESTERN NSW

Wednesday 16 November, 1994

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PROPOSED ITINERARY

The following intinery is to serve as a possible time guide for the day's program. Variations will undoubtedly occur, and depending on time constraints and road conditions, some sites may be deleted. For instance after heavy rains access to Site 1 may not be possible. All other sites can be accessed from sealed roads that should be open at most times.

8:30 am	Bus leaves Mine Host Hotel
8:30-9:15	Travel to Yalcowinna Station
9:15-10.00	Site 1 (Yalcowinna Station)
10.00-10:30	Travel to Haydens Tank
10:30-11:15	Site 2 (Haydens Tank)
11:15-11:45	Travel to Broken Hill
11:45-12:00	Site 3 (Broken Hill Gossan)
12:00-12:15	Travel to the Sculptures Hill
12:15-1:00	Site 4 (Sculptures Hill)
1:00-1:30	Lunch
1:30 - 2:00	Travel to Stirling Vale
2:00 - 3:00	Site 5 (Stirling Vale)
3:00 - 3:30	Travel to Limestone Station
3:30 - 4:00	Site 6 (Limestone Pits)
4:00 - 4:15	Travel to Silverton Railway Cutting
4:15 - 4:45	Site 7 (Silverton Railway Cutting)
4:45 - 5:00	Travel to Mundi Mundi Lookout
5:00 - 5:15	Site 8 (Mundi Mundi Lookout)
5:15 - 5:20	Travel to Umberumberka Creek
5:20 - 6:00	Site 9 (Umberumberka Creek)
6:00 - 6:15	Travel to Silverton
6:15 pm onwards	Site 10 (The Silverton Hotel)

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INTRODUCTION

Since late last century, the Broken Hill region has been an area of major geological interest and significance. Much of this interest has been due to the great mineral wealth that the region hosts, particularly the main Broken Hill lead-zinc-silver deposit which was one of the largest and richest metalliferous deposits in the world. When Charles Rasp pegged the blackest section of the "Hill of Mullock" in 1883, the Broken Hill orebody cotained between 200 and 250 million tonnes of ore and has yielded ore worth some $70 billion. Current reserves, however, are limited to as little as 10-15 years, and despite concerted efforts, exploration has not yielded any major new deposits.

The bedrock features of the Broken Hill region have been the focus of most geological investigations in this region, with little consideration given to the regolith and landscape features. Geological exploration is now extending into areas of regolith. The success of this exploration relies heavily upon the development of an understanding of the regolith and associated landscape features in the region.

Mid-1993 saw the commencement of a study of the regolith and landscape features of the Broken Hill Block by the Centre for Australian Regolith Studies (CARS). The initial stages of this study have been concerned with regional regolith-landform mapping (1:100,000 scale) and characterisation of some of the area's regolith materials and landscape features (Hill *et al.*, 1994). Later work will include further and more detailed regolith mapping (1:25,000 scale) and characterisation of regolith and landscape materials as well as correlations of these features within the framework of a regional landscape evolution model.

This field guide has been prepared for the Australian Regolith Conference '94 Field Trip held on Wednesday 16 November, 1994, although it is hoped that it will be self-explanatory enough to be used at other times as an introductory field guide to some of the region's regolith and landscape features. If this field trip is being conducted privately on another date, be sure to gain permission from the relevant landowners before entering private property.

REGIONAL SETTING

The area covered by this field guide centres on Broken Hill, which is located in far western New South Wales, about 1,200 kilometres west of Sydney (Figure 1). This area and the general location of field sites are shown in Figure 2.

Climate

The climate of the Broken Hill region is semi-arid. The mean annual rainfall is about 200 mm, with a high degree of yearly variability and no regular or predictable seasonal pattern. The prevailing wind directions in the region are essentially a consequence of anticlockwise circulation about the eastward moving subtropical highs and clockwise moving subtropical lows. The leading edge of the highs give rise to south-southwesterly winds that predominate in most seasons, although in the winter westerly and northerly winds are also a major feature.

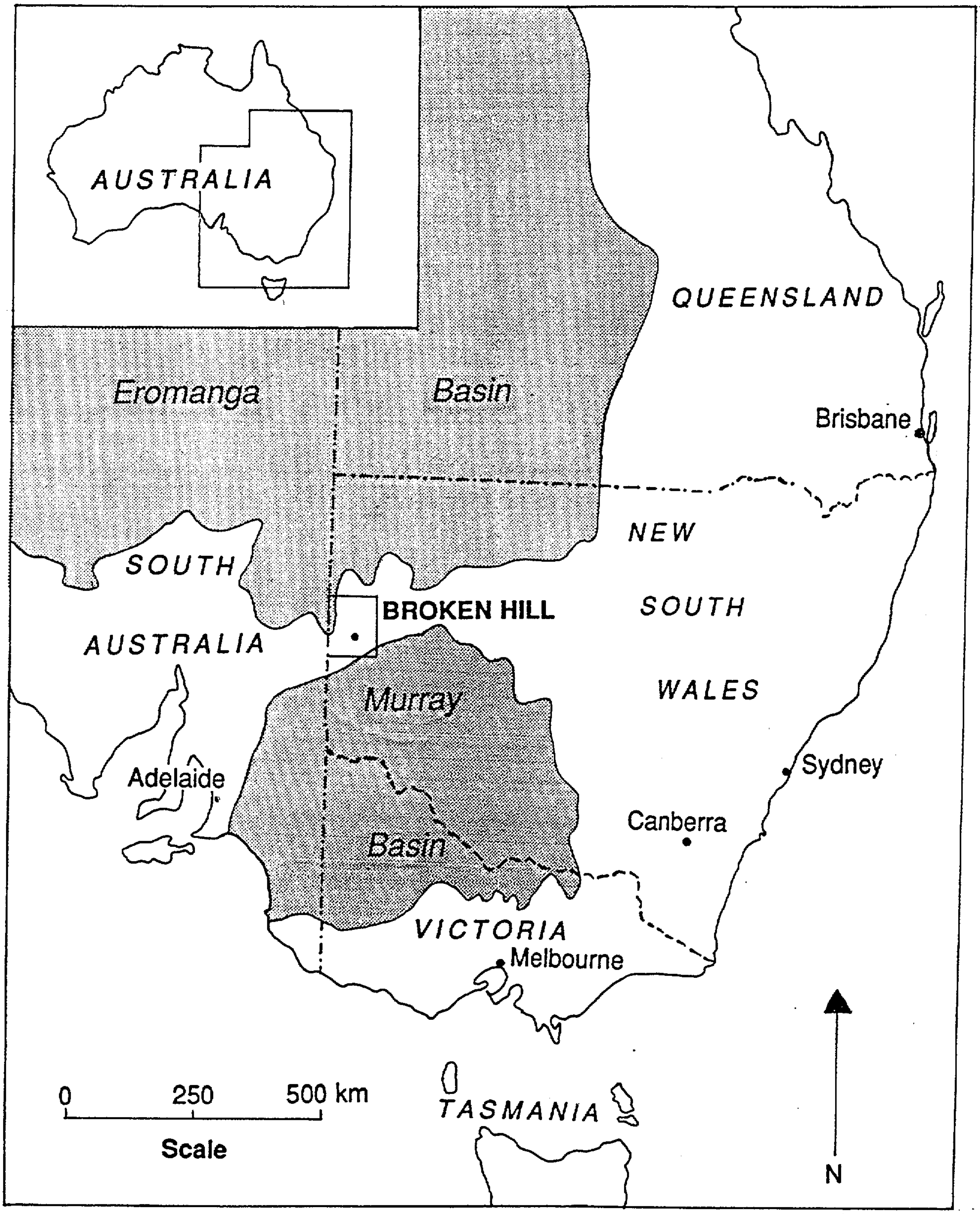

Figure 1. The location of the Broken Hill region and its relationship to the Eromanga and Murray Basins.

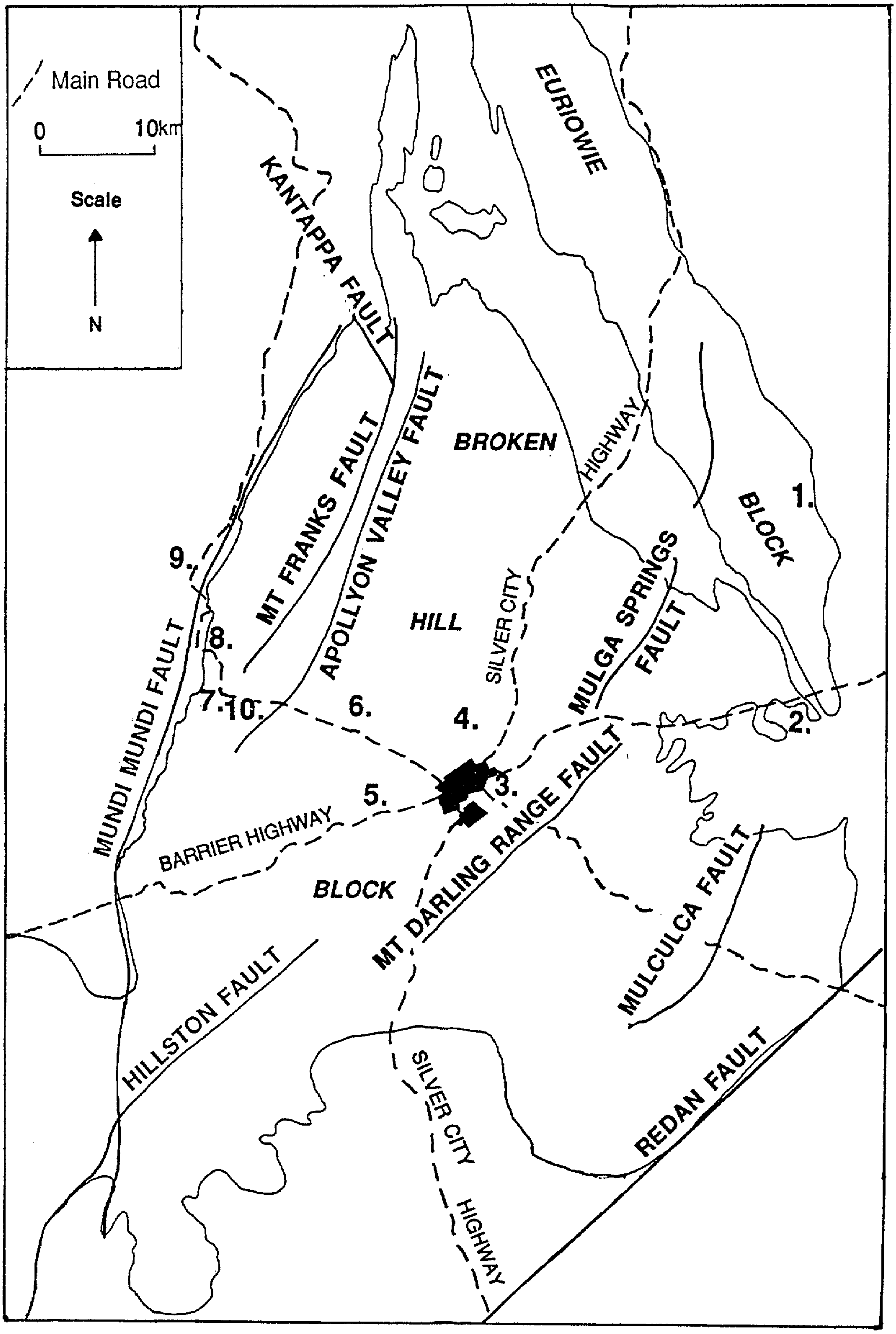

Figure 2. The Broken Hill region including the Broken Hill and Euriowie Blocks and major faults (after Willis, 1989). The numbers refer to the location of the field sites.

Vegetation

The main vegetation communities in the region are mulga woodlands, bladder saltbush and bluebush shrublands.

Mulga (*Acacia aneura)* communities are common on the lithosols and desert loams of the Barrier Ranges This community was formerly more widespread, but was largely cleared in the late 19th century to provide timber for nearby mines (Beadle, 1948). It normally forms open woodlands, where mulga may be the dominant tree with occassional belah (*Casuarina cristata*). The understorey may contain a mixture of species including various grasses, hopbushes (*Dodonaea sp.*), cassias (*Cassia sp.*), emu-bushes (*Ermophila sp.*), sandhill wattle (*Acacia ligulata*), and dead finish (*Acacia tetragonophylla*). Towards the edges of the ranges, or where the sedimentary cover is thicker bladder saltbush (*Atriplex vesicaria*) may dominate the understorey.

Bluebush (particularly black bluebush, *Maireana pyramidata*; and pearl bluebush, *Maireana sedifolia*) and bladder saltbush communities form extensive low shrublands on the gently undulating plains flanking the Barrier Ranges or within major valleys in the ranges. Both of these communities are normally treeless or occur beneath an open cover often of mulga, belah or nelia (*Acacia loderi*). The composition of the communities may vary from being monospecific to occurring in association with grasses, forbs and shrubs such as, old man saltbush (*Atriplex nummularia*), mitchell grass (*Astrebla sp.*), copperburrs (*Bassia sp.*) and bottlewashers (*Enneapogon sp.*). Bluebushes, such as the pearl bluebush, are typically associted with the occurrence of calcretes (see Site 6).

Ribbon stands of River Red Gum (*Eucalyptus camaldulensis*) occur along the ephemeral creeks of the region, sometimes with a ground flora consisting of grasses, forbs and low shrubs.

Further detail on the vegetation features of the region may be found in Cunningham *et al.* (1992) and the further references given therein.

Geological Setting

Inliers of the early Proterozoic Willyama Supergroup crop out as a series of blocks in western New South Wales and eastern South Australia and are unconformably overlain or faulted against later Proterozoic (Adelaidean) metasedimentary rocks. These blocks comprise complexely folded and metamorphosed metasediments and metavolcanics and pre- and post-folding intrusives.

This field guides covers most of the Broken Hill Block, part of the Euriowie Block and flanking Adelaidean sedimentary rocks (Figure 2). The geological history of the region is described by Stevens (1986).

Deposition of detritus derived from the Willyama Supergroup rocks of the Broken Hill Block provide information about the post-depositional history of the Willyama Supergroup. Much of this information may be related to events within the landscape evolution of the Broken Hill region. A review of much of this evidence may be found in Stevens (1986), and only some of the more significant events are outlined here.

The earliest evidence of uplift and erosion of the Willyama Supergroup rocks is seen in the detrital fragments of early Proterozoic pebbles and boulders within the basal conglomerates and fluvioglacial rocks of the Adelaidean sequence. There is no direct evidence of Willyama derived detritus in adjacent areas of Palaeozoic sediments, although it is probable that sediments were derived from uplifted parts of the Broken Hill Block during these times (Stevens, 1986). Permian glacial and marine sediments from areas surrounding the Broken Hill region indicate a possibility that the region was glacially eroded during the early Permian. This is supported by an approximate Early Permian apatite fission track date obtained from the region (Harrison and McDougall, 1981), suggesting that the rocks were cooled to below 100°C at this time, possibly due to erosion.

The Murray Basin laps onto the southern and southeastern margins of the Broken Hill Block (Figure 2). It is filled with Tertiary sediments that overlie partly marine Cretaceous sediments which can be correlated with sediments in the Eromanga Basin. The Eromanga Basin lies to the north and west of the region and is filled with Jurassic and Cretaceous sediments, mainly derived from the East and South. The Broken Hill region was probably part of a low relief landmass during the Mesozoic and a bedrock high during the Early Tertiary (see the following section on Landscape Setting). Miocene - Pleistocene fluvial and lacustrine sediments, with alluvial fan deposition, occurred in the Lake Frome area (Callen, 1977). Stevens (1986) suggests that this may relate to uplift of the Broken Hill region, particularly along the Mundi Mundi Fault

REGOLITH AND LANDSCAPE FEATURES

Landscape Setting

The Barrier Ranges trend north-south through the field area, and are surrounded by plains that extend towards the Lake Frome playa in the west, the Murray-Darling drainage basin in the south and the Lake Bancannia drainage system to the east.

The Barrier Ranges have experienced major episodes of relative uplift since the deposition of the Proterozoic sediments and volcanics of the Broken Hill Block. Some faulting within and around the Block has occurred and this is often associated with schist zones (Figure 2). Later tectonism is expressed in the landscape as a series of fault blocks that are generally tilted downwards towards the south-east. These tilt-blocks are a major regional geomorphological feature and have significant influence on the drainage and distribution of regolith materials. For instance, the low parts of the downthrown blocks typically contain deeply weathered bedrock often associated with silcretes, ferricretes and fluvial sediments, whereas the uplifted parts of blocks feature bedrock exposures and truncated weathering profiles, with greater topographic relief and only pockets of alluvium. Some of the faults which have a major influence on the landscapes are shown in Figure 2.

The region covered by this field guide forms part of the Canobolas Divide (Ollier, 1994), that separates the contemporary Murray Basin drainage and the Eromanga-Surat Basin drainage. This divide was in existence by at least the middle Eocene (Stephenson and Brown, 1989) and Ollier (1994) suggests it to have formed by down warping of the Murray Basin rather than uplift of the divide. The area from the Olary Block, through the Barrier Ranges to the Cobar region formed a bedrock high during the Palaeocene which was the provenance of the Eyre Formation in the Frome Embayment (Wopfner *et al.*, 1974). The development of this divide led to the formation of the present drainage divide presumably after a Late Mesozoic north flowing drainage (Ollier, 1994). The present drainage network and divide is shown in Figure 3.

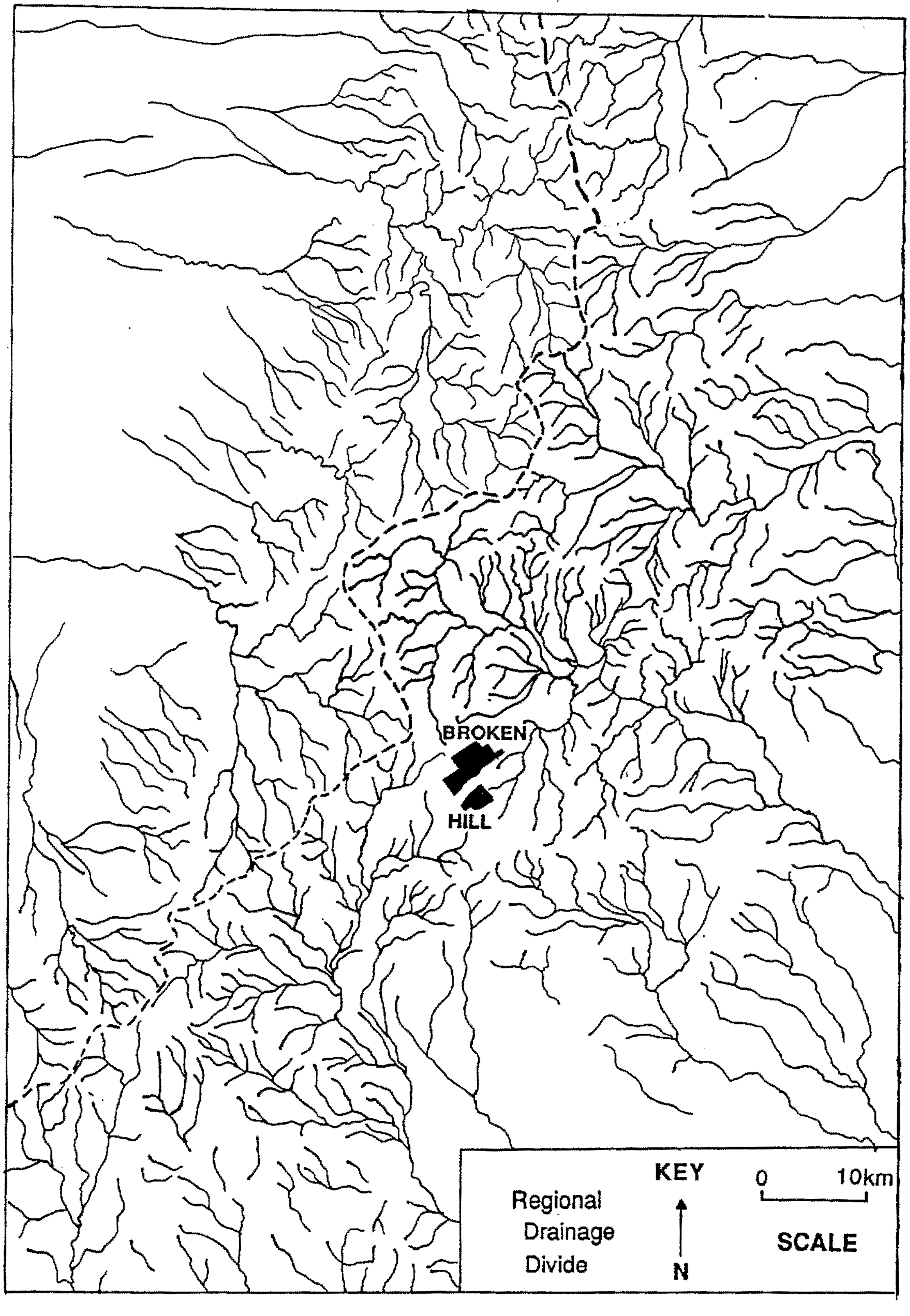

Figure 3. The drainage network of the Broken Hill region and the regional drainage divide.

Deeply Weathered Terrain

Weathering profiles in the Broken Hill region extend for variable depths below the present landsurface. Exploration drilling programs by various companies in areas to the South, East and beneath the Mundi Mundi Plains in the west typically record depths of weathering up to 50 meters below the surface. In areas where shear zones are weathered, depths may even extend beyond this. The profile usually contains an upper zone containing ferruginous mottles within a matrix of kaolinitic saprolite that overlies a kaolinitic pallid (bleached) zone over bedrock. It must be stressed, however, that many variations in the morphology of the weathering profiles exist, and it is not possible to generalise about a "typical" or "normal" weathering profile for the entire region. The profiles are often buried beneath a veneer of sedimentary deposits of varying thicknesses. Duricrusts may also be associated with various zones of the weathering profiles.

The major controls on the depth of weathering profiles are largely a function of both the underlying bedrock characteristics (eg. lithology, mineralogy and structure) and the extent of erosive truncation that has taken place. A large surface relief of the weathering front may exist and an example can be seen in areas where micaceous schists are weathered to depths of up to 50 m and fresh pegmatites and quartz veins may crop out. Prominent topographic bedrock highs may largely relate to the relative resistence of these rock types to weathering and erosion. For example the Pinnancles form prominent hills to the west of Broken Hill, largely due to the greater resistence of the quartz magnetite bedrock relative to surrounding lithologies.

The amount of stripping of weathering profiles is mainly controlled by the local tectonic history. As discussed above, the down-thrown parts of tilt blocks are normally characterised by the preservation of deep weathering profiles. The degree of stripping gradually increases towards the higher parts of tilt blocks where the terrain is dominated by bedrock exposure.

Sedimentary Deposits

Fluvial and Colluvial Deposits

Recent alluvium covers plains and valley floors associated with the present drainage network. Colluvial deposits typically occur along valley margins and are complexely associated with alluvial fans along scarps. Much of the valley fill consists of reworked aeolian sediments similar to those described from the Belarabon area by Wasson (1982), but fluvial sand and pebble deposits, derived from areas of bedrock exposure form a major component. Streams in the region are ephemeral and have channels incised into the shallow alluvial valley fill. These gullies are often filled with a narrow terrace. The litho-stratographic sequence described from the Mundi Mundi alluvial fans (Site 9) is thought to be applicable to catchments in the southern Barrier Ranges (Wasson, 1979).

Topographically high-level gravels deposited by ancient streams have been identified on a regional scale. The surface exposure of these sediments is silcreted, largely accounting for the inversion of relief that now places these sediments on hill and ridge-tops (Stops 1 and 2). Conglomerate and well-sorted, fining upwards sandstone lithologies form the most prominent outcrops. Pebble clasts are mostly well-rounded although have a low sphericity (discoidal and ellipsoid shapes) and are mostly composed of quartz with occassional silcrete and bedrock components. Finer fractions consist of subround to subangular quartz sand and kaolinitic clay. Large-scale tabular cross-strata and laminations (tabular cross-strata) may be seen in sandy lithologies and enable the determination of palaeocurrent directions (see Stop 1). Stroud & Stevens (in prep.) make a litho-stratigraphic correlation between these deposits in the Yalcowinna area (Stop 1) and the Lower Tertiary Eyre Formation as described by Wopfner *et al.* (1974). Some of these sediments, particularly in the south of the region, may also be equivalent to the Renmark Beds, that are the Lower Tertiary basal sequence of the Murray Basin (Brown and Stephenson, 1986). There is also the possibility that these sediments may pre-date the development of the Canobolis Divide and therefore be of Permian or Mesozoic age.

Aeolian Deposits

Uniform, well-sorted sand and clay pellet (parna) deposits occur over a wide range of bedrock types across the Broken Hill region. They are often deepest on the eastern side of hilltops, where under present day conditions, shallow, poorly developed soils would be expected. These features are indicative of a mantle of aeolian material that covers much of the landscape in this region. Desert Loam Soils, which occur throughout much of the region, are mainly derived from this aeolian mantle (Chartres, 1983).

The main aeolian landforms associated with these deposits are sand sheets (particularly on the Mundi Mundi Plain, Site 8), source bordering dunes, and longitudinal dunes. The source bordering dunes occur as hummocky, transverse dunes on the north-eastern banks of many of the watercourses in the region (eg. Stephens Creek and Yancowinna Creek). They are formed from the prevailing south-southwesterly winds moving sand from the dry stream beds and depositing it on the leeward bank. Longitudinal dunes occur in areas away from the predominance of fluvial outwash near the ranges. In the northwest of the region, there are W-SW to E-NE trending longitudinal dunes from the southwestern part of the Strzelecki dune field.

A study by Wasson (1982) in the Belarabon area, some 300 km east of Broken Hill shows that the aeolian contribution mainly occurred before 28,000 years BP, although it is also likely that aeolian deposition also occurred during the Last Glacial Maximum (25 - 15 ka).

Duricrusts

Calcrete

Accumulations of carbonate in the form of hardpans, pisolitic and nodular structures, mottles and pedogenic layers or horizons are widepread throughout the landscape. They may be developed in aeolian and alluvial sediments, soils, weathering profiles or directly overlying fresh bedrock. Calcareous rinds overprint many of the regolith and landscape features, such as ferricretes and silcretes, indicating that they are a relatively late feature in the landscape development of the region, probably related to increasing aridity during the Quaternary. Their prevalence in areas with aeolian accessions and development on non-calcareous igneous and metamorphic bedrock suggests an aeolian source for the calcareous material. The zones of carbonate accumulations develop by pedogenic processes such as illuviation. In localised areas of calcareous bedrock (such as the Adelaidean sequence near Torrowangee, approximately 50 km north of Broken Hill) calcareous contributions originate from the bedrock, although this source does not predominate over the whole region.

Most profiles are similar to those described from other parts of Australia (Read, 1974; Arakel, 1982; Milnes and Hutton, 1983; Milnes, 1991) in that they contain a pisolitic and nodular horizon at the landsurface, with laminar calcrete, massive calcrete and carbonate mottles successively deeper in the profile (Figure 15; Stop 6).

Ferricrete

A variety of regolith materials have been impregnated by iron oxides. They occur as a crust or as a lag or glaebule component in soils. They largely consist of a finely crystalline matrix of hematite and goethite, and occassionally maghemite. Small vermiform voids often lined with yellow goethite and clay occur in many ferricretes, and have developed largely as a result of dissolution. The main types of ferricretes in the region, as classified as ferruginised bedrock and sediments (Bourman *et al.*, 1987).

Ferruginised bedrock often occurs in the form of mottles within a weathering profile. They are best developed in profiles formed in iron-rich mafic and ultramafic bedrock (Figure 4). As well as hematite and goethite they also contain some kaolinite. The original parent material fabric is normally well preserved (for example bedrock layering may be evident through dark iron mottles) as well as primary quartz and micas. Pseudomorphs after primary minerals may also be seen. Surface lags of ferruginous bedrock fragments are derived from hardened iron mottles that have been concentrated at the surface by winnowing of the less consolidated material from between the mottles during landscape downwasting.

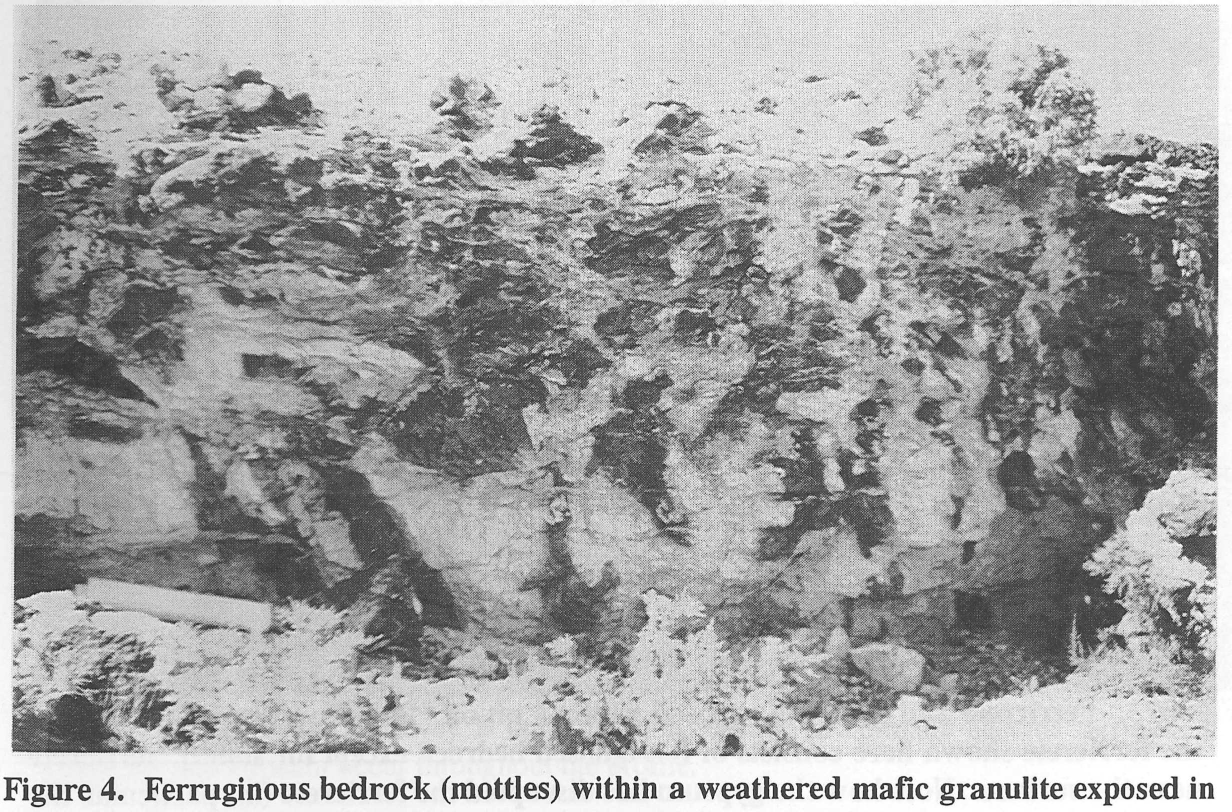

Figure 4. Ferruginous bedrock (mottles) within a weathered mafic granulite exposed in a pit wall on "Balaclava Station". (Scale 1: 50)

Ferruginised sediments contain abundant clasts of detrital quartz and lithic fragments, derived from the provenance rocks. Colluvial sediments are the most common material to be ferruginised. In some cases ferruginous and silcrete clasts are incorporated in ferricretes indicating reworking of earlier duricrusts.

Slabby ferricretes are composed of horizontally arranged plates or lenses of ferruginised material. Thin section examination show these ferricretes to be clay-rich material impregnated by iron-oxides. They typically occur flanking hill crests and at breaks in slope, usually in close association with the margins of silcretes (Figure 12; Sites 1 and 2). Bourman *et al.* (1987) relate the formation of these types of ferricretes from elsewhere in southeastern Australia to the precipitation of iron oxides at the surface of a fluctuating soil water table. This interpretation is also consistent with observations from the Broken Hill region where they occur in areas of palaeo-springs.

The presence of ferricretes either overlying or flanking silcrete capping inverted topography, and the widespread occurrence of silcrete clasts within ferricretes indicates that in many areas ferruginisation has occurred after a phase of silcrete formation.

Gypcrete

Gypsum is common in younger alluvium, soils and weathering profiles in topographic lows across the region. In some areas, such as at "Balaclava Station" (to the south of Broken Hill) and near Yanco Glen (north of Broken Hill), masses of gypsum crystals have coalesced to form up to 1 m thick horizons within the regolith. The gypcretes on Balaclava Station have precipitated along an hydromorphic barrier associated with a ferricrete (Figure 5). The subsequent crystallisation of gypsum has disrupted the ferricrete.

Figure 5. Ferricrete and gypcrete exposed within a pit on "Balaclava Station". Most of the ferricrete shown here consists of ferriginised bedrock except for slabby ferricrete near the surface. Note how the gypsum has disrupted the ferricrete (in particular the slabby ferricrete). (Scale 1:30).

Much of the gypsum appears to be related to the weathering of rocks containing sulphides (particularly disseminated pyrite), although a transported origin (eg. aeolian inputs) may also be a major contributor in some areas.

Silcrete

Silcretes are common in deeply weathered terrains of the Broken Hill region, particularly along the southern and eastern margins of the Broken Hill Block. They occur along the tops of rounded hills and ridges that are usually elevated about 30 to 50 m above the adjacent valley bottoms. They are formed by micro-quartz, quartz overgrowth and / or anatase cementation of quartz-rich fluvial sediments (e.g. Sites 1 and 2).

The most prominent silcretes exposed in the region would be classified as pedogenic silcretes according to Thiry & Milnes (1991) and Milnes & Thiry (1992). Vertical elongate blocks of silcrete, which correspond to the columnar horizon, form the most prominent parts of silcrete exposures in the area. They display numerous pedogenic features including glaebules, silans (silica skins formed by illuviation), cappings and columnar structures. Groundwater silcretes also occur in the region. They contain lesser amounts of anatase and occur lower in the regolith profile. In the the Yalcowinna region (Site 1), the primary sedimentary structures are preserved in groundwater silcretes developed within an ancient fluvial sequence.

Some silcretes contain silcrete clasts coated with successive laminae of micro- quartz and quartzose detritus, suggesting polygenesis of silcrete has occurred in the region. The cores of these pisolitic silcrete clasts may consist of rounded and sub-rounded quartz clasts. Complex rinds consisting of micro-quartz and anatase laminae occur in a concentric arrangement around many of the cores.

Soils and Associated Features

Sands (Calcareous sands Uc.1.13 and Siliceous sands Uc1.21)

These include calcareous and siliceous sands. They are typically deep, lightly coloured massive soils. These soils mainly occur in the far northwest and south of the region, where they are developed on unconsolidated aeolian and fluvial sand.

Lithosols (Uc1.43 and Um1.43)

Lithosols, or skeletal soils, are common in bedrock dominated terrains such as the higher parts of the Barrier Ranges. These soils are stoney or gravelly and lack any horizon development except for an occasional A1 horizon. They are usually sandy to loamy in texture and contain abundant broken and weathered stone.

Desert Loam Soils (Dr1.13, Dr1.23 and Dr1.33)

Profiles associated with these soils characteristically show a moderate texture-contrast with a shallow light-brown to reddish-brown loamy A horizon abruptly overlying a medium blocky, red-coloured, clay-loam to clayey B horizon. Soil reaction is normally alkaline throughout. Carbonates and gypsum occur throughout the profile.

Chartres (1983) made a detailed study of these soils north of Broke Hill at Fowlers Gap. He proposed a complex polygenetic origin, involving truncation of an older soil developed in bedrock, followed by the addition of an aeolian horizon which was then covered by a slope wash deposit. The development of these soils over a wide range of parent materials supports the idea of a transported origin.

Lags

Many soils in the region have a surface lag covering of scattered bedrock and duricrust fragments. These lags develop from a combination of processes that concentrate stony fragments at the soil surface. Processes involved include: (i) deflation of the surface by wind and surface wash, removaing fine material and concentrating lithic fragments; (ii) the upward sorting of stones by expanding soil minerals (eg. smectites) and (iii) biological activity (eg. burrowing animals, tree roots).

Gilgai.

Gilgai (Australian aboriginal word meaning a small waterhole) are small-scale surface undulations in clay-rich soils. They appear to be related to the differential expansion and contraction of the soil from periodic wetting and drying. Different patterns of gilgai occur (Hubble *et al.*, 1983), with the main types in this region being melonhole gilgai and linear gilgai. Melonhole gilgai occur extensively in topographically flat areas where desert loam soils occur east and southeast of Broken Hill. Linear gilgai are more common in areas with stoney desert loams and gently sloping topography, particularly to the South and East of Broken Hill (see Site 1). Linear gilgai are very distinctive on aerial photographs with a characteristic pattern of alternating bands of stoney rises and bare clay running sub-parallel to the topographic contours.

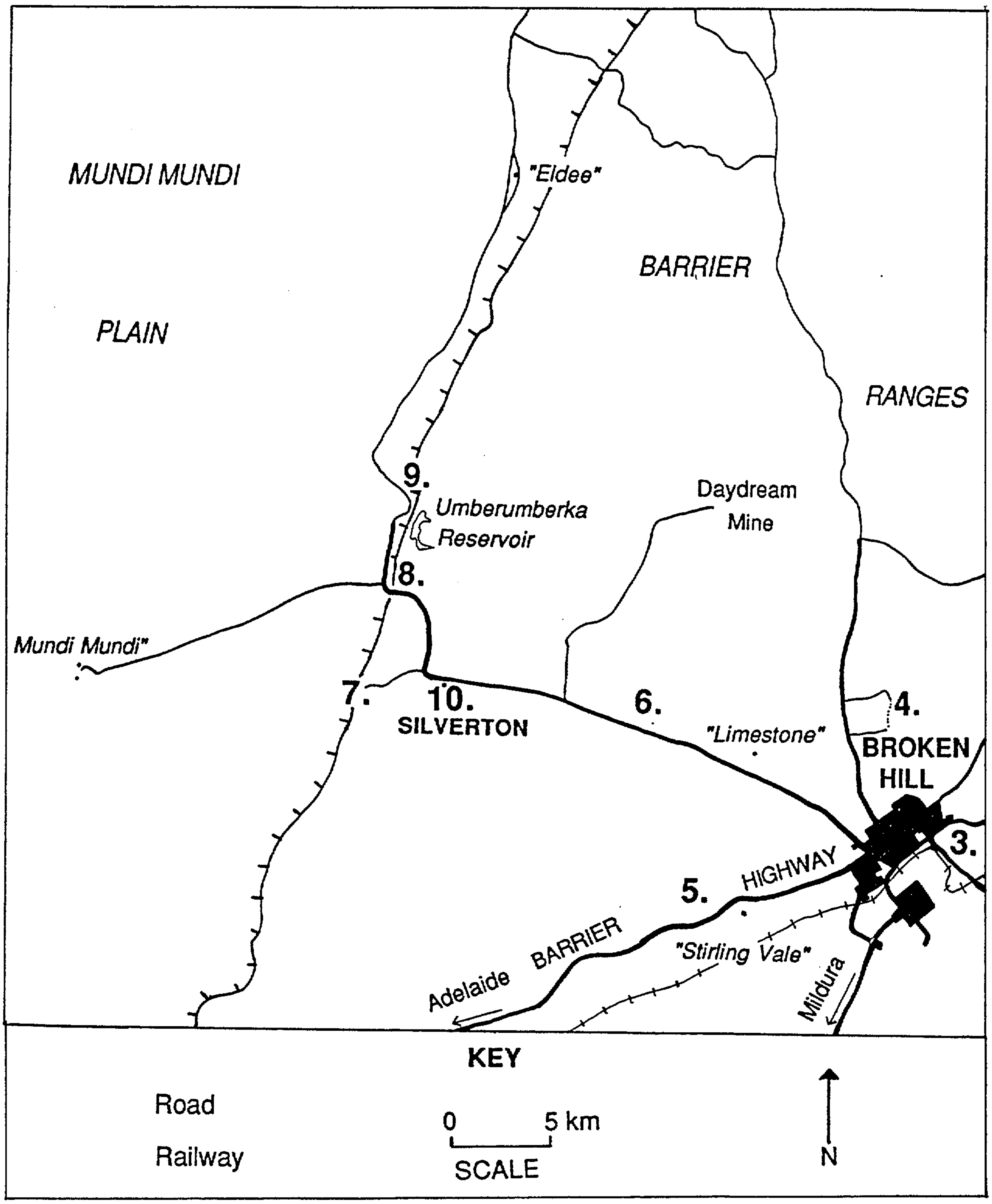

Figure 6. Broken Hill and the area west of the city, showing the location and general access roads for sites 3 to 10.

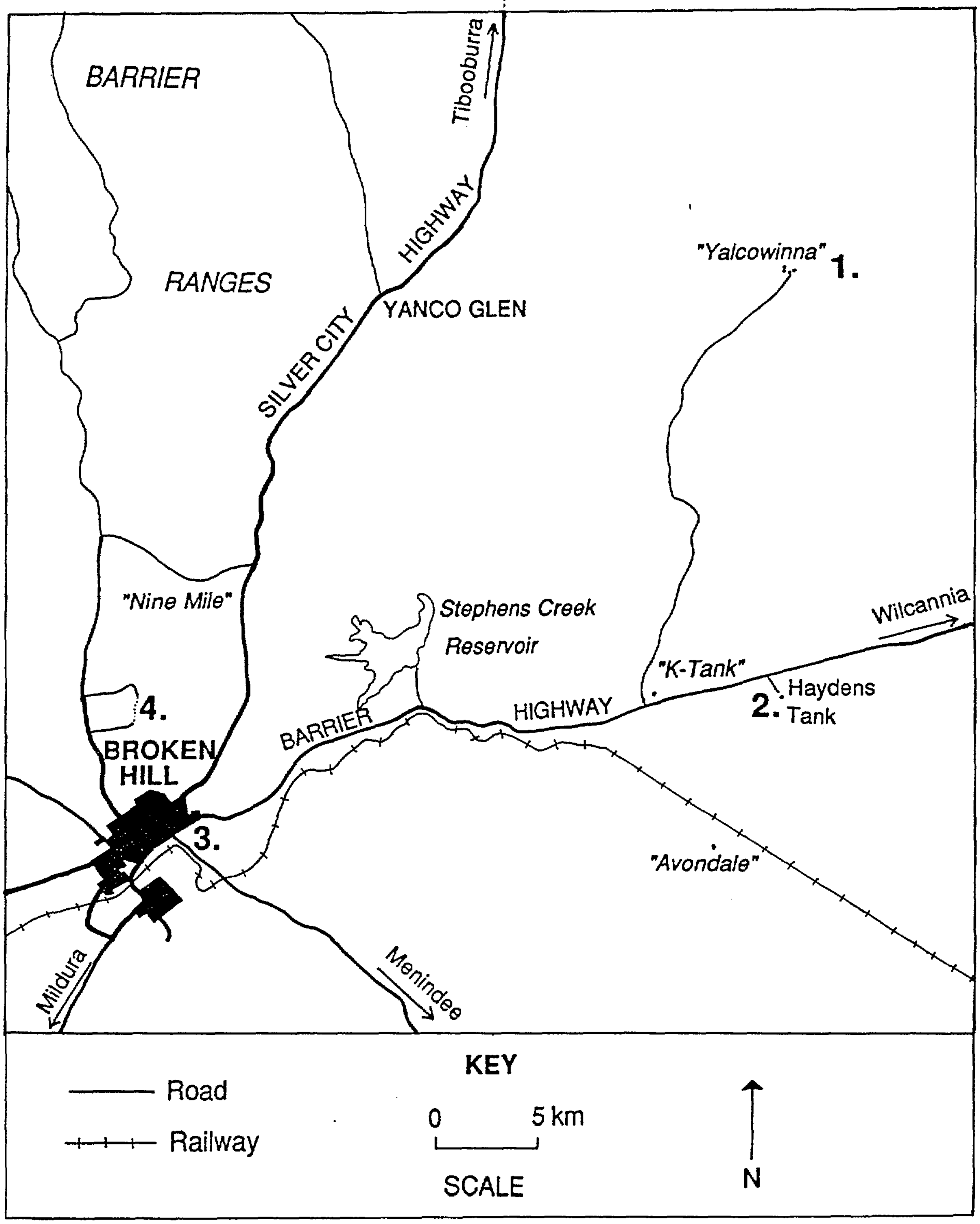

Figure 7. Broken Hill and the area east of the city, showing the location and general access roads for sites 1 to 4.

FIELD SITES

The sequence of field sites is arranged so that it follows a general east-west transect across the region. In so doing it travels from areas on the down-tilted parts of fault blocks, where deep and extensive regolith occurs, through areas of variably truncated weathering profiles and into bedrock dominated terrain in the up-tilted parts of fault blocks. The trip concludes on the western edge of bedrock dominated terrain, along the Mundi Mundi Fault, and then re-enters an area of deep and extensive regolith on the Mundi Mundi Plains. The location of field sites and access roads is shown in Figures 6 and 7.

In Transit to Site 1:

After departing the Mine Host Motel travel east down Argent Street and then follow the Barrier Highway east towards Wilcannia for approximately 35 km. At this point turn left along a dirt road to "K Tank" homestead. The terrain between here and "Yalcowinna" is largely bedrock dominated hills with a thin mantle of aeolian sediments and a combination of reworked aeolian deposits and alluvium in the valley fill. Follow this road to the gate at the front of the homested where you veer left, passing around the western side of the homested buildings. Continue north along this road through two gates. After travelling for approximately 15 km from the Barrier Highway, continue past the abandoned "Golden King" homestead buildings for another 13 km to "Yalcowinna" homestead. At the station homested take the track to the east for approximately 1.5 km to the shearing shed, where a track continues to the east. Stop at the first ridge approximately 500 m east of the shearing shed (refer to Figures 7 and 8).

Site 1: "Yalcowinna"

Site 1a : Silcrete ridge

This site is underlain by Adelaidean metasediments. The range of hills to the west and northwest consist of Willyama Supergroup rocks of the Euriowie Block. To the south is a ridge of Adelaidean metasediments with prominent outcrops of quartz veins. Quartz vein material forms a distinctive angular white lag gravel. The line of River Red Gums to the north define the channel of Yancowinna Creek, as it flows from southwest to northwest in this area before looping around to the northeast of this site to flow towards the southeast.

This hill is capped with silcrete cropping out along the northwest to southeast ridge trend. The ridge top is covered with a silcrete lag with occasional rounded reef quartz clasts. The rounded quartz clasts which occur as a component of the surface lag also occur cemented within the silcrete, indicate the silicification of an ancient fluvial deposit. The silicification has made the fluvial sediment relatively resistent to erosion and subsequent inversion of relief has occurred.

The best exposure of the silcrete can be seen on the NW side of the ridge where columnar structured silcrete occurs. The base of many of the columns consists of rounded silcrete nodules up to 20 cm in diameter, with geopetally arranged anatase drapings around the nodules. Silans of SiO_2 and TiO_2 can be seen throughout the columns.

Flanking the silcrete on the N, E and S sides of the ridge-top is a lag gravel of ferricrete. This flanking ferricrete is typical of many of the silcrete localities in the region, and is probably associated with palaeo-springs at the base of the silcrete. In some situations, however, the ferricrete may represent ferriginised bedrock from the mottled zone of the underlying weathering profile.

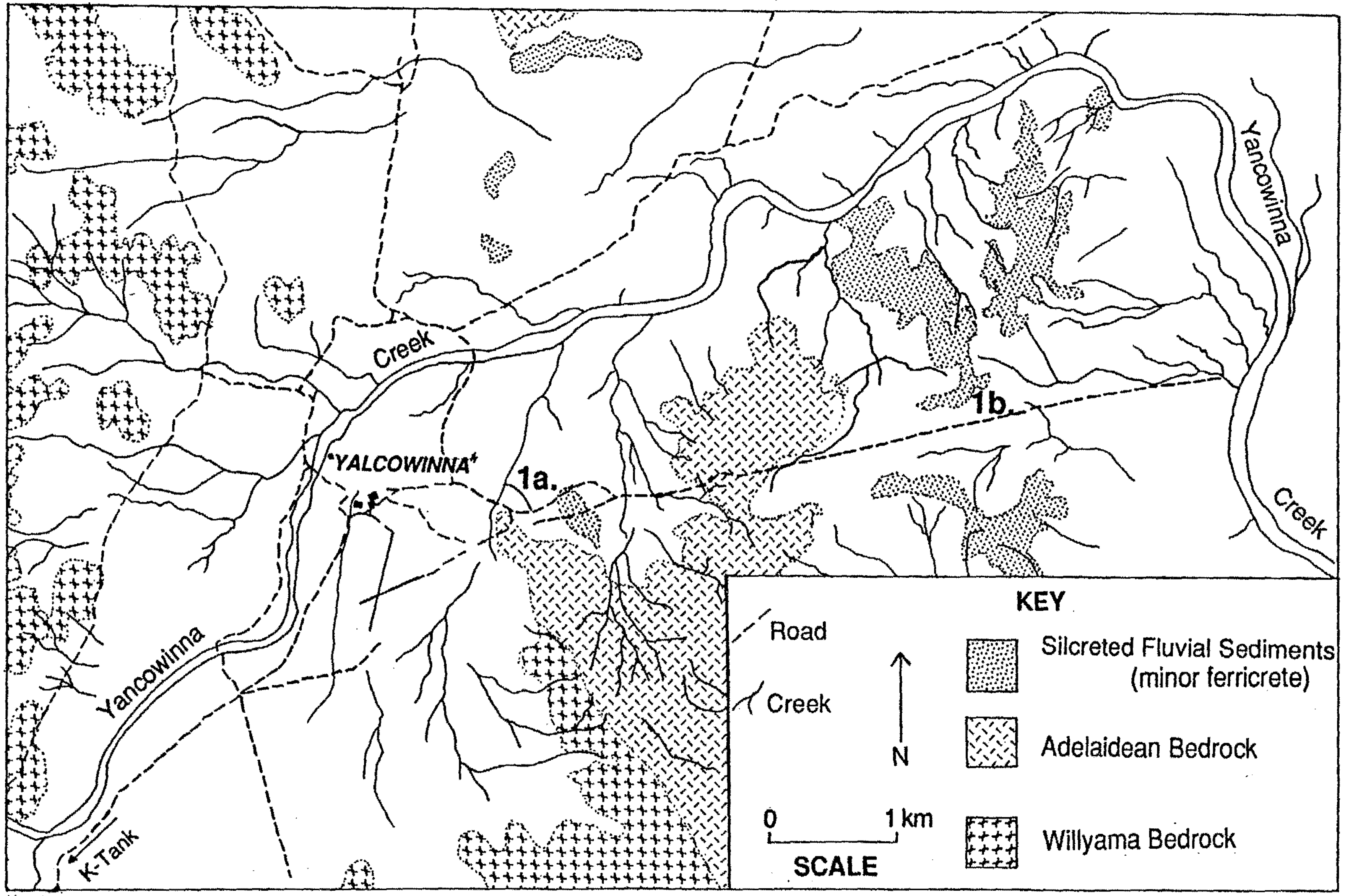

Figure 8. Map of the "Yalcowinna" area showing sites 1a and 1b as well as major bedrock and silcrete exposures.

Continue east through the gate near "Woolshed Tank" and along the easterly running track that follows the fence-line (care needs to be taken travelling along this track as in some parts it is gullied and also very sandy). After travelling for approximately 3.8 km from the last stop, park near a pair of leopardwoods (*Flindersia maculosa*) on the south side of the track. Walk approximately 200 m to the top of the hill to the north.

Site 1b: Silcreted palaeochannel

This hill is also capped with silicified fluvial sediments. Most of the exposures consist of silicified sandstones, but, in places conglomerates and surface lags of rounded quartz pebbles occur (Figure 9). The silicified sediments and rounded quartz pebble lag gravels continue along the ridge crest to the north. In some exposures, original cross-bedding and laminations can be seen. Measurements of these suggest palaeocurrent flow towards the north, in contrast to the predominance of southerly flow direction of modern channels in this area. This palaeochannel can be continuously followed northwards as far as Yancowinna Creek, beyond which only scattered exposures of these sediments occur.

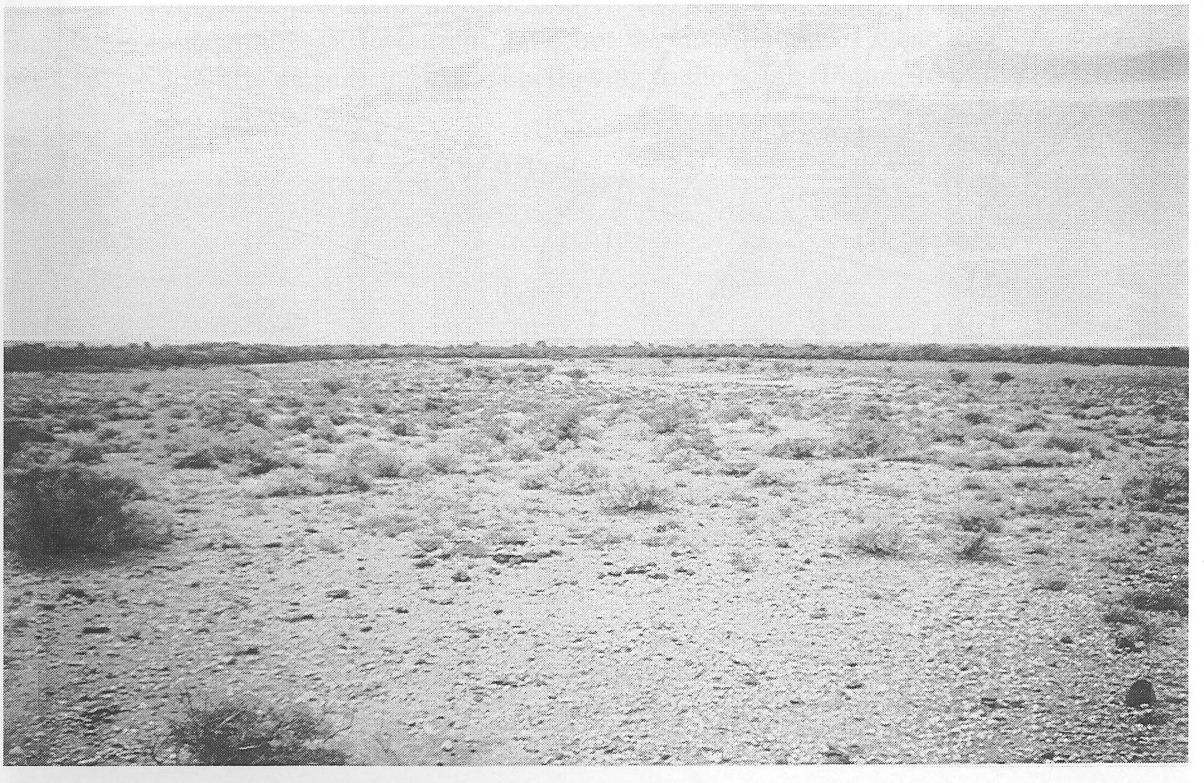

Figure 9. Looking north along the silcreted palaeo-channel at Site 1b. The white surface lag gravel consists of rounded quartz pebbles derived from the underlying fluvial sediments. In the distance, the River Red Gums along Yancowinna Creek can be seen.

Gullies incised into these sediments reveal, groundwater silcretes lower in the sequence, and also ferricretes. Exposures of fresh Adelaidean bedrock in the base of many of the gullies, show that these sediments unconformably overlie bedrock. Calcrete also occurs in this area, usually coating silcretes. In some places calcareous rhizomorphs may be seen on the surface of some silcrete exposures. These have formed from the interaction of plant roots and carbonates along the hydrological barrier associated with the silcrete.

Aeolian deposits can also be seen in this area. Source bordering transverse dunes occur along the banks of Yancowinna Creek, and an extensive aeolian mantle also covers these hills and this has been reworked into the valley-fill deposits. On the eastern slopes of the hills to the south of where the vehicles are parked, liear gilgai occur.

If time permits walk northwards along the ridge crest for approximately 1 km, observing many of the features described above. This effectively is a walk downstream along this ancient channel (shown in Figure 9).

In transit to Site 2

Backtrack past "Yalcowinna" and "K Tank" homesteads to the Barrier Highway. At the Barrier Highway turn left. Travel east along the Barrier Highway for approximately 6 km, until the highway passes over the northern flanks of a rounded hill, approximately 1 km west of the turn off to "Haydens Tank" (refer to Figure 10).

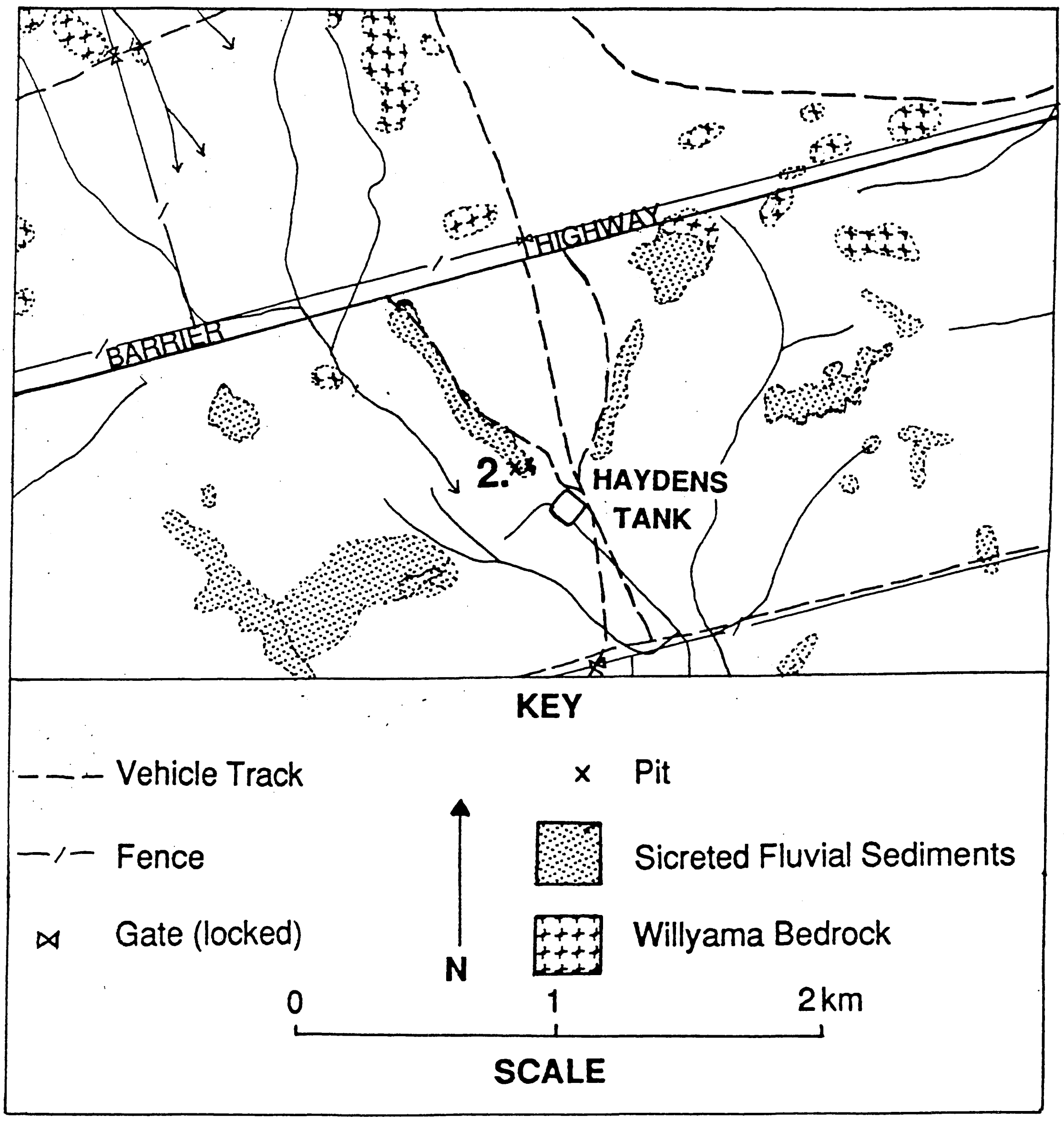

Figure 10. The Haydens Tank (Site 2) area, showing major silcrete and bedrock exposures. Minor areas of ferruginisation associated with many of these silcretes have not been shown. (Map base after Stoud, 1985).

Site 2: Hayden's Tank

The features at this site are similar to those seen at site 1b. This site can be used to further investigate some of the features at the last sites or used as an alternative if it is not possible to gain acess to the Yalcowinna sites.

The bedrock in this area consists of weathered Willyama Supergroup rocks on the northeastern edge of the Broken Hill Block. The weathered bedrock is buried beneath fluvial and aeolian sediments. To the northwest are hills of the bedrock typical of the terrain of the northeastern Broken Hill Block. The edge of the Broken Hill Block is approximately 3 km east of this site.

The hill on the south side of the road is capped by an anatase-rich pedogenic silcrete. The incorporation of rounded quartz clasts in the silcrete and their presence as a component of the surface lag indicates that underlying fluvial sediments have been silicified. As at "Yalcowinna", erosion of the interfluves in preference to the silcreted fluvial sediments has resulted in relief inversion (Figure 11). Ridges to the south and east of this site are capped with similar silcretes. Pedogenic processes have destroyed the original sedimentary fabrics, making it impossible to determine palaeocurrent data, but the distribution of these silcretes suggest the presence of dendritic meandering channels flowing to the south (Figure 10).

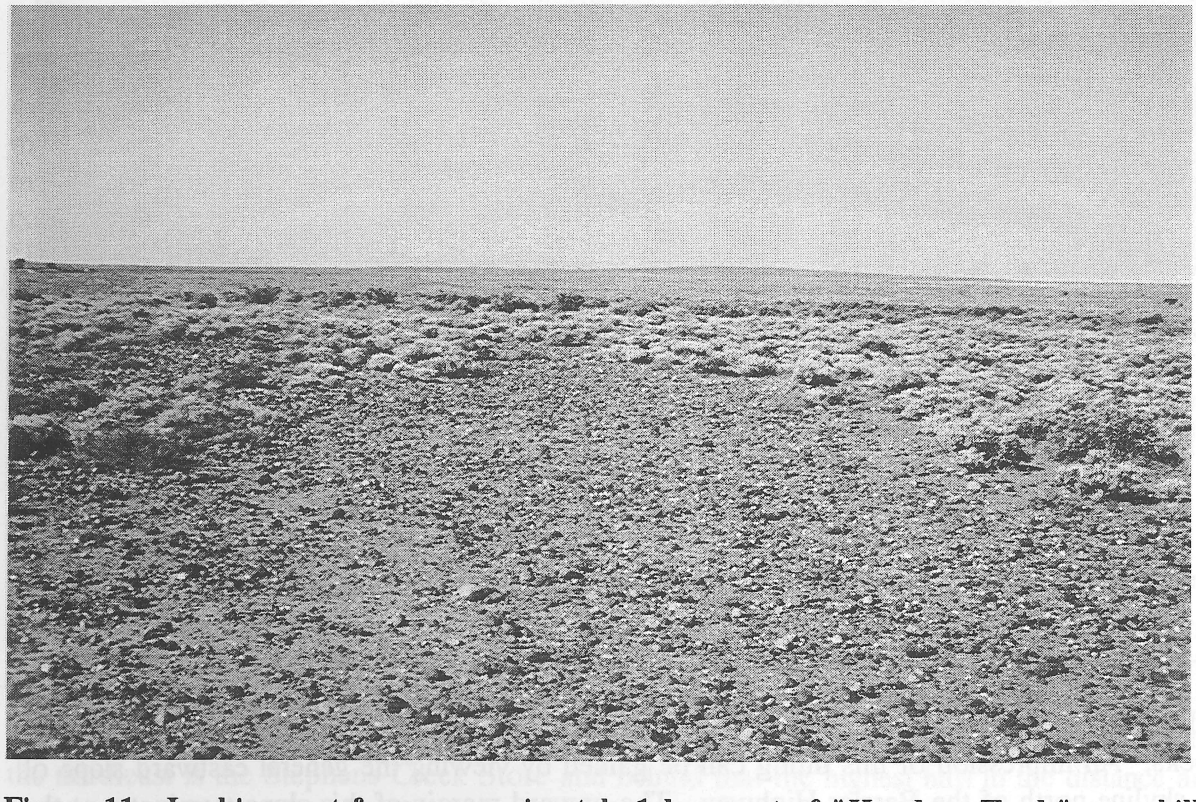

Figure 11. Looking east from approximately 1 km west of "Haydens Tank" over hills capped with sicreted fluvial sediments. The surface gravel lag in the foreground consists of slightly ferruginised silcrete.

Many of the silcretes in this area contain rounded silcrete clasts that have concentrically arranged successive coatings of micro-quartz and anatase. Slabby ferricretes may be found as lag gravels around the margins of some of the silcretes in this area, as shown in Figure 12 (as at Site 1a).

The best way to see the features of this site is to walk for approximately 1 km southeastwards along this ridge to the shallow pits near the "Haydens Tank" dam. Then return to the highway along the old vehicle track.

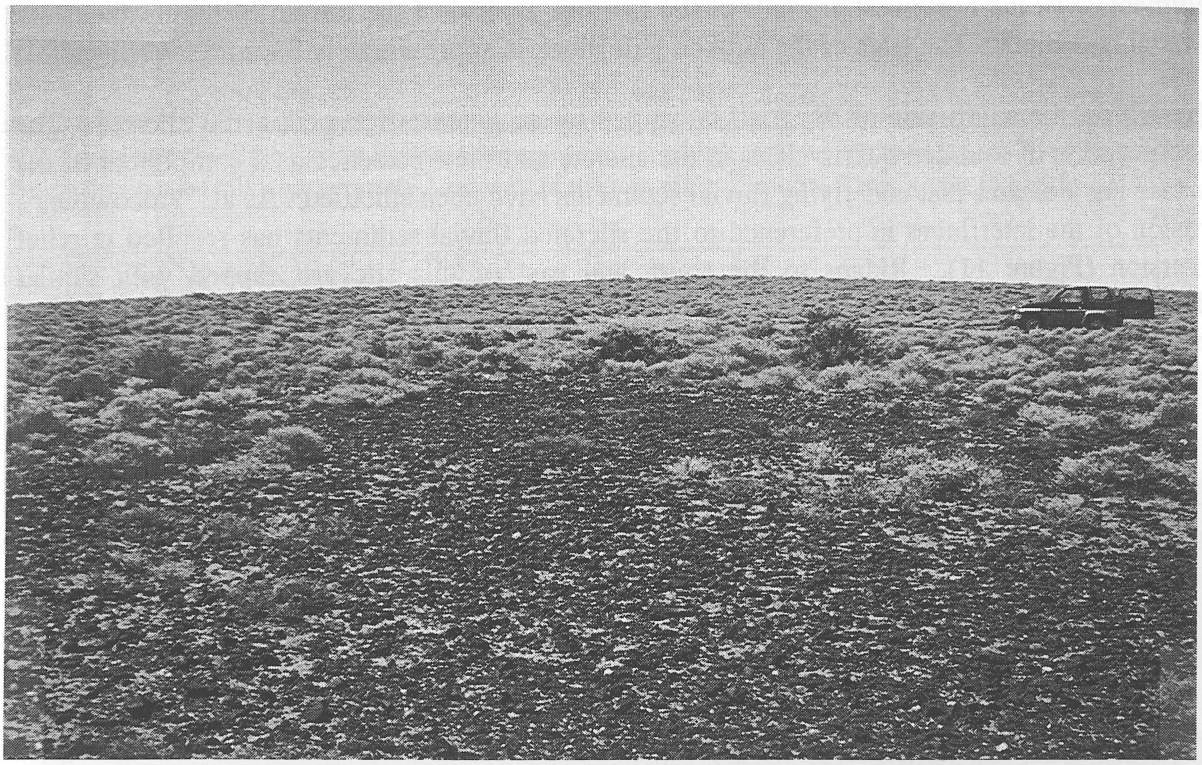

Figure 12. A surface lag gravel of slabby ferricrete flanking a silcrete capped hill on Avondale Station (approximately 3 km south of Site 2). The sharp transition from ferricrete lag gravel to silcrete lag gravel occurs at about the same elevation as the parked vehicle.

In transit to Site 3:

Return to Broken Hill by travelling west along the Barrier Highway for approximately 40 km.

On the way several features should be noted from the vehicle. As you bare travelling west you are gradually leaving areas of deep regolith and entering terrain with more bedrock exposure and greater topographic relief, because we are travelling across one of the gently tilted fault blocks. An impression of this tilting can be gained by viewing the general eastward slope of the skyline north of the Barrier Highway. The upward margin of this slope terminates at the Mulga Springs Fault where a prominent scarp can be seen on the southwestern side of Stephens Creek Reservoir.

Another feature to be seen while in transit is the source bordering transverse dunes on the northeastern banks of Stephens and Mount Darling Creeks. These dunes are composed of sand derived from the adjacent stream beds. The highway cuts through these dunes at approximately 12 and 15 km from Site 2.

After returning to the eastern side of Broken Hill, turn left along the Menindee Road. Approximately 500 m along this road there is a road cutting on the left just before a turnoff to the "Junction Mine".

Site 3: Broken Hill Lode Gossan

At the time of discovery, the gossan associated with the Broken Hill orebody was over 2.5 km long and 6-23 m wide (Plimer, 1984). Plimer (1984) reports that the average depth of oxidation of the sulphides in the orebody is 100 m, but in parts this extended up to approximately 200 m (Andrews, 1922). The black colour of the coronadite-rich gossan was thought by Charles Rasp to resemble cassiterite when he first pegged the orebody in 1883.

The oxidised zone at Broken Hill contains a great diversity of secondary minerals, that have been described in the studies of Plimer (1984), Lawrence (1968), Swensson (1977). The gossan mainly consists of manganese oxides (particularly coronadite), quartz, hematite and geothite. Small cavaties within parts of the gossan contain botryoidal and stalactitic manganese oxides, although most of the gossan is dense and massive. Within the oxidised zone below the gossan the principle minerals also include kaolinite, various halides and carbonate (particularly cerrusite).

This is one of the few remaining outcrops of the Broken Hill lode gossan. At this exposure there are spessartine garnet quartzites and sericitised sillimanite schist on either side of the quartz-coronadite gossan (Figure 13). At the southern end of the cutting a vertical joint within the sillimanite schist contains black gossanous material, mainly cemented by goethite. This material probably remobilised from the main outcrop into the joint. The gossan can be seen to continue southwards across the road towrds "Thompson's Shaft", and northwards into the "Junction Mine" area.

In transit to Site 4 :

Drive back along Menindee Road to Argent Street and turn left. Then turn right approximately 500 m along Argent Street at Iodide Street. Travel along Iodide Street for 1.1 km and turn left at Williams Street. Travel along Williams Street for 1.1 km and turn right at Kaolin Street. Continue along Kaolin Street for approximately five km. Take the first turn off to the right into the sculpture site.

Site 4: The Living Desert (Sculptures)

On the hill top are sculptures carved from Wilcannia Sandstone by sculptors from over the world. Figure 14 shows the directions of major features from the summit of this hill. To the south approximately 6 km away is the city of Broken Hill. Stephens Creek Reservoir and the scarp coinciding with the Mulga Springs Fault can be seen 15 km away to the ENE. 9.5 km to the northeast is the Stephens Creek Store and behind that the highest hills in the distance are part of the Euriowie Block. To the north and northwest are the hills of the Barrier Ranges. West of this hill is the Umberumberka Creek catchment, where we will be travelling for the most of the afternoon. The Pinnacles are obvious landscape features to the southwest, with there characteristic concave pediment slopes and quartz magnetite outcrop. Behind the Pinnacles are the Thackaringa Hills and south of the Pinnacles is the regolith dominated terrain near Balaclava Station. The regional drainage divide can be followed from the southwest to the north of this site (Figure).

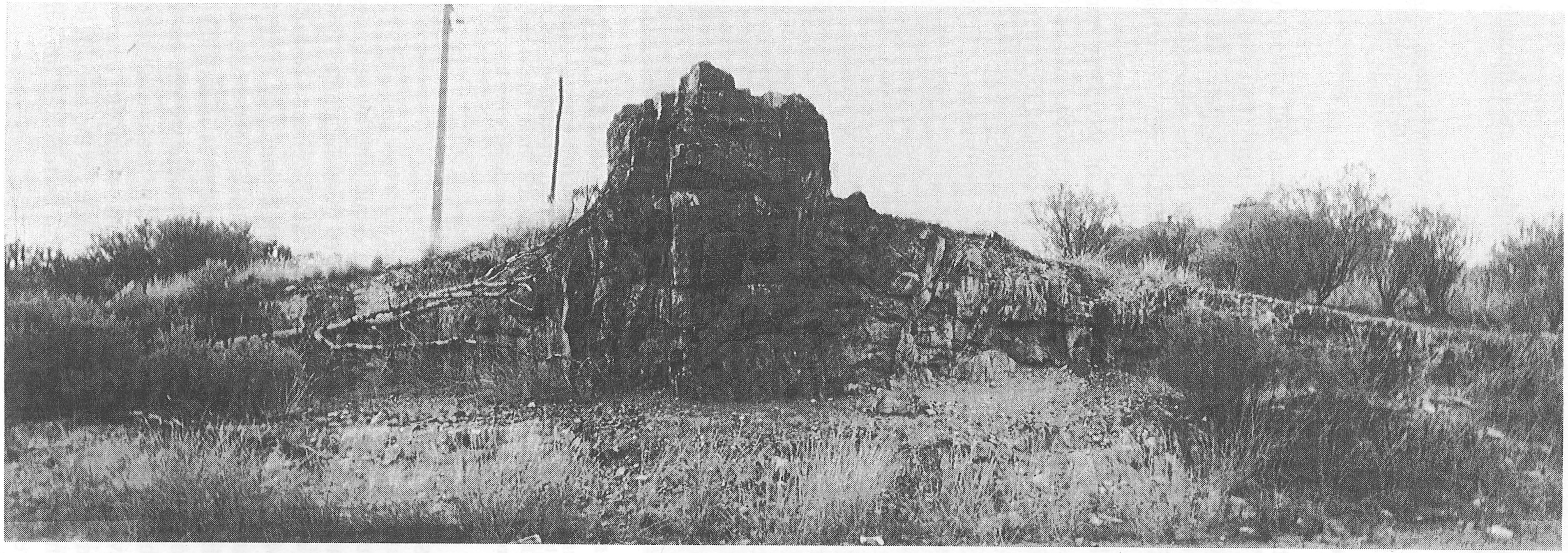

Figure 13. The road cutting showing part of the Broken Hill gossan (Site 3). The centre of the cutting consists of coronadite stained garnet quartzite. This is flanked on either side by sillimanite schist.

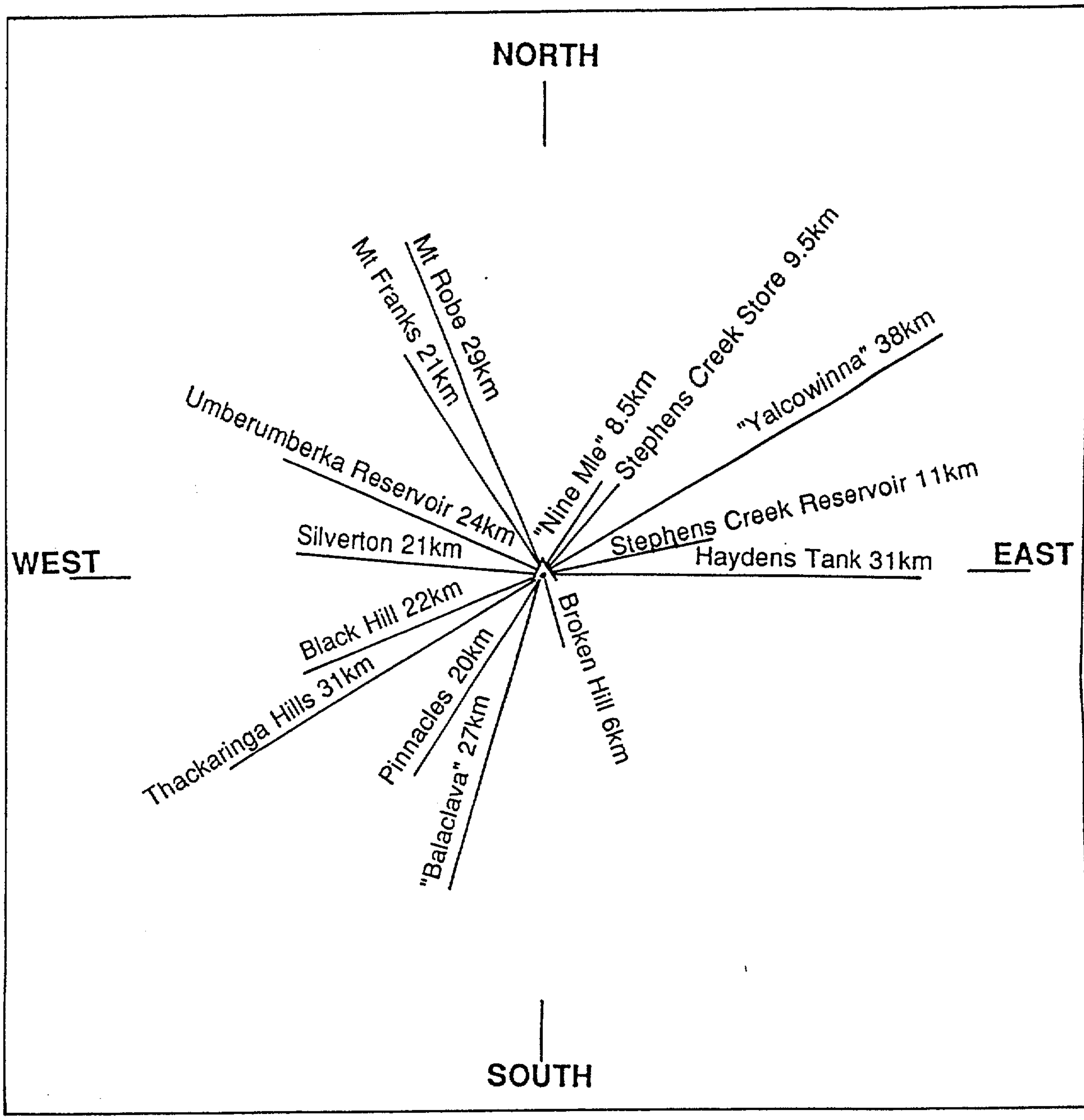

Figure 14. A rose diagram showing the direction and distance to major regional features from the summit of the hill at Site 4.

A number of concordant summits and upland surfaces can be seen from this point. Concordant upland surfaces in the Barrier Ranges have been interpreted by several previous workers (Pleistocene erosion surface corresponding to the original peaks of the 'broken hill', Andrews, 1922; "Tertiary land surfaces", Mabbut, 1972; 1973) as representing at least two palaeosurfaces. Many of these are based on rather tenuous evidence, and need to be further investigated before they can be fully accepted. Other possibilities such as lithological and structural control, drainage and lithology interactions, exhumed weathering fronts and optical illusions may also account for much of the apparent summit concordancy.

After viewing these features walk down the north side of the hill to the main picnic area, where the buses will have driven around to meet us and lunch will be served.

In transit to Site 5:

Following lunch, travel back into Broken Hill. At the intersection of Kaolin and Williams Streets turn left and follow the Adelaide Road for approximately 10 km to "Stirling Vale Station".

Site 5: Stirling Vale

This site has been studied in detail by Lulofs (1993). The field trip details of this site are given in Appendix 1.

In transit to Site 6 :

Return to Broken Hill. At the first roundabout, turn left along the Silverton Road. Continue for 15.5 km. At this point Umberumberka Creek is approximately 500 m north of the road and the windmills of "Limestone Bore" can be seen a further 100 m over the creek.

Site 6: Limestone Pits

Calcretes developed in alluvium from Umberumberka Creek are exposed in pits dug at the turn of the century to provide flux for the local smelting operations and later for use as a road base. The calcrete profiles exposed are up to three metres deep and are some of the best exposures of these duricrusts in the region. A series of pits have been dug in the area. This trip will concentrate on the western pits nearest the road, although if time permits some of the other pits may be examined. Note the association between the pearl bluebush (*Maireana sedifolia*) and areas with pedogenic carbonate within the root zone of these shrubs.

The profiles at this site typically consist of an approximately 10 cm deep surface covering of recent alluvium, overlying the typical calcrete horizons. The uppermost part of the calcretes typically consists of a pisolitic and nodular horizon, overlying laminar calcrete pans and massive calcrete horizons. Below the massive calcrete is a friable and sometimes mottled calcareous horizon, that may rest on bedrock or overlie deeper alluvium. The calcrete is mainly developed within alluvium, although in some pits calcium carbonate has impregnated the fractures between fresh bedrock. The features of the calcrete profile exposed in the south face of the most westerly pit at this site are shown in Figure 15.

In transit to Site 7 :

Continue west along the Silverton Road, through the town of Silverton. On the west side of town the road bends to the right, where there is a track departing the road at this point. Turn left along this track and follow it through the Silverton Common to the top of a slight rise near the rubbish tip. Leave the vehicles at this point and walk to the deep railway cutting immediately to the south.

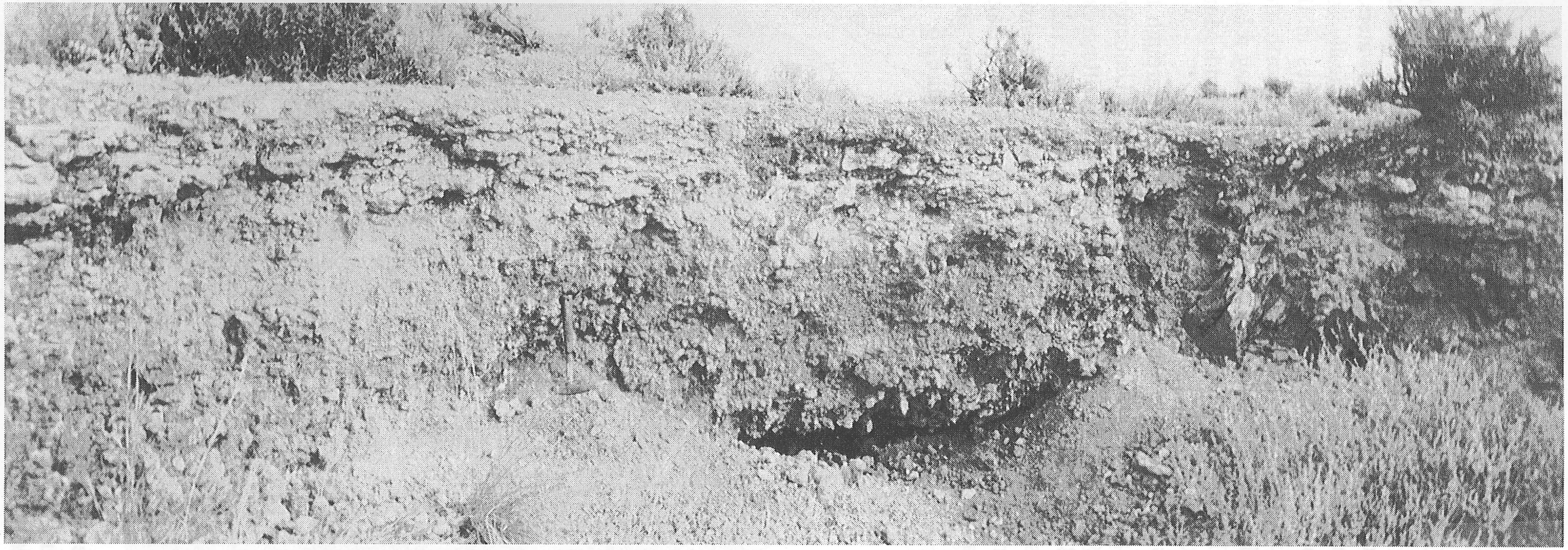

Figure 15. Calcrete exposed in the south wall of the western-most pit at Site 6.

Site 7: Silverton Railway Cutting

The terrain at this site consists of undulating hills, with bedrock largely obscured by a thin aeolian and colluvial mantle. Fluvial sedimentation is mainly restricted to localised valley fills and the broad alluvium filled valley of the Umberumberka Creek headwaters. Retrograde schist zones have a major influence on the landscape, where they typically form low lying areas such as along the Apollyon Valley and Pine Creek Schist Zones in the vicinity of Silverton to the east and continuing to the southeast of this site. To the north, the elevation of the ranges appears to gradually decrease towards the southeast. This may relate the regional southeasterly tilting of fault blocks, in this case due to uplift along the Mundi Mundi Fault.

This railway cutting provides an excellent means of viewing a section through the regolith in this area. Weathered and slightly weathered micaceous schists of the Umberumberka Schist Zone and medium-grained pegmatites can be seen in a large part of the cutting exposures. The weathering profile developed on these rocks has been truncated and near the centre of the cutting have been buried by sediment. The sediment is poorly sorted and consists of angular bedrock fragments poorly ordered within a clayey matrix. The bedrock fragments mainly consist of pegmeatite that has been weathered since its deposition. Some of the clay rich lenses have become hardened. Many of these features can be seen in Figure 16.

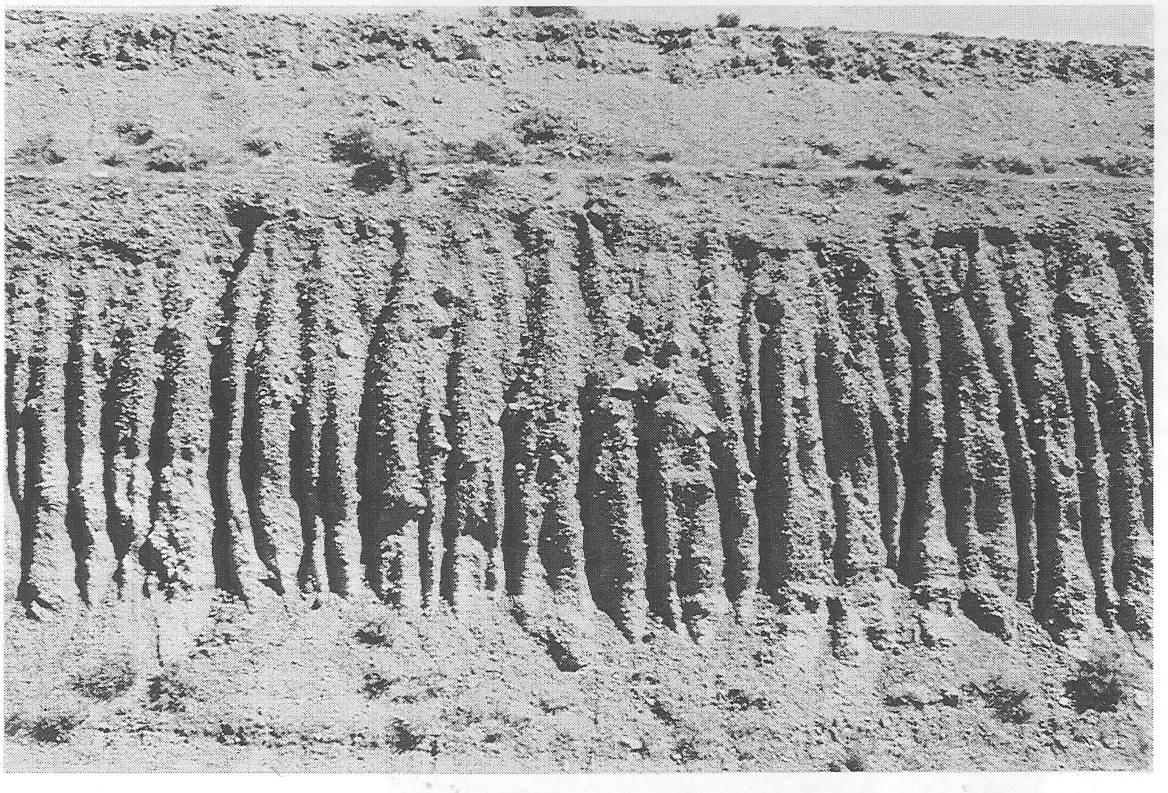

Figure 16. The centre of the south face of the Silverton Railway cutting (Site 7) showing the weathered micaceous schists and the overlying ancient colluvial deposits. (Approximate scale 1 : 100).

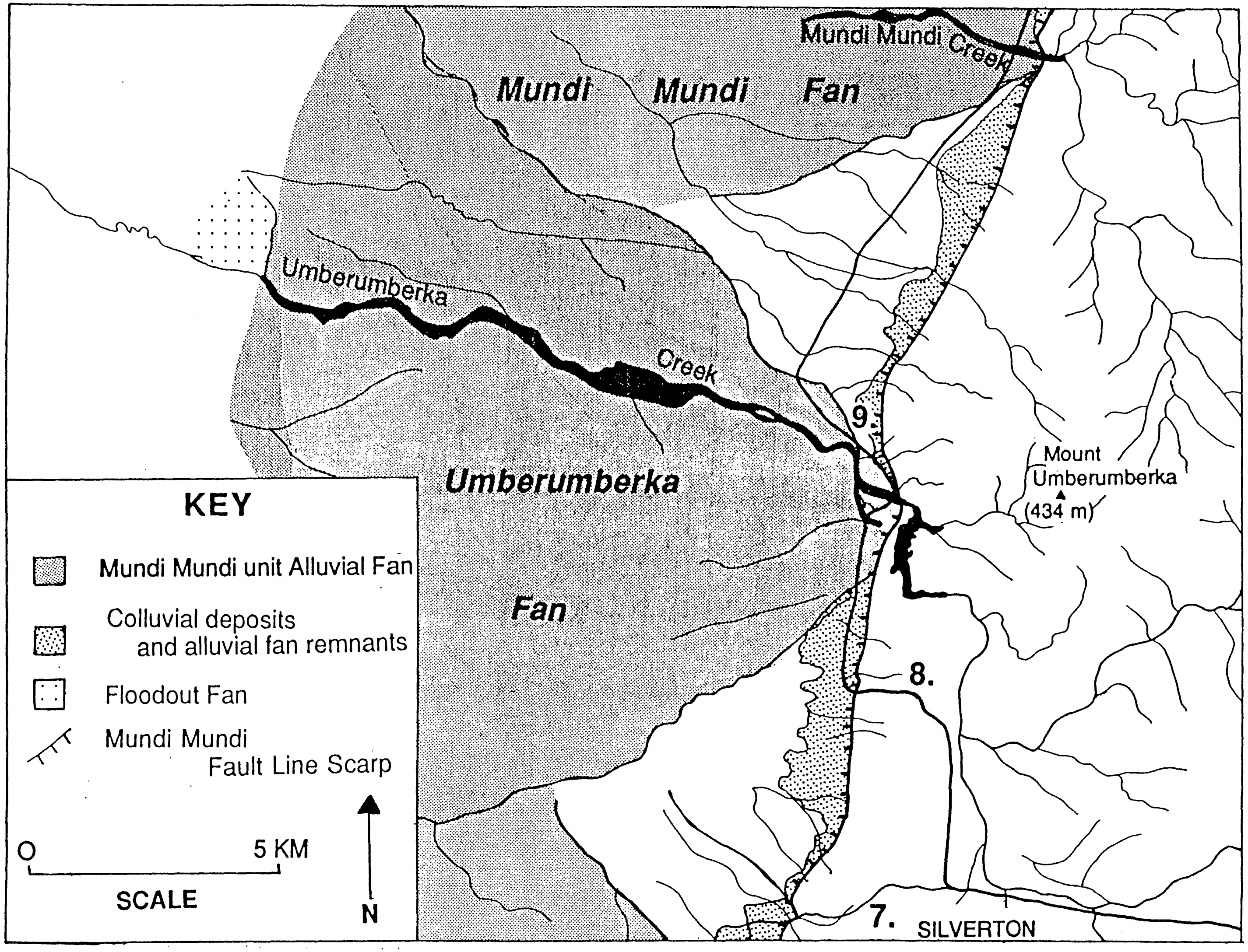

Figure 17. A map of the Umberumberka fan and surrounding features.

These sediments are colluvial deposits mainly deposited in a slurry or debris flow. Their current landscape position on a hillcrest suggests that they are ancient deposits that are not related to the current landscape. The great age of these deposits is further supported by the weathering of bedrock clasts and the partial consolidation of some of the clayey lenses. The development of these features may relate to fault movements associated with the Umberumberka Schist Zone.

There are several other features of further interest. The deposits vary in thickness considerably across the cutting. For instance on the south face the deposits are some ten m thick, whereas on the northern face they are only up to 1 m thick. This suggests a considerable amount of palaeo-relief across the width of the cutting. This relief would accomodate the development of slurry and debris flow deposits that now fill the ancient valley. Another interesting feature is that there is negligible surface expression of these deposits. This is of concern when trying to characterise regolith in areas without these types of exposures, based on surface morphology.

In transit to Site 8 :

Back to the main road through Silverton and turn left and travel for approximately 5 km, when a road sign forewarns motorists of a scenic lookout. Pullover at the scenic lookout (refer to Figure 17).

Site 8: Mundi Mundi Plains Lookout

This is a spectacular view from the western edge of the Mundi Mundi Fault Block, looking westwards over the Mundi Mundi Plains into eastern South Australia. In the distance to the West are the hills of the Olary Ranges, that consist of Willyama Supergroup rocks of the Olary Block.

This scarp is largely fault controlled. The Mundi Mundi Fault lies just to the west of the scarp that has been eroded back slightly from the faultline. The Mundi Mundi alluvial fans lie along the western margin of the Mundi Mundi Scarp. The most recent period of movement pre-dates the deposition of the alluvial fan units currently exposed at the surface, as this and previous studies (Wasson, 1979) have found no evidence for disruption of the fans.

To the south, looking along the scarp front there is a complex array of bedrock slopes, colluvial slope mantle and alluvial fans (Figure 18). These continue along the length of the scarp. Northwards along the scarp the large alluvial fan associated with Umberumberka Creek and several smaller and different age fans can be seen. These will looked at in more detail at Site 9. The channel of Umberumberka Creek is defined by the line of River Red Gums running east-west out onto the plains to the north of this site.

The plains also contain aeolian features, that become more significant away from the predominance of fluvial outwash near the scarp. Sand sheets occur across much of the plain and source bordering transverse dunes occur on the lee side of many of the stream channels. In the far northwest are the linear dunefields of the Strzelecki Desert.

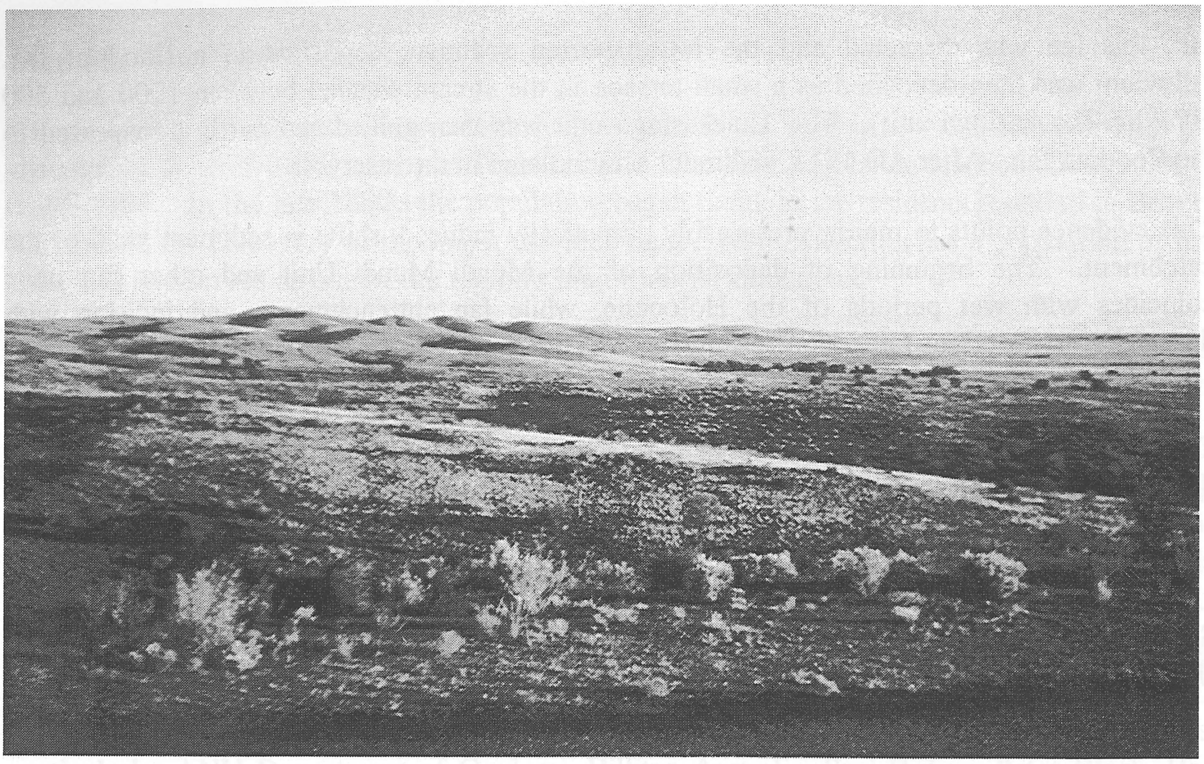

Figure 18. Looking south along the Mundi Mundi Fault line escarpment from the Mundi Mundi Plain Lookout (Site 8).

In transit to Site 9:

Continue along the sealed road for a further 5 km to Umberumberka Reservoir.

Umberumberka Reservoir is used as a standby facility to supplement Broken Hill's main water supply. It was completed in 1915 with an original capacity of 13,197 megalitres. This has been reduced by siltation and the present capacity is 8,178 megalitres.

After the revervoir, continue on for another 1 km to the point where the road just begins to leave the edge of the scarp. Leave the vehicles here and walk along the edges of the fans mantling the scarp, until you come to the next creek to the north (approximately 200 m from the road). Follow the creek downstream for approximately 100 m to where it has cut a section through a fan.

Site 9: Umberumberka Creek

At this site we will examine some of the colluvial and alluvial fans that extend along the scarp associated with the Mundi Mundi Fault (Figur 19).

Wasson (1979) studied the sedimentation of some of these alluvial fans. He was able to place some age constraints on the Late Quaternary litho-stratigraphy of the Umberumberka Fan with ages derived from radiocarbon dating of the rare organic material found in the sediments. His findings are summarised as follows:

Between 15,000 BP and 13000 BP, sediment of the Umberumberka unit was deposited in a large alluvial fan. A palaeosol caps this fan unit (the Belmont palaeosol). This overlain by the thin Korkora unit (13,000 BP), which in turn is overlain by another large alluvial fan unit deposited between 6000 and 3000 BP (the Mundi Mundi unit). Between 3000BP and 1000

BP, this fan was dissected and the retransported sediment deposited in a floodout fan. Alluvium was then deposited as a small terrace in the stream channel between 1000 and 500 BP (the Thackaringa unit). The Thackaringa unit was then gullied and partly transported to the floodout fan. After AD 1915, sediment accumulated in the reservoir.

This evidence points to major, presumably climatically induced, shifts in sediment yield of the catchment. The beginning of deposition of the Mundi Mundi Unit and other fan units coincides with wet periods of the Holocene, while fan entrenchment and incision with deposition of floodout fans occurred during dry times over the last 10,000 years. (Wasson, 1979; Wasson & Galloway, 1986).

The features examined at this site occur within the proximal parts of the fans. These parts of the fans commonly interdigitate with colluvium derived from the scarp. This can be seen in sections such as downstream of the causeway over the Umberumberka Reservoir spillway channel and within the section cut into the fans by the small creek to the north of Umberumberka Creek. Smaller fans near the scarp tend to be steeper and corser grained. Some of the small older fans have been deeply incised and had their distal portions eroded (Figure 19).

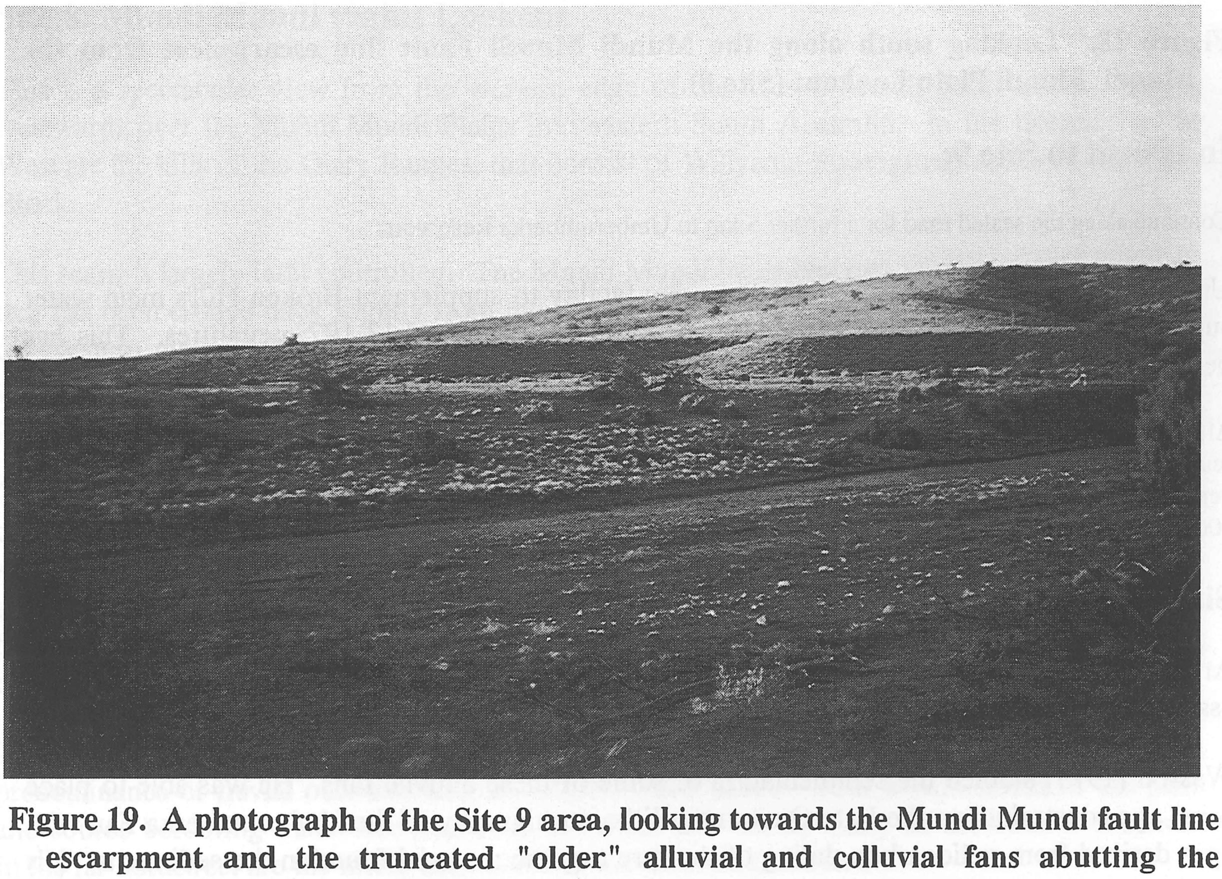

Figure 19. A photograph of the Site 9 area, looking towards the Mundi Mundi fault line escarpment and the truncated "older" alluvial and colluvial fans abutting the escarpment. At least three separate fan units can be seen in this photograph.

In transit to Site 10:

Return to the vehicles by either walking over the surface of the older fans or by following the rough vehicle track. Follow the road back into Silverton (11 km), and stop at the Silverton Hotel.

Site 10: The Silverton Hotel

The township of Silverton was established to service the mining of the lead-silver-zinc ore discovered in 1875-1876 nearby at Thackaringa. The peak population reached about 3,000 in 1885-1886. In the late 1880's the population began to fall as the residents resettled in Broken Hill due to the discovery of the major ore lode there. Now, Silverton has a population of less than 100 and serves as one of the region's major tourist attractions.

The present Silverton Hotel was the site of the Silverton Post Office until 1897. Prior to this the Silverton Hotel occupied two sites adjacent to the present hotel. In its 'hey-day' there were up to ten hotels trading in the town.

This provides a excellent place to finish the field trip and reflect upon the sites seen during the day while enjoying a taste of outback culture and a cold ale.

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Limestone Station

K-Tank Station

Stirling Vale Station

Yalcowinna Station

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APPENDIX: STIRLING VALE SITE

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Introduction

A recent study of the regolith at two sites near Broken Hill, NSW, included mapping the regolith in detail and chemically analysing near surface samples with known regolith relationships. This Honours project (Lulofs 1993) was carried out with the support of Leigh Bettenay of BHP Minerals Limited, and supervised by Bernie Joyce, and by Basil Johns of the Department of Organic Chemistry at the University of Melbourne.

Areas at Stirling Vale and Maybell were selected with the help of Ian Plimer for their minor Pb-Zn mineralisation and lack of major disturbance by mining, and Damien Lulofs began field work early in 1993. Later we looked at the areas in more detail, and found that there was little or no true saprolite present, and the regolith was a thin windblown mantle lying directly on only slightly altered rock.

Detailed regolith maps at 1:500 scale were compiled, and the regolith units described in detail in the field. Then geochemical sampling was carried out with the sampling sites related to regolith units, and laboratory analyses of samples made.

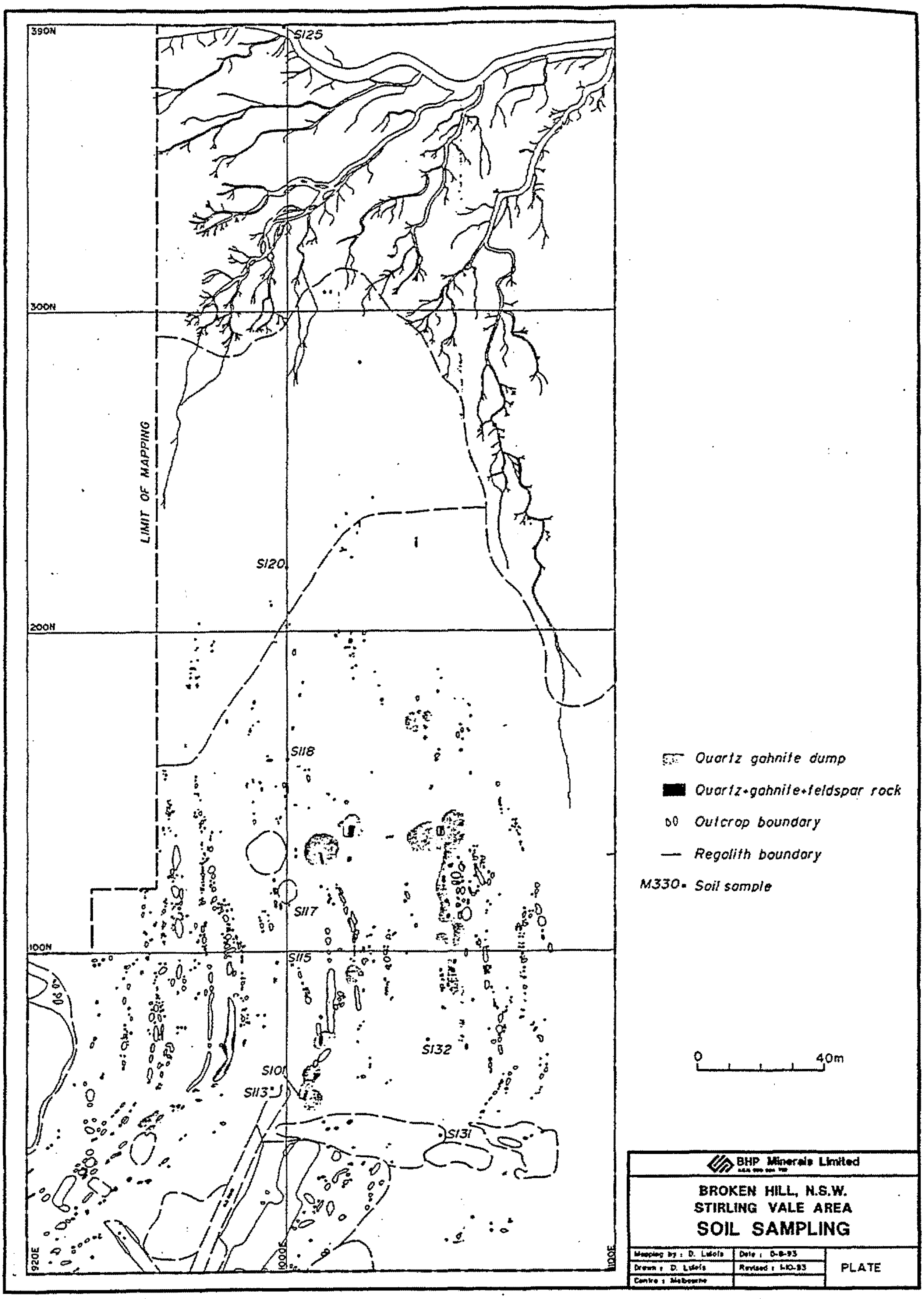
Unexpectedly, it was found that mineral signatures from the underlying rock were present in soil samples of the windblown mantle, as well as in stream samples from the bottom of the slope, although not in soil calcrete samples (Joyce and Lulofs 1994).

The excursion area

The Stirling Vale area south west of Broken Hill will be visited on the excursion. A traverse from the ridge crest near the Barrier Highway, northwards down to the foot of the slope (Figure 1) will allow an examination of the bedrock and the overlying regolith horizons (Figure 2) exposed in small excavations and the walls of shallow gulleys and stream channels.

The rocks are metasediments and metavolcanics of the Proterozoic Willyama Supergroup including quartz-gahnite rock with up to 13.5% Zn. The area is on the western limb of the Stirling Vale Syncline, with a strike of 0 to 40° and a steep easterly dip. The rocks outcrop on the ridges and upper slopes as discrete ridges, domes or knobs, and without the development of corestones (*Outcrop* regolith unit in Fig. 3). A thin coarse to medium-textured soil (Uc to Um) is found between the outcrops. Gossans are occasionally found on the quartz-gahnite rock.

A mantle of wind-blown and water-reworked sediment covers the *Mid-slope* and *Lower slope* regolith units (see Fig. 3). Soils developed on these deposits can in general be called desert loams, by comparison with soils described at Fowlers Gap, to the north of Broken Hill (Chartres 1982a & b). pH ranges from 7 to 9.5.



390N
300N
200N
100N
920E
1000E
1100E
LIMIT OF MAPPING
S125
S120
S118
S117
S115
S101
S113
S132
S131
Quartz gahnite dump
Quartz+gahnite+feldspar rock
Outcrop boundary
Regolith boundary
M330• Soil sample
0 40m
BHP Minerals Limited
BROKEN HILL, N.S.W.
STIRLING VALE AREA
SOIL SAMPLING
PLATE

Figure 1. (Opposite) Stirling Vale area, on the north side of the Barrier Highway southwest of Broken Hill, NSW, showing north-trending outcrops of quartz-gahnite rock and other rocks (principally amphibolite, pegmatite, and psammopelitic metasediments) on the upper slope, with regolith unit boundaries and soil sampling sites, and drainage lines below the foot of the slope. (Note that the sides of the map run approximately north-south, with north to the top, and a local grid has been used on this map).

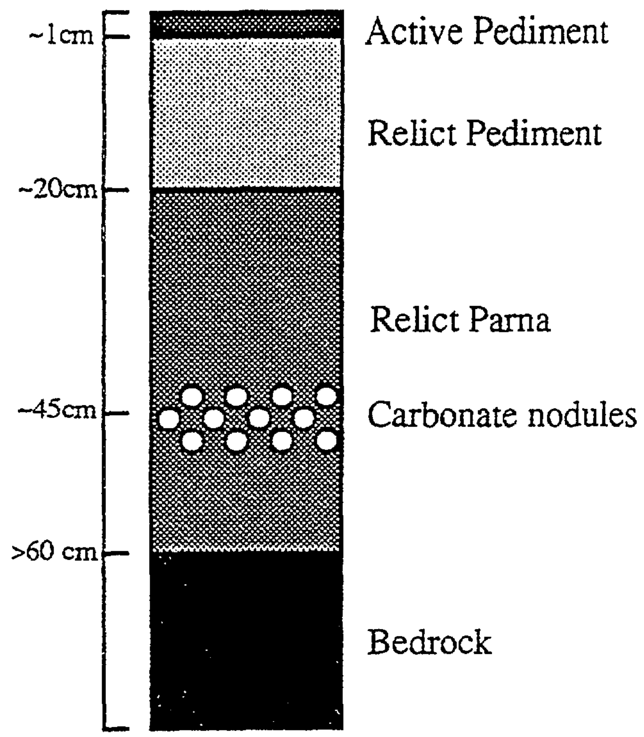


Figure 2. Generalised regolith profile, showing regolith horizons. (Note that "pediment" is used here to describe a lower slope mantle derived by water erosion from further upslope; thus "relict pediment"= slope mantle due to past deposition by running water, "active pediment" = slope mantle due to present deposition by running water, perhaps initiated by European settlement.)

On the ridges and upper slopes disturbed areas have been mapped as the *Anthropogenic* and *Burrowed* regolith units. These are areas disturbed by human activity (prospecting and road construction) or bioturbation (rabbit burrowing) and the soil and regolith horizons are buried or disturbed.

Vegetation is sparse. The acacias Mulga and Dead finish are found on the upper slopes and also on the drainage lines. The footslopes are treeless, but carry saltbush and bluebush, copperburrs, Butterbush, bottlewashers and Silvertails, and Kerosene grass and Windmill grass.

The wind-blown deposit is a parna, a dark red silty clay with angular blocky structure and well-developed clay skins, and dominantly of quartz, muscovite, albite, kaolinite and amorphous iron oxides. The parna unit has a generally abrupt contact with the underlying rock.

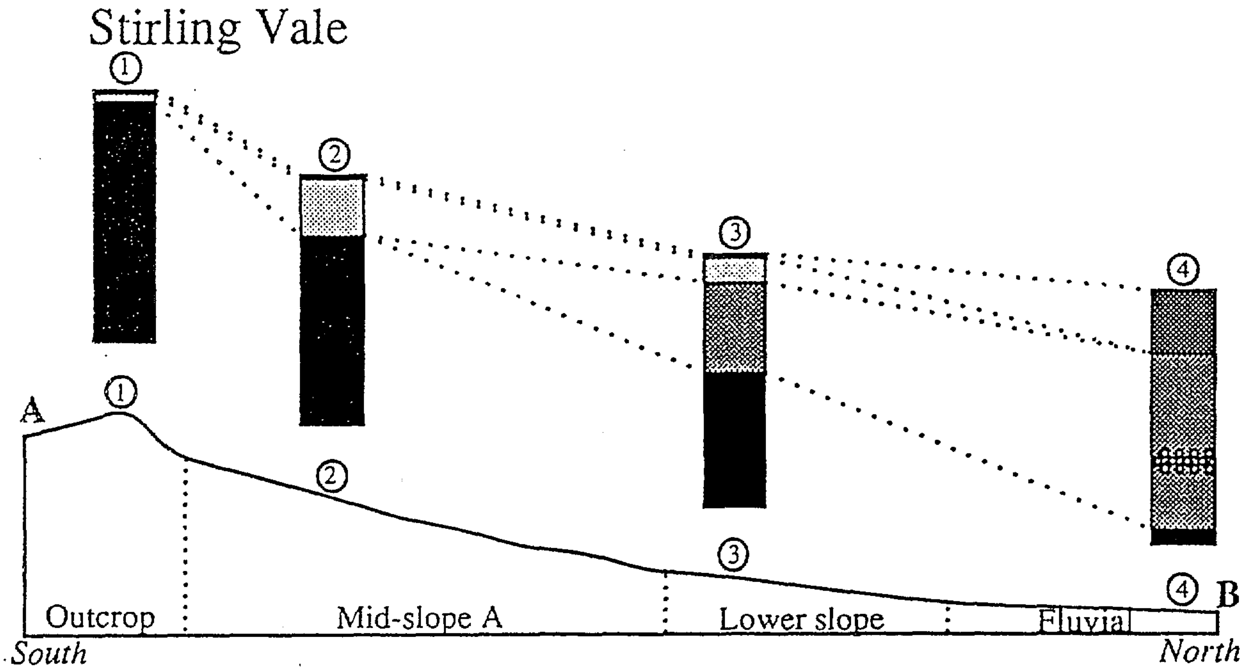


Figure 3. Cross-section of Stirling Vale study area, extending from south to north, over approximately 350m, along the local 10000E grid line (see Figure 1). Vertical exaggeration = 5x. Slope varies from 0 to 7°. The positions of the four major regolith units of Figure 1 are shown, with schematic profiles (see Figure 2 for key).

From south to north, the regolith units are:

1. ***Outcrop*** **- bedrock and loose rock fragments**
2. ***Mid-slope A*** **- wind-blown and water-reworked sediment, often thin, with local rock outcrop common**
3. ***Lower slope*** **- wind-blown and water-reworked sediment to 2m**
4. ***Fluvial*** **- extensive stream sediments with interbedded wind-blown deposits, thickness up to 2m, and locally gullied and channelled.**

Main regolith units

Deposits of reddish brown sand to silty clay sand, often with no soil structure, and with pebbles throughout, are interpreted as water-laid, and the result of reworking of the upper slope mantle which has been dominantly parna. The deposits include an older and a modern unit. On the *Mid-slope* regolith unit (Fig. 3) a modern deposit of sand, less than 1cm thick, overlies an older and thicker water-laid deposit, which in turn rests on the parna deposit. The soil is Uniform, of medium to coarse texture, Uc to Um, and the area carries abundant grass.

On the *Lower slope* regolith unit, below a break of slope, the water-laid units thicken. Together the modern and older water-laid units, and the underlying parna unit, may be up to

2m thick. The soil can be classified as Duplex, with a red clay B horizon (Dr), and soil carbonate nodules are found at ca 40 to 50cm. The area is characterised by saltbush.

Tributaries of Stirling Vale Creek form the lower part of the study area (*Fluvial* regolith unit in Fig. 3). Up to 2m of stream sediments and interbedded parna and water-laid slope deposits have a Duplex soil with a red clay B horizon (Dr) and well-developed soil carbonate nodules at ca 40 to 50cm. Saltbush is rare and scalding is common on the bare ground between the shallow gulleys and stream channels.

Analyses

Rock, soil and sediment samples were analysed using SEM, XRF and ICP-AES and sequential leaching techniques applied. It was found that base metal occurrences in the regolith of soils and stream sediments were of Cu and Zn, and As and Cd pathfinders. These were associated both with amorphous iron oxides and also with silicates (presumably fragments of quartz-gahnite rock). Secondary minerals containing base metals were not found.

The dispersion haloes show variations within the shallow regolith, both in depth and laterally, which indicate their source is the quartz-gahnite rocks. We conclude that the haloes are due to both chemical (water-borne) and physical (rock fragment) dispersion.

Questions raised by this study

How old is the aeolian mantle? And has there been more than one accession of aeolian material?

How did the dispersion haloes move into the transported regolith in the arid conditions of the Broken Hill area? And what are the implications of this finding for future study of mineral signatures in other transported regolith e.g. alluvial fan, stream and lake deposits, and for the planning of geochemical sampling programs? For example, how thick can a transported mantle be and still allow the signature through?

We thank Keith Allison of "Stirling Vale" for his help in access to his property.

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