Excursion guide, silcrete field workshop, South Australia, August 19–30 1985

AR Milnes, MC Benbow, RS Robertson and MJ Wright

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EXCURSION GUIDE

SILCRETE FIELD WORKSHOP

South Australia

August 19-30, 1985

AR Milnes[2], MC Benbow[1], RS Robertson[1] and MJ Wright[2]

1 South Australian Department of Mines & Energy
2 CSIRO Division of Soils

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(Text from original excursion notes. See also Department of Mines & Energy SA Report Book 86/00058)

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Includes: Notes made and photographs taken during the Field Workshop; Google Earth location coordinates for waypoints, landmarks & sites; List of selected references to post 1985 research studies.

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PREFACE

This Silcrete Field Workshop developed from a comment made by Graham Taylor at the CECSEA Conference in Canberra in 1981, at which several papers on silcretes were presented. It seemed at that time that considerable benefit could be gained by having people from several related disciplines look at silcretes in the arid zones of Australia where there are good exposures of these materials.

The opportunity to do this in northern South Australia subsequently presented itself because of the active mapping programme of the South Australian Department of Mines & Energy. Recently published geological maps at 1:250 000 scale including BILLA KALINA (Ambrose & Flint 198la) and COOBER PEDY (Benbow 1983) incorporate invaluable data on the nature and distribution of Cainozoic sediments and associated silcretes, soil materials and landforms not previously available. The extensive occurrence of opal in the northern regions has also been the subject of investigations by the Department (Barnes & Scott 1979; Carr et al. 1979; Barnes & Townsend 1982). Although there has been a long term interest in silcretes and silicification in the Department and in other research organisations including CSIRO Division of Soils, these recent investigations really provide the foundations from which to develop detailed studies of the materials.

There is still considerable controversy about the ages, stratigraphic significance, origins, and environments of formation of silcretes in South Australia, even among geologists in the Department who have mapped adjacent regions. Some of the arguments have been summarised by Callen (1983). This is a healthy state of affairs, and provides us with some confidence that the critical observations are yet to be made. As field mapping of regions in which silcretes are well represented is continuing in the northern and western parts of the State, it is an opportune time to actually see the work in progress and to examine the important sites. Background information is summarised in the following notes, and with regard to the sites we have selected, is gleaned mainly from the current work of Mark Benbow and Roger Callen. We don't presume to have many answers to the questions you may have about the sites. Rather, we hope that the discussions generated by such a gathering of people from several disciplines about the silcretes, sediments, soils and landscapes may point towards cooperative research possibilities that individually we have not perceived.

INTRODUCTION - LEG 1

The tectonic framework of South Australia is illustrated in Figure 1.

Leg 1 covers a wide range of geological and geomorphologlcal features on the western margin of Lake Torrens and northwestwards to Coober Pedy. The region to be traversed is essentially that illustrated in Figure 2 and described by Ambrose & Flint (1981b).

From Port Augusta northwards, Late Proterozoic bedrock is conspicuous in plateaux and mesas and consists of quartzites and sandstones of the Tent Hill Formation. Older sedimentary rocks of the mid- to Late Proterozoic age form the tablelands west of Pernatty Lagoon between Woocalla and Mt Gunson. These units are all part of the Stuart Shelf and Gawler Platform sequences which are essentially undeformed and overlie unconformably the crystalline basement of the Gawler Craton to the west. To the east, equivalent Proterozoic sediments in the Adelaide Geosyncline orogenic belt form the Flinders Ranges.

South of Woomera, outliers of Early Cretaceous sediments appear as bleached siltstones and shales in diggings and roadside scrapes. These become increasingly important in the regions north of Woomera as the margin of the Eromanga (Great Australian Basin) is approached and include the Cadna-owie Formation and the overlying Marree Subgroup. The Cretaceous sediments are commonly exposed as bleached and weathered materials in breakaways at the margins of plateaux and tablelands. Their presence is also indicated by rounded boulders of quartzite and other exotic rock types scattered over the stony landsurface. The clasts, weathered from the Marree Subgroup sediments, are of uncertain origin but may have been erratics derived originally from the Late Palaeozoic glacigene sequences. In the same region, bedrock outcrops are subdued and consist mainly of Cambrian limestones and shales (Andamooka Limestone, Yarrawurta Shale). Between Stuart Creek opal field and Coober Pedy, bedrock is rarely encountered.

The Cretaceous sediments were deposited in the southern part of the Eromanga Basin in a marginal marine environment. The Marree Subgroup consists dominantly of dark coloured, montmorillonitic, carbonaceous and pyritic muds with sandy and conglomeratic intervals and scattered boulders of quartzite and other rock types. The sediments are characteristically weathered to white, kaolinitic claystones. Barnes & Scott (1979) reported rapid alteration of Marree Formation sediments once exposed in excavations, and so the bleaching and kaolinisation may not reflect pervasive deep weathering. The Cretaceous sediments contain the main opal deposits of the region (Barnes & Townsend 1982).

The Tertiary sequence which hosts the silcretes occurs predominantly in a system of low, north-south trending ridges. The sediments are mainly sands which rest on a gravel layer marking the contact with the underlying Cretaceous sediments. They are assigned to the Mirikata Formation (Mount Sarah Sandstone of Barnes & Scott (1979), and a number of members are recognised depending on local facies relationships (e.g. Watchie Sandstone Member, Danae Conglomerate Member). Barnes & Scott (1979) considered the sands to be of fluviatile origin and of Miocene or Pliocene age, related to drainage patterns associated with the shrinking of a Miocene lake centred on the area between "*Millers reek*" and "*Billa Kalina*" homesteads. Clay and dolomite sediments (Billa Kalina Clay and Millers Creek Dolomite Members of the Mirikata Formation) which are well exposed in the tablelands near "*Billa Kalina*" homestead represent the final phases of deposition in this lake. An earlier sequence of sediments incorporating a so-called "reed mould silcrete" and a significant fossil flora has been described by Nicol (1979), Ambrose et al. (1979) and Callen (work in progress). Ambrose & Flint (1981a,b) regarded the ridges as strandlines developed at still stands during regression of the lake shoreline and suggested that they were preserved by selective silica and carbonate cementation. A widespread Palaeocene to Eocene succession of fluvial sands, carbonaceous silts and pebble conglomerates (Eyre Formation) occurs in the region and also hosts silcretes (Wopfner et al. 1974; Callen 1983). However , the relationships between Eyre Formation and Mirikata Formation (formerly Mount Sarah Sandstone) are still controversial, and it is possible that they are partly equivalent (Callen 1983).

Our attention during the Workshop will be focussed on the characteristics of the silcretes within the Tertiary sequences, and on discussions of the field relationships and other criteria which might be used to interpret processes and environments of formation.

TRAVERSES AND SITE DESCRIPTIONS

1. PORT AUGUSTA TO BEDA HILL (SITES 1 & 2)

(Refer to PORT AUGUSTA and TORRENS 1:250 000 map sheets)

Set trip meter to zero

We depart Port Augusta west (32.469874° lat; 137.742791° lon; elev 23m) and travel along Highway 87 through pans and low lunettes developed in Quaternary sediments of ancient Spencer Gulf (landscape unit DD2, Table 1) for about 7km. The vegetation is principally bladder saltbush (*Atriplex esicaria*). Proterozoic sediments of the Stuart Shelf form conspicuous mesas to the west, while equivalent sediments in the orogenic belt form the Flinders Ranges to the east.

Between 7-22km low tablelands with stony lags form part of landscape unit BB2. The vegetation is mainly shrub steppe. Land use is confined to sheep grazing. The Woomera water pipeline and the Transcontinental Railway (main east-west line, and also the line to Alice Springs) are adjacent to the road.

From 22km, in landscape unit DD1, the vegetation is initially an open woodland of western myall (*Acacia sowdenii*) with occasional mulga (*Acacia aneura*), and a bluebush (*Maireana astrotricha*) understorey. The plateau remnant visible to the east at about 38km is Uro Bluff, with an elevation of 277m. Hesso Dam and the turnoff to "*Yudnapinna*" pastoral property (bequeathed to the University of Adelaide Waite Agricultural Research Institute) occur at about 49.5km. The country here is slightly elevated and more undulating, with broad dunes and local stony tablelands. The vegetation is shrub steppe and includes *Bassia* spp., saltbush and bluebush. Mulga appears at about 56km - the vegetation here is open woodland. Dunes are well exposed in road cuttings.

The turnoff right to Beda Hill occurs at about 76km, immediately south of Bookaloo railway siding (~31.898607° lat; 137.361576° lon). The track passes through myall woodland towards Dutton Bluff (280m) and forks to the north towards Beda Hill at about 94km approaching the shores of Lake Torrens in landscape unit Na1. The lake has a saline and gypseous surface crust. Locality 1 is on the eastern flank of Beda Hill (200m) at about 105ka.

LOCALITY 1[1]

This site (~31.839524° lat; 137.620204° lon; elev 63m) is thought to be part of the scarp foot zone (Fig. 3) of an ancient pediment (Twidale et al. 1970). It contains large blocks of Proterozic sediments (Simmens Quartzite and Corraberra Sandstone Members of the Tent Hill Formation) which appear to have slumped from the edge of the high level Arcoona Plateau. Distinctive titania-rich silcrete 'skins' occur as joint and fracture fillings in the sedimentary rocks as well as coatings on rock surfaces and over boulders in adjacent colluvial and alluvial deposits (Hutton et al. 1972). The titania can be recognised by its distinctive yellow to buff colour. Chemical analyses of 'skins' and associated quartzite are given in Table 2. Hutton *et al*. argued that the titania-rich 'skins' developed by preferential dissolution and leaching of silica from the bedrock quartzites. Such a mechanism requires large volume losses because the quartzite contains comparatively low concentrations of titania. However, there is clear evidence that leaching of silica and attendant volume losses have not occurred. On the contrary, petrographic and X-ray diffraction studies indicate that microcrystalline anatase has been introduced and deposited from mobile solutions or suspensions together with silica (Milnes & Hutton 1974; Milnes & Twidale 1983). In fact, the 'skins' are the indurated part of a former sediment cover at this site. The association of titania with silica in silcretes is now well established, and will be demonstrated at many sites. The origin of the titania presents a problem, although at this site the bedrock sediments contain heavy mineral bands with abundant ilmenite.

On the pediment surface downslope from the scarp foot zone there are quartzite blocks and boulders encased in thick rinds of silicified sandy sediments with somewhat lower titania concentrations than in the 'skins' in Locality 1. A section exposed in the nearby creek contains bleached sandy sediments indurated with silica near the landsurface. Silicifled rhizomorphs and a nodular facies are evident, together with iron-rich mottles in the unconsolidated sands at depths. The sediments are probably of Tertiary age.

We back track, crossing the creek in which there are good exposures of Proterozoic shales (Woomera Shale). The track skirts the tablelands east of the creek, crossing a broad pediment on which stony tableland soils and linear gilgai are conspicuous. An old seismic track leads southwards to breakaways at Locality 2 (~31.868388° lat; 137.595552° lon; elev 47m).

LOCALITY 2[2]

The breakaways exhibit good sections through presumed Tertiary sediments and underlying gypsum- and halite-impregnated Proterozoic shales (Woomera Shale) which are stratigraphically beneath the quartzites and sandstones of the tablelands. The base of the Tertiary sequence is marked by a fluvial boulder bed. Most of the clasts are of quartzite and many have relict titania-rich silcrete 'skins'. Such clasts were evidently derived from silcretes in adjacent scarp-foot zones such as that seen at Locality 1. A thin veneer of sandy sediments above the boulder bed contains a silicified horizon with well

[1] See photographs (Appendix 5). See also figure, Appendix 4.

[2] See photographs (Appendix 5). Noted well-developed columnar silcrete facies with cappings. The floor of the gully has scattered clasts of quartzite and silcrete, the surfaces of which have distinctive salt etching.

developed prismatic columns. Hutton et al. (1972) regarded this silcrete as part of the silicified landscape in which the titania-rich silcretes formed (Fig. 3). However, it is demonstrably a younger material, contains low titania (Table 2), and is likely to have formed in a pedogenic environment.

Campsite nearby.

Return to Bookaloo railway siding.

2. BOOKALOO TO STUART CREEK OPAL DIGGINGS (SITE 3)

(Refer to TORRENS and ANDAMOOKA 1:250 000 map sheets)

Set trip meter to zero

We travel north from Bookaloo along Highway 87. The landscape unit is DD1, consisting of undulating plains with calcareous red earth soils (Gn1). The vegetation is dominantly myall woodland but there are small areas of mulga. Occasional red sand dunes are seen in section in road cuttings. Tablelands are visible in the distance about 23km out of Bookaloo. Soil site 19 (1968 International Soil Science Congress Tours 1/11) is located here in myall woodland, and the soil is a calcareous red earth Gn1.13.

The landscape changes to Nb42 at around 25km at Ironstone Lagoon, with shrub steppe vegetation (Bassia spp. and saltbush) on the stony tableland. Note the extensive stone pavements with reddish desert varnish. Macro-gilgai features form distinct pans and swamps in which canegrass (*Eragrostis australasica*) is common. The soils are dominantly alkaline, gypseous clay soils (Ug5). A railway ballast quarry on the left at Woocalla railway siding (about 32km) is in Proterozoic dolomites of the Tapley Hill Formation. Conspicuous mesas of flat-lying Simmens Quartzite and Corraberra Sandstone are clearly evident from the turnoff to "*Oakden Hills*" pastoral property.

At about 36km there are well developed stony pavements with desert varnish. The Woomera water pipeline is on the left of the highway. Vegetation consists mostly of scattered small shrubs including *Eremophila* sp., which appears to be spreading because it is unpalatable to grazing animals. The landscapes are distinctively treeless except for black oak (*Casuarina cristata*) along the creeks. Sites 20A, 20B and 20C of the 1968 International Soil Science Congress Tours 1/11 were located here in grey, brown and red clays (Ug5.36) typical of the stony tablelands.

At about 42km there is a good view to the west of the Oakden Hills and the edge of the tablelands. Note the contrast in vegetation between the tableland and the sandy red earth plains. Pernatty Lagoon is visible on the right in the distance at around 45km.

A dunefield (Birthday Sandhills) of red sands occurs at 51km in landscape unit DD1 (31.521294^o lat; 137.117618^o lon; elev 149m). Uc1.1 soils on the dune crests host mulga and occasional native pine (*Callitris* sp.). The swales contain sandy Gn1 soils. The turnoff to the Mt Gunson Mine occurs at around 56km (31.478725^o lat; 137.074974^o lon; elev 113m). At this point, high tablelands formed of Proterozoic Tent Hill Formation sandstones are obvious ahead. Lakes and lagoons fringe the southern margins of the tablelands, and a good example of the large dunes bordering the lakes is seen to the north as the highway crosses the southern edge of Lake Windabout. From the Wirrappa railway siding at about 66km, the highway climbs 122m to the crest of the high stony tableland at just over 200m. The landscape unit is Nb41, a treeless stony tableland with saltbush and Bassia spp. Bleached A2 horizons characteristic of the red duplex desert loam soils (Drl.43) are visible in roadside gutters, but much of the tableland is covered by Ug5.3 soils.

At 74km there is a good view of Island Lagoon to the west. Bleached Cretaceous sediments appear here as outliers overlying Proterozoic rocks. Trenches and excavations in these sediments were presumably dug in search of opal. At 87km you may glimpse the dome structure of Narrungar tracking station on the left.

We turn right for Woomera at Pimba "township" at around 92km (31.259417° lat; 136.804434° lon; elev 189m). After refueling, we depart Woomera eastwards from the water storage tanks (31.190014° lat; 136.812853° lon; elev 174m). An old homestead, "Phillip Ponds" outstation, occurs on the outskirts of the town. The tracks from here are unsealed, and pass through dissected low tablelands with minor dunefields and saline swales in which the vegetation is mainly saltbush and shrubby succulents. The landscapes are underlain at shallow depth by Proterozoic Tent Hill Formation quartzites and sandstones. Small swampy basins are common. An intersection at about 111km marks Paradise Wells to the left and Bosworth to the right.

At about 137km (now on the ANDAMOOKA 250 000 map sheet) dune country of landscape unit DD1 is encountered in a northeasterly trending depression of possible fault origin. The dunes form a thin sand veneer over Tertiary Eyre Formation sediments which are widely distributed throughout the depression. The vegetation is mostly mulga and low acacias, but *Callitris* occurs on the dune ridges.

"Purple Downs" homestead, Purple Lake and Purple Swamp are on the left at around 146km. To the north, there are small tablelands, essentially treeless, of flat-lying Cretaceous sediments assigned to the Marree Subgroup. These are remnants of the extensive deposits of Cretaceous sediments in the southern part of the Great Australian Basin. At around l56km, with Courlay Lagoon on the right (~30.713198° lat; 136.892521° lon; elev. 98m), the country is essentially a dune landscape covering Cambrian Andamooka Limestone. The vegetation is a *Callitris*-mulga woodland, with *Callitris* occupying the dunes and mulga, the swales.

At ~177km (30.554352° lat; 136.919179° lon; elev. 110m), the track forks left to Olympic village. The main Andamooka track is to the right. The landscape unit is DD1. Here the country consists of low dunes with wide swales and some claypans. The ANDAMOOKA map sheet shows the first appearance of the ridge system of Tertiary Mirikata Formation sediments beneath the east-west Quaternary dunes at Olympic village.

We travel northwards from the village to the mine area[3] and then east to the north-south Borefield Road[4], a limited access road along which water supplies to the mine are currently transported by road convoys. Access to the Borefield Road is via a locked gate and a security escort. The landscape consists of low dunes with wide swales containing saltbush. Claypans and swamps with lignum (*Muehlenbeckia cunninghamii*) and canegrass are common. Shrubby acacias with some *Cassia* spp. and mulga occur on the dunes. Occasional low, stony tablelands mark outcrops of Andamooka Limestone or Marree Subgroup sediments.

The dog fence is met at about 206km, and we turn right to follow the track on the northern side, crossing wide stone-littered swales with *Bassia* spp. and patches of canegrass. Stone lags are generally coated with black varnish. Sandier parts of the swales contain saltbush, with small melaleucas and bushy acacias. Stony rises correspond to outcrops of Marree Subgroup sediments which are commonly impregnated with gypsum. At about 225km a north -south track is met in a stone-covered playa. This is the main track between Andamooka and the Stuart Creek opal diggings.

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[3] Olympic Dam Mine

[4] At the time of the Field Workshop the Borefield Road was closed because of wet weather. We backtracked from Olympic Village to the Andamooka track (30.554384° lat; 136.919364° lon; elev. 110m) and turned eastwards towards Andamooka at about 199km, crossing dune landscapes with wide stony swales. Shrubby vegetation only. The track follows a stony swale running parallel to a dune ridge. Passed a shed and tank with cattle yards at about 212km and approached Andamooka, visible on the left, at about 225km (village centre 30.447727° lat; 137.167177° lon; elev. 91m). We took the airstrip road from Andamooka village and travelled north. Crossed a dunefield at about 247km and passed the North Well bores and dam at 248km (30.373238° late; 137.098873° lon; elev. 82m), detouring where necessary to avoid claypans filled with water at this time. The dog fence was met at 254km and an Andamooka-Maree signpost encountered at 262km. We arrived at Coolabah Creek at 274km and forked left past a cattle yard. At around 291km we turned off an east-west track and travelled southeastwards to Stuart Creek opal field (30.097258° lat; 136.266667° lon; elev. 86m).

We turn northwards across undulating stony plains developed in Andamooka Limestone, but partly covered by low sandy dunes. The development of a karst landscape is evident from the common sinkholes. Shallow Um soils are common, and the vegetation is dominantly bluebush. Vegetation on the dunes is largely mulga and bushy acacia. A track off to the left with an Andamooka-Marree signpost occurs at about 234km. Tablelands of Cretaceous and Tertiary sediments are visible to the north on crossing an alluvial plain at about 236km. The vegetation is mainly saltbush with rare native apricot trees (*Pittosporum phillyreoides*). The track skirts the low rises in Cretaceous sediments at Saddle Hill and bears northeastwards. The soils here are calcareous loams on rises above the floodouts, and saline calcareous loams with abundant gypsum in the low areas. The latter support *Salicornia* sp. vegetation. Stone lags are extensive, and black desert varnish coatings on the stones are common.

Across a creek lined with coolabahs (*Eucalyptus microtheca*) at about 244km the road splits into two alternate routes to the Stuart Creek diggings. The right fork passes elongate ridge-like tablelands composed of Marree Subgroup sediments with cappings of Mirikata Formation sands and silcretes, for example at Yarrawurta Cliff. The track crosses subdued outcrops of reddish-coloured Cambrian shales (Yarrawurta Shale) and Andamooka Limestone, as well as stony pediments with abundant boulder "erratics" weathered from the Cretaceous sediments. Locality 3, in the abandoned Stuart Creek opal field, is a prominent mesa on the eastern side of the field at about 252km (30.097258^{o} lat; 137.266667^{o} lon; elev. 86m).

LOCALITY 3[5]

The geology of the Stuart Creek opal field (Fig. 4) has been described in detail by Nicol (1977), Vnuk (1978), Barnes & Scott (1979) and Barnes & Townsend (1982). Several deep bulldozer costeans have been cut through the mesa in Locality 3 to expose the geological relationships very clearly. The Cretaceous Marree Subgroup sediments at the base of the sequence in the costeans are composed dominantly of brown to grey montmorillonitic muds with sandy and gravelly intervals, and scattered boulder clasts. The sediments were originally dark-coloured pyritic and carbonaceous, and are believed to be of marginal marine origin. Foraminifera and rare molluscs have been found in the sediments.

Gypsum is ubiquitous throughout the sediments, and there are other secondary sulphate minerals including alunite and jarosite often present in veins. Gravel beds are commonly ferruginised. Opal is also present and is generally found in 'levels' defined by the contacts of gravel beds with underlying clays.

The Marree Subgroup sediments are overlain unconformably by fluvial sediments assigned to the Mirikata Formation. These are dominantly cross-bedded sands and silts with occasional gravel beds, usually near the base, containing rounded and polished pebbles of a variety of rock types including silcrete. Carbonate is present in some intervals. In some localities fossil leaf and wood impressions have been found in indurated fine sands considered to be part of this formation (Nicol 1977). In this locality, vari-coloured ferruginised sands dominate parts of the sequence and conspicuous silicified horizons occur at the base and near the top of the succession.

At the base of the sequence impregnation of vari-coloured sands by secondary silica has produced an indurated horizon with highly irregular boundaries and internal structures typical of variable impregnation. This appears to be a quartz-overgrowth silcrete formed in a groundwater situation. Above the silicified horizon are spectacular red, green and black sands containing silicified and gypseous rhizomorphs which reflect plant growth in prior pedogenic environments. Gypsum-impregnation of sands has produced clusters of sandy gypsum rosettes.

The silicified horizon near the top of the succession displays nodular, burrowed and columnar facies, as well as abundant dissolution channels infilled with red-coloured detrital materials that have been subsequently silicified. Microcrystalline anatase is conspicuous as buff-yellow laminated deposits on the floors and walls of burrows and channels, and as coatings on the tops of nodules and clasts. The base of the horizon is very irregular and appears to merge with the underlying poorly consolidated sediments in a series of crude columnar structures. The surface is commonly highly indurated. The material is a

[5] See photographs (Appendix 5). See also figure, Appendix 4.

typical pedogenlc silcrete and is believed to have formed in a soil environment. Several stages in the formation of the silcrete are evident, signifying a complex history of biogenic and pedogenic processes, silica impregnation, dissolution and re-silicification. This silcrete is widely developed on the Mirikata Formation throughout the area.

The soil on the mesa surface is a uniform fine-textured variety (Uf) with a layer of fine gypsum less than 30cm below the surface. Excellent panoramic views across the opal field and of Lake Torrens to the south are obtained from here.

Campsite nearby

3. STUART CREEK DIGGINGS TO "BILLA KALINA" (SITES 4 TO 7)

(Refer to ANDAMOOKA, CURDIMURKA and BILLA KALINA 1:250 000 map sheets)

Set trip meter to zero

We depart Stuart Creek opal field by travelling about 7km northwest to a T-junction and turning right. The track crosses a dune landscape with stone-littered swales. The soils are dominantly Uc1.1 on dune crests and Gn1 sandy red earths in the swales. The vegetation is mainly a mulga-bluebush association, but patches of calcareous Gc soils support dominantly bluebush. Small canegrass swamps, and gypseous, saline pans with samphire vegetation are common. At about 16km there are low outcrops of Proterozoic siltstones and sandstones. The track forks at about 19km; eastwards via Pidleeominna Dam to an ALTERNATIVE LOCALITY at Cockatoo Cliff; and northwards via Charlie Swamp to Locality 4.

The north track passes through breakaway country consisting of Marree Subgroup sediments capped by Tertiary sands and silts, some of which are calcareous (Nicol 1977). Note the scattered excavations in Marree Subgroup sediments for opal. Saline soils on Cretaceous sediments at about 23km (now on CURDIMURKA 1:250 000 preliminary map sheet) support mainly *Bassia* spp. with some annual saltbush . Scalds are common.

Abandoned diggings in relatively unweathered Marree Subgroup sediments at about 27km mark the site of the Charlie Swamp opal field (~29.969070° lat; 137.373682° lon; elev. 84m). Black and white non-precious opal occurs in joints and fractures (Nicol 1977; Barnes & Townsend 1982). Beyond this locality the track crosses low tablelands with extensive stone lags. The vegetation is mainly mulga with saltbush and cottonbush (*Maireana aphylla*). The dog fence is crossed at 30km and Locality 4 (~29.923928° lat; 137.386795° lon; elev. 90m), in a creek section in breakaway country, is on the track about 2km to the north of the fence.

LOCALITY 4[6] (locality 379 of Nicol 1979)

The creek section in this locality provides an excellent exposure of so-called "reed mould silcrete" (Nicol 1979). The silicified bed is exposed as a ledge in the water course, and has a polygonal prismatic columnar structure (jointing) and a pavement-like upper surface. On the sides of the columns and in fractured sections it displays abundant moulds of plant stems similar to those of modern bullrushes and root channels. The bed is a silt, and forms part of a succession of thinly bedded sands and silts (Fig. 5) that have been extensively bleached. Spheroidal goethitic nodules are common but their origin is unknown. Vnuk (1978) recorded similar structures in Marree Subgroup sediments at Stuart Creek opal field. Silcrete and quartzite clasts in the base of the "reed mould silcrete" mark an unconformity with the underlying clays.

Based on the detailed work of Nicol (1979) and Callen in localities to the west where the "reed mould silcrete" is well developed, the silcrete and the overlying sediments form part of a regressive Tertiary lacustrine sequence which occurs below the Mirikata Formation. The bed referred to the "reed mould silcrete" here and at other sites seems to be silicified in some parts of the exposures and not in others.

[6] See photographs (Appendix 5).

In this regard it is interesting to speculate on the influence of the aspect of the exposures on cementation, rather than silicification in primary depositional environments.

The plant fossils in the silcrete are regarded as moulds of aquatic monocotyledons resembling bullrushes. They consist of reed-like structures with ribbing parallel to the length and nodes somewhat like bamboo (Nicol 1979). Moulds of leaves are also reported.

The track leads northwards from Locality 4 across dissected tablelands and extensive pediments with gibber pavements. Black desert varnish coatings occur on the exposed surfaces of the rock clasts and reflect sunlight to produce a bright sheen on the landsurface. Gilgai are well developed. The track forks at 36km (29.889456° lat; 137.399075° lon; elev. 58m). To the north is Wimbrinna Dam. We turn west along the southern bank of Gregory Creek which is lined with coolabahs. Proterozoic bedrock is exposed in the banks of tributary streams, and is mantled by thin red duplex (Dr) soils. Scattered "erratics" have been weathered from the Cretaceous sediments. At about 45km the track bypasses Gregory Dam and associated cattle yards. The track crosses Gregory Creek near Junction Dam (29.800692° lat; 137.333703° lon; elev. 30m) at about 50km. Proterozoic bedrock crops out on the northern side of the creek.

The track bears to the northwest to a fence and gate at about 54km; we turn north through the gate. The landscape is mainly base-level stony plains with low sand dunes appearing on the left. At 63km we meet the limited access Borefield Road from Olympic Dam (29.736933° lat; 137.248879° lon; elev. 30m).

Cross the Borefield Road (with considerable care in case of approaching water transport convoys) and travel northwestwards past Campoven Dam (29.713280° lat; 137.171234° lon; elev. 26m). The track skirts canegrass swamps and clay pans, and crosses northeasterly trending sand dunes forming part of the north-south depression seen on the CURDIMURKA map sheet south of Lake Eyre South to meet the track between Bopeechee and "*Stuart Creek*" pastoral property at about 80km (29.701357° lat; 137.091731° lon; elev. 18m). We turn westwards and travel across a broad saline drainage terminus with dominantly halophytic vegetation. There are stony tablelands at about 82km, and "*Stuart Creek*" homestead is visible ahead in the distance. Mandy Dam is on the left.

The homestead, at about 86ka (29.712617° lat; 137.071551° lon; elev. 30m), sits on a desolate, treeless gibber plain. Twin Hill and other mesas are visible to the north. To the southwest we can see Chinaman Hat Hill and Tent Hill, and Locality 5 is at the edge of the tableland beyond. We travel southwestwards from the homestead. Pale-coloured sand dunes are present adjacent to Stuart Creek on the right. At around 100km the track meets a fence and gate on stony tablelands with well developed gilgai. We travel overland to Locality 5 at about 107km, on the eastern edge of the dissected tableland (29.806692° lat; 136.991839° lon; elev. 86m).

LOCALITY 5[7]

The section to be examined is near the top of the plateau remnant exposed in an erosional gully, and consists of a succession of Tertiary sediments and silcretes overlying bleached Cretaceous sediments (Fig. 6). A gravel layer containing milky quartz pebbles and scattered quartzite boulders overlies bleached and iron-mottled clays end marks a distinctive unconformity (A) in the section. This seems to be a transgressive unit overlying an earlier Tertiary lacustrine facies to which the "reed mould silcrete" at Locality 4 belongs. As such, it marks the base of the Mirikata Formation. The contact between the Tertiary and the Cretaceous is likely to be the base of a shale clast interval at B on Figure 6.

The gravel bed is iron-mottled and is overlain by silts which display finely laminated trough cross-stratification and ochreous mottling and are variably silicified. Reddish-coloured cross-bedded sands and grits above contain abundant burrows and silicified rhizomorph structures. Various silcrete horizons occur near the top of the section. A horizon approximately 30cm thick contains vertically-oriented columns held within a reddish gypseous matrix. Above this a complex silcrete exhibits a distinctive nodular facies and contains dissolution channels in which the infill consists of pea-like silcrete

[7] See photographs (Appendix 5). Karl Wyrwoll talked about the problem of understanding the enormous loss of material (specifically Cretaceous and Tertiary sequences) from these landscapes, leaving only remnant tablelands and mesas.

nodules in a deep red gypseous matrix. Many of the dissolution channels and cavities are lined with laminar deposits of silica, and there is also abundant gypsum. This silcrete forms the capping on the tableland.

Campsite in dunes.

Return northwards along the fence to the main track and travel southwestwards to a track at approximately 120km leading south to White Cliff. We pass through a gate at 123km, and at 127km travel overland and up onto the tableland to Locality 6 at about 128km[8] (~29.843558° lat; 136.882016° lon; elev. 124m). Large gilgai with stone ramparts occur on the tableland.

LOCALITY 6[9]

This is the site at which Roger Callen has identified Tertiary sediments forming ridge structures on which there are well developed silcretes, and adjacent somewhat elevated (4-6m) "beach mounds" which are not silicified but contain some columnar zones of white opal. The exposures are not good, but it is possible to observe the change from a nodular silcrete facies on the flanks of the cross-bedded sandstone mound, to a columnar and eventually a massive silcrete on the adjacent ridges. Callen's so-called "ant nest silcrete" is another facies present in the silicified horizon. Below the columnar silcrete are cross-bedded sands and silts with ferruginous mottles. These overlie a coarse interval of sands and gravels marking the base of the Tertiary succession and an unconformity with the Marree Subgroup shales below. The Marree Subgroup sediments exhibit ferruginous mottling and marked gypsum impregnation.

An additional site approximately 4km west of here may be visited if time permits[10] (~29.864669° lat; 136.843905° lon; elev. 30m).

We travel north to the main track and then westwards to Willalinchina Hut on the north side of Stuart Creek at about 139km. Locality 7[11] corresponds to the outcrops of silicified Tertiary sediments north of the hut (~29.804697° lat; 136.791302° lon; elev. 66m). This is the plant fossil site described by Ambrose *et al*. (l979).

LOCALITY 7[12]

The silicified sediments are dominantly cross-bedded fine sands and silts which dip slightly to the south and southwest. They contain abundant and spectacular plant fossils including impressions of leaves, plant stems, wood (branches or trunks) and fruit. Small-scale gravels incorporating fragments of Cretaceous shales are evident. Vertical burrow structures are also present.

The sediments were probably deposited in stream channels or billabongs (abandoned channels), and are considered to be stratigraphically equivalent to the lacustrine sequence containing the 'reed mould silcrete'.

Return via the ruined hut to the main track at 142km. We turn west and travel towards "*Billa Kalina*" [13].

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[8] The landscape is essentially rolling stony downs with conspicuous stone ramparts marking ridge-and-mound gilgai structures, very few trees and general shrubby vegetation.

[9] Site was located at about 168km after following tracks westwards on the upper edge of the tableland after breaking camp in the dunes. Many photographs (see Appendix 5) of columnar and nodular silcretes. Very coarse grits occur beneath the columnar silcrete forming the ridge on the eastern side of the gully exposure.

[10] Locality 6a, west of Locality 6 along the base of the tableland, is an exposure of 'reed-mould silcrete' which is only silicified on the northern edge of the tableland. A pedogenic silcrete occurs at the top of the Tertiary succession. A pebble bed containing highly polished quartz and silcrete clasts sits above the 'reed-mould silcrete' in a breakaway on the east side of the tableland.

[11] Group photograph of Excursion participants taken at the lunch spot near here (see Appendix 5).

[12] Westwards, there are several surface exposures of 'custard-like' structures typical of groundwater silcretes. There was some discussion as to whether these could be the result of the differential dissolution of former 'even' zones or coatings of silica-impregnated sediment, maybe in subcrop or outcrop , or 'primary' constructional features due to a succession of layers or zones of silica impregnation within the original sediment in the groundwater environment. (See photographs - Appendix 5.)

[13] The track forks right at around 196km; at 202km we turn left and eventually meet the brumby fence at around 211km. Turn north and follow an east-west fence along a track on the southern side of the fence (photograph looking back at the convoy – see

The track forks at 147km, and we bear to the right. We cross the brumby fence at 162km. The tracks from here are poorly defined. We hope to travel via Westell Dam (29.905120° lat; 136.589391° lon; elev. 103m), Young Dam (29.927238° lat; 136.505878° lon; elev. 122m), Trig Hill Swamp (29.920683° lat; 136.418637° lon; elev. 63m) and Watchie Swamp (29.946740° lat; 136.270820° lon; elev. 104m) (on BILLA KALINA 1:250 000 map sheet).

4. "BILLA KALINA" TO COOBER PEDY (SITE 8)

(Refer to BILLA KALINA and COOBER PEDY 1:250 000 map sheets)

Set trip meter to zero

After filling with fuel and water at "*Billa Kalina*" homestead (29.916859° lat; 136.187702° lon; elev. 114m), we travel northwestwards through dissected tablelands with gilgai and loam soils (Um) to the dog fence and follow the track north. Dolomitic sediments and green clays exposed in the adjacent breakaways are lacustrine sediments of the Mirikata Formation[14] described by Ambrose & Flint (1981a,b). If time permits, we will briefly examine the exposures here[15] (29.886142° lat; 136.167407° lon; elev. 121m).

The track crosses Mudla Wantamarran Creek near an abandoned hut (on left) at 23km (29.712235° lat; 136.167625° lon; elev. 89m), and then follows the dog fence due west across stony tablelands. Progress is very difficult along the northern side of the fence due to large gilgai with high stone shelves on the hill slopes[16] and so we cross to the southern side at the first gate. The flanks of the Serrated Range are especially rough. There are good views from the high ground of mesas and dissected tablelands and vast stony plains in the region.

The track crosses mesas with cappings of silicified Danae Conglomerate (Mirikata Formation) according to the BILLA KALINA map sheet, and there may be an opportunity to examine some exposures briefly[17]. We turn right through a gate at 54km and follow the dog fence to the northwest and then to the west. At 64km the main track turns northwestwards[18]. We cross the dog fence and continue due west through dissected tablelands and stony plains, past an area known as the Painted Hills because of the vari-coloured weathering patterns in the Cretaceous sediments[19]. Red-brown hardpan (Wright 1983) is exposed in stream beds, for example at 80km, and there may be time to examine this material[20]. Black maghemitic gravel lags are conspicuous in these regions, and cover red duplex (Dr1) soils[21]. The track passes through

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Appendix 5). Conspicuous black ferruginous gravel lag first encountered at around 220km and common thereafter (photograph – Appendix 5). At around 220km there are black gravelly lags on the flanks of low rises and near small claypans.

Set up campsite in dunes at around 240km. Allan Chivas and Michael Bird talked about their isotope research.

At around 245km there are stony downs landscapes with abundant gilgai and accompanying stone shelves and puffy clay depressions which collapse under vehicle wheels. Shrub-steppe vegetation – mainly saltbush, low *Vesicaria* and *Bassias.* Watchie Swamp at about 253km (29.946740° lat; 136.270820° lon; elev. 104m), with tablelands of Miocene sediments (Crown Hill, Coward Hill) east of "*Billa Kalina*" in the distance.

[14] Billa Kalina Clay and overlying Millers Creek Dolomite.

[15] Breakaway exposures at about 3km from "Billa Kalina" examined briefly (photographs – Appendix 5). The dolomite here contains stringers and veins of well crystallised quartz (reminiscent of the meulières in France). Clasts within the dolomite could be intraformational structures. The clay unit is dark green in colour and uniform in structure. Clasts of chert were found on the top surface of the mesas. They may have originated from the dolomitic unit but could also be archaeological materials.

[16] Spectacular stone ramparts on gilgai along the Serrated Range make vehicle travel very difficult (photographs – see Appendix 5).

[17] Stopped on top of one of these residuals to examine the silcrete duricrust (photographs – see Appendix 5), which is silicified Cretaceous and not Tertiary sediments (Danae Conglomerate) as mapped on the BILLA KALINA 1:250 000 sheet.

[18] *E. ocialis* grows well in Cretaceous sediments at the edge of a major stream here.

[19] Travelling due west at this stage.

[20] Brief stop made to examine this material.

[21] Shallow pit excavated in a patch of maghemitic gravel. Much discussion about the origin of these ferruginous lags, and also about the nature of silcrete remnants that appear as isolated masses at low levels in these landscapes.

sheep yards next to a small hut at 106km, and about 3km further west (29.678900° lat; 135.322320° lon; elev. 232m) we turn to the northwest and travel via Bluebird Dam[22] and Skylark Dam[23] to Hat View (29.551661° lat; 135.218792° lon; elev. 232m).

LOCALITY 8[24]

The silicified mesa at this site is capped by a silicified duricrust overlying weathered and vari-coloured Cretaceous sediments (Bulldog Shale, Maree Subgroup). The silcrete is a silica-impregnated iron-mottled zone of a former weathered profile in Cretaceous sediments. The iron-mottles are red to purple in colour and hematitic, although some alteration to yellow goethite is evident. The silicification is extensive, and there is some development of porcellanitic material.

Bleached Cretaceous sediments with hematite mottles occur beneath the duricrust but have also been partly silicified.

Good views of the vari-coloured weathered Cretaceous sediments in breakaway country are obtained from Hat View[25].

Campsite at Hat View. Evening talk by Ross Coventry, and preliminary observations from Max Churchward and Charles Butt.

From Hat View we travel directly to Coober Pedy (29.013138° lat; 134.754451° lon; elev. 167m) via the new road alignment, along which work is still in progress[26], at about 225km.

NOTES ON GEOLOGY OF THE COOBER PEDY OPALFIELDS

by R.S. Robertson (Mineral Resources Branch, Department of Mines & Energy)

Cretaceous

Precious opal at Coober Pedy occurs in early Cretaceous marine claystone of the Bulldog Shale (Marree Sub Group) deposited on

[22] 'Bluebird' Dam and yards (29.651311° lat; 135.290300° lon; elev. 228m). Red-brown hardpan shows up in the landscapes beyond, and is exposed in the track. At around 119km there are spectacular expanses of maghemitic gravel lags on the landsurface amongst patches of grassy vegetation. The lags are mostly of well-sorted pisolitic gravels with the occasional larger rock clast. Scattered silcrete as possible subcrop or degraded outcrops are also present and could be Danae Conglomerate.

[23] 29.530767° lat; 135.151446° lon; elev. 161m

[24] Hat View mesa. Spectacular bleached and Fe-mottled zone is exposed in section in the breakaway on the east and northeast sides of the mesa. The mottled zone appears to have been developed in Cretaceous sediments (there are no Tertiary sediments in this locality but they have been mapped on nearby mesas to the south and west). The entire upper part of the profile has been silicified, post- bleaching and Fe-mottling, producing the duricrust. Distinctive cracking and disintegration of the silicified materials has occurred, generating crazing into roughly equidimensional fragments. Dissolution structures appear to have been enlarged by animals and birds as caves and nesting places. Noted also infilling of dissolution channels with pisolitic gravels in hardpan-like 'soil' matrix. The bleached and mottled zone contains clays and alunite. (See photographs, Appendix 5.)

On the eastern side of the landform there is a good development of Fe-mottling but a variable development of silicification. Noted that the silicified material is breaking down into small blocky fragments of similar size which litter the slopes. (This phenomenon was noted also in the Painted Hills to the north. Is there some effect of smectite still present? Maybe a property of dehydration of opaline silica.) The vari-coloured weathering zone materials in the bottomlands is spectacular – due to highly coloured goethite & hematite (plus alunite in places).

[25] Photographs (see Appendix 5).

[26] We depart Hat View at around 136km, return to the east-west dog fence, cross through a gate and head northwest, crossing remnants of what appear to be silicified Tertiary sediments, mapped as Danae Conglomerate, that crop out low in the landscape. At about 146km we head north to a quarry in Precambrian igneous rocks at 155km (29.472824° lat; 135.282103° lon; elev. 167m). West from here is an access track to the new highway alignment which we followed instead of following the dog fence westwards to Brumby Creek.

At around 165km, in a lowland area, we stopped at one of many roadside excavations in Bulldog Shale (29.441565° lat; 135.035967° lon; elev. 189m photograph – see Appendix 5). The Cretaceous sediments are Fe-stained near the surface, somewhat bleached and weathered below, but contain abundant gypsum and other salts. As we travel onto higher parts of the landscape (Stuart Range), the Cretaceous sediments in roadside excavations become progressively more bleached until they match the bleached and mottled zones typical of breakaways.

the western margin of the Great Australian (Eromanga Basin). When fresh, Bulldog Shale is a dark grey, pyritic, silty or sandy claystone or shale with occasional erratic(?) boulders, sand lenses and fossiliferous cone-in-cone limestone. Montmorillonite is the main clay mineral.

The opalfields are situated along a 40-50 m high east facing escarpment and gently west sloping tableland known as the Stuart Range. Throughout the Stuart Range, Bulldog Shale is deeply weathered and bleached with weathering extending to depths in excess of 50 m. The top 20 m of the weathered zone comprises bleached white or light mauve kaolinitic claystone, often porous and lightweight, overlying denser, grey, brown, mauve or yellow claystone usually containing montmorillonite as the major clay mineral. Precious opal can be found anywhere in the upper bleached claystone (called 'sandstone' by miners) but the most productive part of the profile is usually a zone from about 5 m above to 1-2 m below the change to darker coloured denser material.

In very broad terms the weathered profile and hence the opal bearing zone follows the present topography (see section). The nature of the weathered profile varies, with the opalfield areas having mainly a particular type of profile, strongly suggesting a genetic relationship. This profile is used as an exploration target for new opal bearing areas.

Precious and potch opal is found as irregular veins in-filling cracks and joints and occasionally as infillings of fossil shells.

Opal veins are usually located in subhorizontal structures called 'levels'. As well as opal and other forms of silicification, 'levels' are marked by concentrations of red brown tubules, gypsum, alunite and iron oxides. These features, which are described below, are also scattered through the rest of the bleached profile. 'Levels' probably represent old water tables rather than bedding planes.

Tubules are branching and interconnecting systems of pipe-like structures penetrating bleached claystone. They are infilled with red brown silt, gypsum and claystone fragments. Tubules become less common with depth but have been found as much as 18 m below the top of the claystone. Tubules are thought to be the result of termites burrowing in search of water, hence their concentration in 'levels' at old groundwater tables.

Gypsum is very common throughout the weathered profile either as fine disseminated grains or as veins. Spectacular veins of satin spar gypsum up to 1 m thick have been observed usually near the base of the bleached zone.

Alunite - $KAl_3(0H)_6(SO_4)_2$ is present as nodules and patches ranging in size from a few mm to several metres across, horizontal bands, irregular veins and specks or powder impregnating claystone. Large alunite masses are particularly common near the base of the bleached zone.

Iron oxides (hematite or limonite/goethite) occur as staining on joint faces, in veins and masses finely disseminated through claystone.

Also cutting weathered claystone are steeply dipping structures called 'slides' or 'slips ' by miners who place great importance in them in the location of opal. These are thought to be faults related to volume changes during weathering rather than tectonic movements. These volume changes are also the probable cause of the cracking which produced the open spaces into which gypsum, alunite and occasionally precious opal were deposited.

Precious opal was probably formed by the gradual drying out of silica rich groundwater by evaporation or filtering. Permeability barriers may be provided by occasional clay rich horizons or more likely by the transition from very porous bleached claystone to less porous, darker claystone. Abundant silica would have been produced during weathering by the conversion of montmorillonite to kaolinite and by the corrosion of detrital quartz grains within the claystone.

Sediments Overlyinq Cretaceous Claystone

Throughout most of the Stuart Range, weathered Bulldog Shale claystone is overlain by a complex sequence of Late Tertiary-Quaternary colluvial and alluvial sediments and duricrusts, the majority of which have been termed the Russo Beds (Barker *et al.* , 1979). Thicknesses average 4-8 m but may range from 0-14 m with marked variations common over short distances. These sediments also infill tubules and fissures within claystone.

Precious opal fragments derived from erosion of veins within claystone are found in these sediments. In a few fields most opal production has come from the Russo Beds. In ascending stratigraphic order, these sediments comprise:

- Dark Red Brown Silt. Well sorted silt, sometimes found infilling tubules and fissures instead of the paler red brown Russo Bed material. Occasionally found *in situ* immediately overlying claystone. May be silicified.

- Russo Beds-Lower Gypseous Unit. Variable but in general, red brown, gypsum rich sandy silt and clay with numerous rock fragments. These fragments include:
  - angular to subrounded fragments of bleached claystone sometimes silicified.

  - angular to rounded granules to boulders (up to 3m) of greenish-grey quartzose silcrete ('greybilly').
  - quartz grains and granules.
  - angular fragments of silicified red brown silt ('jasper').
  - fragments of gypcrete.

- Gypsum is disseminated as fine crystals or powder through the silt and clay and as veins of satin spar. The unit may be cemented by fine gypsum to form tough massive gypcrete.

- Silicification is common, particularly at the base near the contact with claystone. Red brown clay/silt may be silicified together with rock fragments to form jasper breccia or pudding- stone silcrete.

- Usually the boundary between the Lower Gypseous Unit containing numerous claystone fragments and the top of the claystone, which is brecciated with red brown silt infilling fissures, is hard to define and irregular.

- Russo Beds-Middle Conglomerate (Bouldery) Unit. Poorly sorted granule to boulder conglomerate with red brown sandy silt matrix. Rock fragments are usually well rounded and descriptions are as for the Lower Gypseous Unit but with silcrete and jasper boulders predominating. May be partially or completely silicified.

- Russo Beds-Upper Carbonate (Platy) Unit. Red brown calcareous sandy silt with rounded fragments of silcrete and other fragments derived from lower units. The development of 'biscuits' of calcrete generally about 0.3 m across and 0.05 m thick produce a characteristic platy appearance. Occasionally, the biscuits are partially ferruginous.

- Various Late Pleistocene to Holocene sediments and soils, as detailed by Benbow (1983), including Benitos Clay, Oolgelima Gravel and sediments of modern drainage channels.

Summary of Silicifications Recorded at Coober Pedy

Mainly derived from Barker (1980)

Gibber (Greybilly) Silcrete:- Mainly present as subangular to well rounded clasts within Dark Red Silts, Russo Beds and younger deposits and as surface lags. Composed of silicified conglomerate of earlier silcrete clasts. In thin section, angular quartz grains cemented by microcrystalline quartz and anatase.

'Blue Ground':- Vari coloured, hard, brittle, pervasively silicified claystone. May occur over large areas. Preservation of sedimentary structures such as bioturbation, less bleached nature, lack of tubule development suggest silicification occurred fairly early in the weathering history. Thought to never contain precious opal. Opal-CT is the silicifying material.

Precious Opal & Potch. As discussed above.

Opal-A. 'Niggerheads' and 'Angelstones'. Spherical and ellipsoid, silicified nodules sometimes found on 'levels'. Composed of opal-CT and sometimes cut by veins of precious opal. Often contain fossil shells and may be replacements of limestone pods.

Partly Silicified Claystone. Normal bleached claystone is often slightly silicified by Opal-CT.

Dark Red Silt Silcrete. Silicification of Dark Red Silt by quartz. Observed as clasts within Russo Beds and as tubule infillings.

Russo Silcrete. Patchy silicification of the Russo Beds by Opal-CT forming jasper breccia etc. Varies in size from small nodules to masses 50-100 wide. Most common towards the base of the Lower Gypseous Unit. The top few metres of bleached claystone is often also massively silicified and this silicification is equated with the Russo silicification. Silicification cuts across bleaching boundaries, tubules etc.

Chalcedony. Veins up to 3 cm thick, infilling cracks and voids and replacing fibrous gypsum within Russo Beds. Occasionally in Lower Gypseous Unit but most commonly in Upper Platy Unit. Thought to be a late stage event.

INTRODUCTION - LEG 2

The region between Coober Pedy and Ceduna lies on the northern and western margins of the Precambrian crystalline basement of the Gawler Craton (Fig. 1). During the Eocene and Miocene the Eucla Basin was a major site of marine sedimentation. Localised non-marine deposition occurred in associated river systems such as the Tallaringa Palaeodrainage System which flowed towards the basin from the northeast (Fig. 8).

The Tertiary stratigraphic framework for both the Eucla Basin and the Tallaringa Palaeodrainage System is summarised in Figure 9 and brief descriptions of some of the units are given in the legend of the TALLARINGA 1:250 000 preliminary map sheet.

Pedogenic silcretes occur within the palaeochannels on the margins of the channels and on the interfluves. Major occurrences are not known southwest of Lake Anthony (Fig. 8). These silcretes formed in Munjena Formation sediments. The sections in the Lake Anthony - Lake Bring area provide some evidence for a relationship between silcrete formation and a cycle of deposition younger than the Middle-Late Eocene Pidinga Formation.

Massive silcretes within the palaeodrainage systems are considered to be of groundwater origin. Similar silcretes occur within the Eucla Basin in the Early to Middle Miocene Colville Sandstone and Plumridge Beds (Fig. 9). These occur extensively in the Yarle Lakes-Ooldea area south of Maralinga and are of post-Early to Middle Miocene age. The massive silcretes in the palaeochannels were thought initially to pre-date the Munjena Formation, but are now considered to relate to the time of pedogenic silcrete formation. Both silcrete types will be examined in section at site 3, which is similar in many respects to the sections at Locality 3 of Leg 1 in the Stuart Creek opal field.

As discussed in Leg 1 of the Workshop, the relationships of the Tertiary sediments and the ages of the pedogenic silcretes are still controversial. Wopfner (1978) assigned the sediments which host the silcretes to the Eyre Formation and suggested that the silcretes formed in the Late Eocene to Oligocene prior to deposition of the Etadunna Formation and its equivalents (Colville Sandstone and Mirikata Formation). On the other hand, Barnes & Pitt (1977), Pitt (1980), Ambrose & Flint (1981) and Callen (1983) suggested that the sediments were deposited during the Miocene, and that the silcretes formed contemporaneously (Ambrose & Flint 1981b) or significantly later in the Pliocene (Callen 1983).

At many sites it will be possible to examine the relationships between silicification and ferruginisation.

TRAVERSES AND SITE DESCRIPTIONS

1. COOBER PEDY TO LAKE ANTHONY (SITES 1 to 3)

(Refer to COOBER PEDY and TALLARINGA 1:250 000 map sheets)

Set trip meter to zero

Coober Pedy lies on the Stuart Range which is the regional divide between the Lake Eyre Basin and the Eucla Basin. The landscape (unit Nb27) is characterised by the presence of red-brown hardpan, which is common on the Stuart Range and in the regions to the south and west. The dissected tablelands and extensive rolling stony downs of the area are referred to the Stuart Range and Uplands by Benbow (1983b), and dip to the southwest into the depression centred on Lake Phillipson. Cretaceous sediments (Bulldog Shale, Maree Subgroup) underlie most of the area. Gilgai micro-relief is common. Vegetation is sparse and mainly concentrated in gilgai depressions and in rare stream channels. Bladder saltbush and *Bassia* spp. are the dominant shrubs, and mulga, coolabah and native apricot the common trees, when present[27].

[27] Southwards from Coober Pedy, on the road to Port Augusta, bulldozer costeans display exposures of red-brown hardpan and other soil stratigraphic units. Typical near-surface exposures are of Benitos Clay overlain by a stony lag typical of the surface of the tablelands (photograph – see Appendix 5). At its base is a gypsum layer. Below the gypsum layer is the Giddina Formation of Benbow in which is developed Coober Pedy Palaeosol (equivalent to the Illeroo Pedoderm of Jessup & Wright, 1971) which is the red-brown hardpan unit. Below the hardpan there are bleached and weathered Cretaceous sediments. These units together constitute the Russo Beds (Benbow's Giddina Formation is the topmost part of the Russo Beds – the Benitos Clay is excluded). The hardpan contains abundant gravels and clasts of a wide range of materials including silicified rock fragments, ferruginised materials and fragments of Bulldog Shale. All are poorly sorted and the whole has been interpreted in the past as an alluvial/colluvial deposit that may have formed in bottomlands where it was subsequently impregnated with silica. There is a conspicuous subhorizontal structure which has been exploited by carbonate precipitated from soil waters or shallow

We travel southwards along the Stuart Highway (Hwy 87[28]) following a major drainage line that eventually feeds Lake Phillipson. The highway crosses Quaternary floodplain sediments and soils with gilgai oriented north-south. These gilgai have a different character to the more prominent structures formed on the interfluves in the red-brown unit mapped as Benitos Clay (Benbow 1983b). At 45km we pass into landscape unit DD29, an extensive and complex landscape of sand plains and dune tracts with scattered hills and ridges, which extend southwestwards to Wynbring. Saline flats, clay pans and seasonal swamps and lakes are common remnants of the palaeodrainage systems. Hard-surfaced plains are characterised by stone pavements and red-brown hardpan at shallow depth. The sparse vegetation includes *Bassia* spp., mulga and *Eremophila* spp. In sandy parts of the landscapes acacias (*Acacia linophylla* and *A. ramulosa*) form a dominant association with mulga.

At about 60km we turn right off Highway 87 onto a track (~29.530063° lat; 134.810314° lon; elev. 155m) which follows the dog fence westwards. These are the Central Sand Plains of Benbow (1983b)[29]. The

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groundwaters. These structures also display coatings of manganese.

In a creek east of Coober Pedy, along the Oodnadatta road, there are good exposures of Benitos Clay and Russo Beds (hardpan) below (Benitos Clay is excluded from the Russo Beds).

Some further 15km into the lowlands, east of the Stuart Range, through the dog fence then immediately left, is a creek with exposures of grey and essentially unweathered Bulldog Shale (photographs – see Appendix 5). The landscape is essentially devoid of vegetation and characterised by conspicuous grey-black cracking montmorillonitic clays overlain by a thin soil and an abundance of large gypsum plates scattered everywhere amongst a boulder lag. Good exposures in shallow sections adjacent to creeks show dark, carbonaceous montmorillonitic shales containing abundant gypsum as well as yellowish jarosite and goethite. Gypsum is present both as flat sheets and plates as well as fibrous selenite. Efflorescences in fractures and partings are of fine, fibrous epsomite. Some fragments of fossil wood appear to be pseudomorphed by fine gypsum.

LOCALITY 1 (~29.030203° lat; 134.779669° lon; elev. 226m)

Quarry in opal-bearing bleached Cretaceous sediments (photograph – see Appendix 5). The bulldozer cut has intersected old underground opal mine workings.

LOCALITY 2 (~29.003866° lat; 134.640430° lon; elev. 215m)

Larkins Folly mine area, located beyond the airport (which is adjacent to old Hwy 87). The locality was formerly called Russo's Folly. The type section of the Russo Beds is here in a deep bulldozer costean in old mine workings in burrowed, bleached Cretaceous shales (photograph – see Appendix 5). The units in the section appears to be *in itu* – however, there is a complex of silicification, solution-collapse structures, gypsum impregnation, and other disruptive features. The section doesn't have the appearance of a colluvial/alluvial sediment as has been proposed (Robertson and others). Wright suggested that the hardpan component of the Russo Beds might have been similar to Benitos Clay, a deposit that contains approximately 70% smectite and could have been aeolian in origin. Shrink-swell behaviour could have distributed clasts from underlying units up into the clay prior to induration by silica, iron oxides and later $CaCO_3$.

Silicified materials in the Russo Beds are mainly fragments of Cretaceous sediments. Complex nodular structures in a fine matrix make up the silcrete clasts. This is interpreted to reflect a long period of complex events. Clear dissolution and collapse structures include conical pipe-like zones filled with mixed debris. Most of the silcrete clasts in the upper parts of the Russo Beds are 'capped' by laminated microcrystalline silica and titania, and the cappings indicate that most clasts are in original (geopetal) arrangement suggesting that silicification occurred *in itu* with no (or little) subsequent disturbance. Checking of capped silcrete clasts in the hardpan to see if they are similarly oriented hasn't yet been undertaken.

See also schematic of the profile, Appendix 4.

LOCALITY 3

Eastern edge of Stuart Range tablelands, south of Oodnadatta road. Silcrete capping weathered profile. Silcrete is a fine silt with vertical structures that are reminiscent of 'reed moulds' seen in silcretes around Stuart Creek. Abundant titania (anatase); massive columnar structures with wispy laminated cappings. Some voids appear to be lined with microcrystalline anatase 'stalactites'. Vertical stripes on sides of columns possibly interpreted as 'reed moulds' but could be dissolution structures with fillings removed.

[28] 'Old' highway – see COOBER PEDY 1:250 000 map sheet.

[29] As we turn off the tableland the dunes have become very red, almost 10R, and much redder than seen earlier in the field workshop. The red colour tends to be paler in the swales but redder on the ridges (possibly a hydromorphic feature in which hematite is transformed into goethite in the wetter swales). The swales also have a coarse lag of gravelly sand. At about 88km the track meets the Adelaide-Alice Springs railway line running N-S (29.535791° lat; 134.544185° lon; elev. 142m). An outcrop of silcrete beyond this is mapped on the COOBER PEDY sheet. Many stony rises are encountered further along the track, and may be calcareous or gypseous materials – no Cretaceous sediments have been mapped here. At around 98km there is a track northwards to Lake Phillipson (29.533766° lat; 134.442219° lon; elev. 138m). Beyond around 115km there are lowland salinas: white gypseous materials are exposed on salina margins and in lunette structures. At around 133km, a forced stop to change a tyre provided the opportunity to examine a soil profile: red earth soils underlain at ~50cm by calcareous material which appears to overly and partly impregnate a hardpan (some suggestion of palygorskite as the material sticks very strongly to the tongue).

vegetation is mainly mulga, but has been killed over large areas by bushfire and drought. Lakes Phillipson and Wirrida, north of the fence, occupy a large local depression in which sub-bituminous coal has been discovered in Permian sediments at depth (Benbow 1983b). The depression was also an area of lacustrine deposition in the Miocene. These sediments are referred to the Garford Formation (Benbow & Pitt 1978) and are equivalent to the Etadunna and Mirikata Formations in the Lake Eyre and Billa Kalina regions. Palaeochannels draining into the depression were also active depositional sites during the Miocene. The fence and track crosses one such palaeochannel marked by claypans and gypsum lunettes at Wildingi Claypan, about 30km west of the main north-south railway line.

Near the intersection with the north-south dog fence we cross the Garford Palaeochannel. This fluvial system flowed southwest towards Wilkinson Lakes (TALLARINGA 1:250 000 map sheet) in the Eocene and the Miocene. At approximately 165km near the locality Jubilee we cross a lake with a prominent small mesa which corresponds to Locality 1 (29.510453° lat; 133.769207° lon; elev. 147m).

LOCALITY 1[30]

The mesa is capped by silcrete 1-1.5m thick which formed in poorly-sorted sands with pebbles at the base. The sands are assigned to the Munjena Formation of Oligocene to Miocene age, and overlie Permian Stuart Range Formation beds of marine origin. The silcrete is composed of large vertical columns, up to 0.5m thick, best seen on the northeastern side of the mesa. A weakly developed "wispy lamination" characterized capping structures on the columns. The underlying Permian clays have also been silicified to produce a silcrete with "custard-like" surface features typical of groundwater silcretes.

We travel about 12km west of Locality 1 to a fork in the dog fence (29.515173° lat; 133.625782° lon; elev. 169m), turn southwest then south via a shed and yard at (29.566766° lat; 133.533730° lon; elev. 187m) to Turkey Flat Bores and finally southwest to Lake Anthony (on the TALLARINGA 1:250 000 preliminary map sheet)[31]. The country is flat to undulating (the Southern Plains of Benbow 1983b) with broad areas of

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At about 150km the dog fence bends southwards (29.523065° lat; 133.903099° lon; elev. 153m) around a large claypan and then continues due west.

UNSCHEDULED STOP before evening camp (~29.533956° lat; 133.884991° lon; elev. 146m)

Western side of large claypan. Low breakaways (photographs – see Appendix 5) expose green clays (which Benbow correlates with Billa Kalina Clay) purported to contain abundant palygorskite. Coarse quartz grits are also present. Above the clays are Quaternary sediments consisting of reddish sandy alluvial materials with a distinct carbonate accumulation layer. Further north in this locality, on the edge of the claypan, are good exposures of white dolomitic clays overlain by a thin sandy lacustrine unit and then dune sands cemented by carbonate. These sections are regarded in part as equivalents of the sequence in the Lake Frome region. The dolomitic interval is correlated with Roger Callen's Namba Formation, with the green gritty clays underlying it and/or interfingering with it. The overlying reddish sandy sediments with carbonate accumulation horizon is equivalent to the Eurinilla Formation which includes the Pinpa Palaeosol of Callen. Overlying these, in the Lake Frome region, are Coonarbine Formation dunes with thin carbonate and gypsum accumulation horizons which may equate with the uppermost dunes and calcretes here.

Camp site near here. Mark Benbow presented a slide-show on his work on the Eocene in this region.

Continuing due west along the fenceline. At around 157km we travel across an undulating plain with sandy red earth soils overlying calcrete/hardpan. Occasional broad sand dunes. At around 160km there is an open mulga woodland with a dense groundcover of tall *Eremophila* spp. and *Vesicaria.* Quite different vegetation was noted on the northern and southern sides of the fence. On the north side are shrubby *Eremophila* spp, whereas saltbush and bluebush is abundant and in good condition of the south side. Bluebush is generally indicative of calcareous soils.

[30] The site is a small mesa on a claypan, just off the dog fence. There is a coarse silcrete capping comprising a silicified grit lag over Permian sediments (photographs – see Appendix 5). Columns, cappings and nodular structures typical of pedogenic silcretes are well displayed. Within the Permian sediments there is good evidence for groundwater silcrete based on mammillary ('custard-like') structures.

[31] At around 165km, where the fence turns southwest, dryland tea-tree (*Melaleuca* spp.) and *Casuarina cristata* are common. A large silcrete-capped mound is seen to the south. Sandhill mulga occurs on large dunes crossing the track. At about 180km we turn south through the dog fence at the Garford gate. The fence continues both to the west and southwest at this point. The map has this area as Q_{Ca} – undifferentiated calcrete. The landscape has large swathes of dead mulga. Fork left at about 187km through a fence and gate, then turn sharp west along the southern side of the fence. A telephone line follows the fence. At about 190km the road bends to the left and a track leads off through a fence to some bores: we take a track south along the southern fence line. Yards and tracks here may be "*Garford*" Outstation. Note black maghemitic gravel lags in lowland areas. Further south are the Nestling Bores (where stony lags composed of silcrete pebbles form a distinct gibber on stony rises). At

ephemeral drainage. Precambrian basement is close to the surface, but there is a cover of red-brown sands with scattered exposures of calcrete and silcrete. As we approach Turkey Flat Bores the landsurface steadily falls towards the Garford Palaeochannel which is filled with Eocene carbonaceous sediments and Miocene lacustrine deposits.

A small lake on the southwestern margin of the Lake Anthony (30.008190° lat; 133.294054° lon; elev. 152m), at around 260km, is the site of Locality 2a.

LOCALITY 2a[32]

On the west side of this lake 5-6m of horizontally bedded and slump-bedded Permian glacigene sediments of the Boorthanna Formation crop out. They are pale grey in colour and exhibit minor ferruginous mottles and staining. A regolith occurs at the top of the sequence, with sand filling cracks and hollows in the fragmented Permian sediments. Above the regolith is an interval, approximately 1m thick, of poorly-sorted Munjena Formation sands which are locally pebbly at the base. The base of the unit is somewhat irregular, though generally flat.

Both the Munjena Formation sediments and the Permian glacigene sediments are silicified. Silcrete in the sandy beds of the Permian sequence display characteristic "custard-like" surface textures. Silicified clay beds near the top of the succession are 1-2m thick. Slump structures in thin sandy intervals have been preferentially indurated but primary sedimentary structures are well preserved. The silcrete formed in Munjena Formation sands is massive with a poorly developed columnar structure. Ferruginous mottles in both formations, including leisegang ring structures in the Permian clays, pre-date the silicification.

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about 205km (29.646374° lat; 133.530018° lon; elev. 162m) there is a first appearance of lakes marked on the map. Gypsum occurs on the tops of rises and gypsum lunettes are common around lake basins.

Turkey Flat Bores are encountered at about at around 217km (29.788148° lat; 133.521840° lon; elev. 175m). The track crosses a grid and fence leading to "*Indooroopilly*" Outstation and at about 236km passes Indooroopilly Bore (29.832366° lat; 133.481085° lon; elev. 188m). Reach Anthony tank at around 256km (29.929461° lat; 133.403148° lon; elev. 168m), then turn right off the track down to Half Moon Lake. The vegetation here is an mulga woodland with abundant bullock bush. Sandy red earths occupy the swales and UC1 soils on the dune ridges. At around 260km we travel down into the lake proper – a very extensive dry salina with a gypsum lunette on the northeastern side. (Now on the BARTON 1:250 000 map sheet.) The track follows around the eastern side of the lake. A bore and tank is encountered at about 281km (Half Moon Lake bore and tank: 30.035295° lat; 133.361131° lon; elev. 177m) and we turn west, following the fence. Tall black oaks here are a spectacular component of the vegetation. Silcrete, together with calcrete, cap many rises and black ferruginous gravel lags are also common in lowland areas. *Eucalyptus socialis* starts to appear in mallee-like stands, together with umbrella mulga (*Acacia brachystachya*) which is an important component of the vegetation. We cross through yards with an adjacent tank (Isthmus Tank: 30.034732° lat; 133.308601° lon; elev. 177m) and head north. Approach a small lake on the southwest margins of Lake Anthony at about 284km (30.008190° lat; 133.294054° lon; elev. 152m): Locality 2a is at breakaways with good exposures on its western side.

[32] The section is 4-5m thick. Clay-rich Permian glacigene sediments (Boorthanna Formation) are slumped, bleached and iron-mottled. They are overlain by a poorly-sorted, gritty and pebbly sand (Tertiary) which has been silicified. Silicification extends down into the Permian sequence forming porcellanite, Leisegang ring-like structures and ropy, custard-like features that are typical of groundwater silcretes. The Tertiary sand is correlated with the Munjena Formation seen in Locality 1 and displays Fe-rich mottles 'preserved' by silicification. Large numbers of white quartz clasts are present in this locality (and also at Locality 1): they could have been derived from vein quartz in the Precambrian rocks in the region, or from quartz erratics in the Permian sequence. They are very conspicuous across the landsurface and may reflect 'factory' sites for Aboriginal stone tool production.

Brecciated zones contain lots of clasts of silicified Permian sediments that may have come from a groundwater silcrete (photographs – see Appendix 5). 'Regolith material' has the appearance of a much disrupted horizon with coarse clastic materials filling dissolution features. At the top of the succession are massive silicified materials with 'swirling' custard-like structures. Thick cappings occur on columns of coarse gritty to nodular silcrete. Silicified grits and gravels appears to be draped over a surface of Permian sediments. Silicified masses were noted within the Permian sequence and it was suggested that they could be silicified slumps and ice-wedge sands: they contain 'custard-like' surface structures.

LOCALITY 2b[33]

If time permits we can examine this site on the southwest margin of Lake Anthony where up to 8m of cross-bedded, pale grey to white, kaolinitic, fluvial sands of the Munjena Formation overlie sands rich in sponge spicules assigned to the Bring Member of the Pidinga Formation (latest Eocene). A silcrete capping the sequence contains marked vertical structures that may be ant burrows, and pedogenic features such as conical structures.

The poorly-sorted sands at Locality 2a are equivalent to the sands in this exposure, and the silcrete in both instances is considered to be the same.

LOCALITY 3[34]

There are three components to this site.

Scattered over the floor at the western end of the lake are outcrops of the latest Eocene Bring Member of the Pidinga Formation. The sediments include finely laminated and cross-laminated fine to very fine sand, silt and clay, which are carbonaceous in part. Siliceous sponge spicules, impressions of plant fossils, and various burrows including *Skolithus* attest to a marginal marine environment in this part of the Tallaringa Palaeodrainage System. Variable silica impregnation of the sediments has aided their preservation. In particular, quartz-rich laminae and burrow infillings have been silicified.

On the north side of the lake there are several metres of massive silicified sands of the upper Bring Member of the Pidinga Formation which overlies the lower Bing Member. They contain sponge spicules in places, as well as lenses of coarse sands derived from local sources. Ferruginised mottles and zones (Yapinga Ferricrete) within the sands pre-date the siliciflcation. The silcretes are massive, very hard and brittle, and vari-coloured yellow-brown and brown to black.

On the south side of the lake the principal exposure is of weathered and iron-mottled Precambrian basement overlain unconformably by poorly-sorted to well-sorted sands of the upper Bring Member of the Pidinga Formation. The sands are strongly ferruginised and have been partly silicified. White

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[33] From Locality 2a we followed the western side of the small lake then tracked over a dune through a gate and fence northwards towards Lake Anthony. On the southwestern edge of the lake at around 287km (~29.993812° lat; 133.268892° lon; elev. 154m) there are outcrops of columnar silcrete with distinctive cappings on columns (Locality 2b).

The typical pedogenic silcrete (columnar, with cappings) is underlain by gritty sands that are cross-bedded and indurated to some extent by silica. The sands contain abundant burrow structures and other features. An exposure in the creek nearby is of columnar facies overlying a much disturbed nodular facies (photographs – see Appendix 5). The columns have relatively thick cappings. (See photographs, Appendix 5.)

[34] We return southwards and at around 293km, at the tank and yard (Isthmus Tank; 30.034732° lat; 133.308601° lon; elev. 177m), turn west along the fence. Native peach (Quandong, *Santalum acuminatum*) occurs here together with *Cassia* spp. The landscape is largely of dunes and swales. At about 300km the track meets a north-south fence (30.034647° lat; 133.149376° lon; elev. 178m) with a telephone line and a telephone box at a corner in the fence. We turned south through the gate. A calcreted hardpan occurs in erosion gutters in the track and was examined briefly - Churchward suggested that this could be the Wiluna Hardpan. At around 303km there was a silcreted rise standing prominently above a sandplain. Deep erosion gullies in which carbonate and gypsum accumulation layers are exposed run southwards into lakes. The soils are calcareous red earths. At around 305km we travelled down into an area of lakes and followed the track around the northwest side - one vehicle became bogged in the floor of a lake. Locality 3 is located at the southwestern corner of the lake (photograph – see Appendix 5).

Ferruginised sediments here are indurated by silica (silicified ferricrete, mostly goethitic but with some hematite mottles) and have been assigned to the Khasta Member (photograph see Appendix 5). No indications of pedogenic features were observed, although possible dissolution features were noted. Quartz clasts and silcrete pebbles on the lake floor are markedly etched, presumably by chloride salts. Carbonaceous Eocene sediments (Pidinga Formation) exposed at the centre of the lake are slightly tilted, very well laminated and generally greenish in colour. Structures within the sediments include back-filled burrows, generally vertical, appearing as round holes in bedding surfaces. Sponge spicules are common (seen with a hand lens). A pit dug in the lake floor intersected unconsolidated lignitic sediments. On the opposite side of the lake there are silicified, finely laminated silty sediments with micro-burrows and some sand intervals. Plant fossils on bedding surfaces include leaves, but there are many burrows, trails and other organic structures (photograph – see Appendix 5).

An outcrop of Precambrian crystalline basement rocks on the eastern side of the lake contains mottled ferruginised (hematitic and manganiferous) zones and weathered (white, bleached kaolinitic zones). Benbow indicated that palaeomagnetic work had been undertaken on some mottles. The basement is overlain by Tertiary sediments that are also iron-mottled and have the form of a ferricrete or ferruginous sand. This has a complex form and structure, is brecciated and full of pebble clasts and grit. A pedogenic silcrete capping at the surface presents as a columnar facies with capping structures on the columns. There are large ‘boulders’ lower in the profile, some with capping structures, beneath a series of nodular and columnar zones.

kaolinitic sands l-2m thick overlie the Bring Member. The presence of occasional rounded quartz pebbles and rare, polished, rounded silcrete pebbles is thought to indicate a sedimentary break within the interval. These sediments are correlated with the Munjena Formation. A pedogenic silcrete formed in the top of this unit has a prominent vertical structure marked by conical and columnar features and the orientation of nodules and "candle-like" structures. Note also the presence of horizontal to sub-horizontal "wispy lamination". The lower part of the silcrete is predominantly nodular, while the upper part appears more intensely silicified and forms a resistant capping with some development of horizontal partings. The silcrete can be traced discontinuously from the palaeochannel (150m elevation) to the adjacent highlands (up to 180m). Silcretes formed on the uplands of the region which were drained by the Tallaringa Palaeodrainage System display a similar range of pedogenic characters and, it is suggested, are part of the one silicified landsurface. On the other hand, the silicification of ferruginised sediments lower in the stratigraphic sequence may have been a groundwater phenomenon, though related temporally to the pedogenic silcrete.

Campsite near here. Charles Butt and Mike Freeman made slide presentations after the evening meal.

2. LAKE ANTHONY TO CEDUNA (SITES 4 to 6)

(Refer to BARTON and FOWLER 1:250 000 map sheets)

Set trip meter to zero

We travel south and east to the dog fence, and then south to the dunefields of the Great Victoria Desert for approximately 50km[35]. This landscape (B62) is composed dominantly of east-west sand dunes with narrow

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[35] We retrace our route eastwards. Early on the vegetation included tall Black Oak woodland, with *Eucalyptus socialis* in places. Dense woodlands with occasional stony rises capped by silcrete and calcrete were encountered. *Acacia aneura* dominated in places, with subdominant *Casuarina stricta*, and some *A. brachystachya*: *A. linophylla* and *A. amulosa* occurred on sandier areas. *Eucalyptus* spp. Became obvious at around 15km from the campsite where there were also claypans with a very red surface cover. Native apricot (*Pittosporum hillyraeoides*) was also commonly observed. In places, fire damage to the larger trees was widespread. Beyond around 32km the country was open and casuarina and mulga with a bluebush understory dominated. The intersection of several fences occurred at around 50km from the campsite (30.197334^{o} lat; 133.308601^{o} lon; elev. 177m) and signposts to Geisha Bore and to Lochaline were present. At ~30.198710^{o} lat; 133.509901^{o} lon; elev. 182m we passed through a gate and headed south along the western side of the north-south dog fence. *En route* to Mt Christie Corner (signpost on gate) we traversed red earth soils with mulga-dominated woodland, areas of surface maghemitic gravel lag, stone-capped rises (calcrete and silcrete), and outcrops of bedrock.

From Mt Christie Corner (30.198710^{o} lat; 133.509901^{o} lon; elev. 178m), we travelled essentially south, reaching a large gate with sign 'Burdon Tank Gate' at around 65km (30.345124^{o} lat; 133.511627^{o} lon; elev. 183m). Through the gate we begin to traverse east-west sand dunes at the margins of the Great Victoria Desert. Thick woodlands with tall casuarinas and acacias form the vegetation. '10 mile Tank' gate encountered at about 76km (30.427394^{o} lat; 133.502994^{o} lon; elev. 156m). Myall appears in the vegetation, and there is a noticeable change in topstorey dominance from mulga to myall with *E. ocialis* (red mallee) becoming more important. Sandalwood with mulga occurs on the dune ridges, and some *E. eptophylla*. Eucalyptus mallee abundant at around 83km. At around 87km the main Adelaide-Perth railway line is visible ahead (30.551763^{o} lat; 133.503125^{o} lon; elev. 166m). (Groundwater Resources vehicle suffered oil loss here due to a loose oil filter.) We travel west along the northern side of the railway line (now on BARTON 1:250 000 map sheet). At 115km we arrive at the Mt Christie railway siding (33.544339^{o} lat; 133.222500^{o} lon; elev. 195m).

At about 136km there are calcreted stony rises and areas of thick calcareous silts which J.B. Firman would have assigned to the Woorinen Formation. Approaching the Barton Sand Range and the soils are noticeably lighter in colour. The dunes are large and the topography pronounced. Mongala railway siding is at 144km. There is a good profile through calcrete in one of the track-side excavations here: prominent carbonate nodule horizon at the top of the calcrete. There are also good sections through the dunes in railway cuttings. A brief examination showed carbonate accumulation layers in the sands like those known from the Woorinen Formation.

Bilby railway siding is reached at around 164km (30.555727^{o} lat; 132.779276^{o} lon; elev. 219m). Spinifex now appears, with desert poplar and *Pittosporum*. At around 171km we reach Barton railway siding (30.520250^{o} lat; 132.658460^{o} lon; elev. 154m) where there is an airstrip south of the railway line on the outskirts of a small village of houses and a power generating station. We cross the railway line, and travel back eastwards on the south side of the line past the airstrip to the Stockdale Prospecting field camp at 175km for refueling and lunch.

After lunch we travel back to Barton RS and head west along the south side of the railway line. Some dune crests in this area are mobile. The vegetation is mainly mallee woodland with a spinifex understory. The sand dunes are becoming very light coloured. Small stony rises are intersected at intervals in the track. A large cutting occurs through the dunes and underlying sediments at corridor plains and some seasonal swamps and lakes. Here, as in the sandier parts of the previous landscape complex, vegetation is dominated by acacias (*A. linophylla*, *A. amulosa*, and less abundantly *A. aneura* and *A. brachystachya*). In contrast to other major sandy deserts in Australia, little geological research has been carried out in the Great Victoria Desert.

The track continues south along the dog fence to the east-west railway line, and then west to the Stockdale Prospecting Camp at Barton at approximately 150km. As we travel westwards eucalypts become increasingly obvious and include *Eucalyptus ocialis*, *E. eleora* and *E. yriformis* (subspecies *youngiana*), the Ooldea mallee. Spinifex (*Triodia irritans*) becomes increasingly important as groundcover. After refueling at Barton, we travel westwards to Ooldea at about 230km.

The Immarna railway siding (now abandoned) between Barton and Ooldea is located on the crest of the Ooldea Range, the significance of which has only recently been recognised. During deposition of the Early-Middle Miocene Nullarbor Limestone, the Ooldea Range was active as an aeolian coastal feature along most of the length (approximately 700km) of the northern and eastern margin of the Eucla Basin. It stands 150m above the height of the Nullarbor Plain and is composed of siliciclastic sands. There are good views of the range to the northwest from Immarna, and to the north between Ooldea and Watson. The range may provide the basis for relating dated marine sediments with the undated non-marine sequences on the landward side of the dune and in the palaeochannel systems.

Ooldea is located on the eastern margin of the Nullarbor Plain, on one of the largest karst terrains in the world. It was just west of the siding that the golden spike was placed in 1917 to mark the completion of the east-west railway line. A few kilometres north of Ooldea Daisy Bates managed a mission for aboriginals after the First World War.

The track leads south from Ooldea to Lake Ifould (also named Lake Pidinga) at about 280km. This is part of landscape unit BB34, typical of the Nullarbor Plain. The vegetation is characteristically shrub steppe with saltbush and bluebush. Occasional patches of open scrub are dominated by mallee (*Eucalyptus socialis* and *E. racilis*) and the dryland tea-tree (*Melaleuca lanceolata*). As we reach Ifould Lake the landscape

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around 226km (~30.500624^{o} lat; 132.172409^{o} lon; elev. 242m). (Immarna railway siding is at 228km – 30.500219^{o} lat; 132.151965^{o} lon; elev. 233m.) The section in the cutting shows a sequence of sand dunes with carbonate accumulation layers. One such layer about half-way up the section includes a spectacular nodular facies which is continuous over some distance (photograph – see Appendix 5). Near the top of the sequence there is a clayey sand (40-50% clay from hand texture) with burrows and illuviation structures. A second cutting at 232km exposes light-coloured sands with carbonate accumulated in abundant rhizomorph structures (photographs – see Appendix 5). Some discussion was had about the history of dune formation, and the possibility that the dunes may have been essentially fixed and set in place for a long time to account for carbonate accumulation. At around 242km we passed a ruin and bore (marked at western edge of BARTON 1:250 000 sheet). From a high dune at around 253km, it s possible to see the Ooldea Sand Range a long way to the north. At 260km we arrive at Ooldea railway siding (30.459010^{o} lat; 131.833260^{o} lon; elev. 112m). We have now traversed the dunefield and arrived at the edge of the Nullabor Plain which can be seen to the west. Miocene limestone representing the upper part of the Nullabor Limestone is exposed in railway cuttings at Ooldea. It has been extensively modified by calcretisation.

We turn south onto a north-south track. The vegetation community here is dominantly *Eremophila* spp. and *Cassia* spp., together with bluebush. But we cross a range of different vegetation communities along the track, including areas of *A. brachystachya* and 'deadfinish', with *Pittosporum* in places, myall woodlands with saltbush understory, and so on. Sinkholes are evident at 268km and contain Um1 soils (shallow calcareous loams). Taller vegetation occurs in depressions or sinkholes. Dunes are evident to the east at the edge of the Nullarbor Plain. Camp made on a track off to the right at around 305km.

Campsite. We had Aboriginal landowners visit during the evening to discover our purpose.

Just south of the campsite we turn left towards Lake Ifould (Lake Pidinga). Limestone outcrops and calcareous loam soils were noted. The vegetation community is a myall woodland with saltbush and bluebush understory. Closer to the lake, gypsum occurs on the edge of the track and there are gypcreted lunettes, devoid of vegetation. Bedrock outcrops occur at the lake edge. The Pidinga rockhole here is essentially gnammas formed in a floor of gneissic granite (30.864985^{o} lat; 132.116220^{o} lon; elev. 98m: photographs – see Appendix 5). There is well-developed flaking of the rock masses. Cement walls have been constructed to aid water retention and storage. From here the track turns east towards the lake. There are small claypans, abundant bedrock outcrops, extensive 'floors' of granite in the depressions and in creek bottoms. There are also spectacular weathering structures on the margins of salt lakes. Locality 4 is on the northwest bank of the lake at about 316km.

(unit DD32) changes to undulating terrain with some sand dunes associated with lakes, although the region is mainly a calcreted plain with occasional granite inselbergs. The vegetation is both open mallee scrub and low woodland with a common understorey of bluebush and saltbush.

LOCALITY 4[36]

In this locality we examine ferruginised and brecciated silcrete formed in possible Cretaceous sediments.

Greenish-brown sandy clay and clayey sand overlain by more than 4m of well-laminated and bedded claystones are exposed in the floor of a small lake (Fig. 10). These sediments were thought to be part of a Tertiary lacustrine series (King 1950) but are probably much-altered equivalents of the Cretaceous sediments of the Eromanga Basin. Cretaceous marine radiolaria have been identified in these sediments (Crespin *In* King 1950). If correctly identified, these outcrops are the only known exposures of Cretaceous sediments in the Eucla Basin.

The sediments have been extensively silicified and pods of white opal occur at the eastern end of the section. They have also been folded. The fold axis (plunging towards 330^{o}) can be seen at the western end of the section where there are steeper dips in the bedding and where an axial plane parting has developed. Impregnation of the brecciated silcrete by iron oxides post-dated silicification.

Pods of soft white clay (possibly alunite) occur in sediments in the lower part of the section. Drilling by SADHE in this locality (King 1953) identified extensive alunite deposits which King thought were related to the formation of the silcrete, and thus part of a classic laterite profile. It is possible that the white opal pods at the eastern end of the section are silica-replaced alunite.

Moulds of gypsum occur in similar silcretes 1km south of this locality in Lake C of King (1953).

LOCALITY 5a[37]

In this locality there are examples of silcrete and ferricrete beneath sandy limestone, and it is proposed that they post-date limestone deposition.

Marginal marine, near-shore sediments of the Colville Sandstone (Lowry 1968, 1970) overlie with sharp contact a black ferricrete and ferruginised sandstone of Eocene to Miocene age. The sediments are medium to coarse, unfossiliferous, sandy limestones or calcareous sandstones up to 1.3m thick with tabular cross-bedding indicating shoreward current directions of 80^{o} to 150^{o}. They were probably deposited contemporaneously with the Nullarbor Limestone in the Early to Middle Miocene. Minor silicification is evident in the form of flat sheets and pods up to 8cm thick parallel to bedding.

The underlying ferruginised sandstones (1.5-2m thick) are upward-coarsening, very fine to medium

[36] Weathered and altered Cretaceous sediments contain large alunite pods and opal (white-bluish potch) masses and pods (photographs of outcrop patterns and opal pods on the lake floor at its western margin – see Appendix 5). Note salt crusts and peculiar curved crystals growing on the underside of overhangs in the outcrop (photographs – see Appendix 5). Brecciated silicified sediments gave off a distinct sulfurous smell when broken by hammer. Some of the upper part of the section is ferruginised. In some ferruginised zones strongly brecciated opal masses have been re-cemented by introduced silica and iron oxide (photographs – see Appendix 5). There was some discussion as to the possibility of these features being the result of soft sediment deformation or early diagenetic alteration. In terms of the possible source of silica, reactions such as:

- primary muscovite/illite reacts with sulfuric acid derived from the alteration of pyrite to form halloysite + alunite, + silica

Noted also the formation of pedestals forming in bedrock on the lake floor just west of this locality (photograph - see Appendix 5).

Followed the west side of Lake Ifould southwards. Noted a very dark red zone in the lake floor on the west side of the lake, just beneath a stone mantle, resulting from alteration of bedrock.

[37] Locality 5a occurs at about 320km (~30.902106^{o} lat; 132.09453^{o} lon; elev. 68m). A pit in the lake floor at this locality exposes unconsolidated carbonaceous and pyritic sediments. Above is a thin sequence of ferruginised Miocene sands and sandy limestones that are sporadically silicified. (Several photos of people around the outcrop – see Appendix 5.) The ferruginised sands (mostly hematitic) are very coarse and gritty. The sandy limestones above are cross-bedded and very gritty at the top (probably better described as carbonate-cemented sands). These are considered to be a marginal marine facies.
Rocks and sediments crop out all along the western side of the lake, with many examples of deep red ferrihydrite-hematite altered sediments in the lake floor.

grained and gritty in part with tabular cross-bedding with current directions of 70° to 160°. They are clayey at the base, and overlie sharply white to brown silty carbonaceous clays of the Eocene Pidinga Formation. More than 2.85m of the latter sediments were intersected in a nearby trench. This is the type locality of the Pidinga Formation.

Ferruginisation was earlier considered to pre-date the Colville Sandstone (Benbow 1983a), but it may have post-dated its deposition. Ferruginised sediments in the northern outcrop contain clasts of silicified sandy mudstones of various shapes. Such clasts are similar to those within silcretes and ferricretes at Yarle Lakes which contain Miocene fossils including *Marginopora vertebralis*. The sediments at Yarle Lakes include the marginal marine Plumridge Beds and the Colville Sandstone (Lowry *et al*. 1972). Petrological evidence suggests that in this locality silicification of the sandstones and the clasts of sandy mudstone of the northern outcrop post-dates ferruginisation.

LOCALITY 5b[38]

Silicification of the Colville Sandstone in this locality is clearly seen at the northeastern end of the section. The underlying silcrete and ferruginous silcrete are altered fine to medium grained Early to Middle Pliocene sands equivalent to the Plumridge Beds. The sediments are part of a transgressive marine sequence, with current directions towards the northeast.

The matrix of parts of the silicified sands originally contained carbonate, and it appears that carbonate-free sands were preferentially impregnated by silica. A variety of forms of silica is evident in thin sections of the silicified sands, including quartz overgrowths, microcrystalline silica and automorphic quartz infilling voids. Silicification appears to post-date ferruginisation, as seen in previous sites.

Southwest of Locality 5b there are exposures up to 0.5m thick of flat-lying, laminated sands and clays. These were deposited after formation of the silcretes at a time of major incision of Nullarbor Limestone at the edge of the Nullarbor Plain.

If time permits we can examine outcrops of the fossiliferous marine Nullarbor Limestone in the area. The outcrop nearest the centre of Lake Ifould is intensely silicified[39].

We travel southeastwards from Lake Ifould to Lake Tallacootra in the southwest corner of the BARTON 1:250 000 map sheet[40].

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[38] This locality is still on the western side of the lake and at about 325km. Noted silicified sands containing goethite spheroids possibly originally a calcareous sand. There is also hardened, silicified sediment in the lake floor. This is thought to have been deposited during the Pleistocene, after incursion of the Nullarbor Limestone and erosion of sediments exposed on the lake margins, in alluvial depressions.

[39] At a nearby lunch spot, there are exposures of Nullarbor Limestone (specifically the marginal facies of the Nullarbor Limestone). The limestone is very gritty and contains abundant shelly fossils. It is silicified in part.

Back across the lake there are outcrops of the lagoonal facies of sediments that occur beneath transgressive sands and clays that are overlain by the marginal facies of the Nullarbor Limestone. Extremely weathered, mottled and bleached Precambrian bedrock occurs beneath this section (photograph see Appendix 5).

[40] At around 330km there is a large expanse of bluebush-saltbush landscape. At about 337km (30.954407° lat; 132.090848° lon; elev. 88m) we turn left off the main track towards Lake Tallacootra. The saltbush here is probably *Atriplex ipitata*. Large numbers of wombat burrows. At 347km we turn right off the track and start to enter a large depression with a lot of dead myall. Bedrock outcrops are relatively common from this point, including an unusual outcrop of quartzitic sandstones or schists at around 349km. At around 350km we arrive at Lake Tallacootra and travel right around the margin to a campsite near bedrock outcrops on the northern margin of the lake (~30.999976° lat; 132.198517; elev. 81m). This is locality 6.

LOCALITY 6[41]

The outcrops along the northern margin of Lake Tallacootra provide part of the evidence for pre-Middle Eocene weathering which is not related to the post-Eocene ferruginisation and silicification we have examined to date. White silcrete skins on black ferricrete attest to silica deposition after ferruginisation. Two periods of silcrete formation are evident here.

On the northern margin of the lake, highly weathered Precambrian gneisses with well-preserved primary structures are exposed. Black carbonaceous sediments of Middle-Late Eocene age (Pidinga Formation) fill depressions in the Precambrian bedrock on the western side of the lake, but have not been affected by the weathering. Sharply overlying the weathered bedrock and the Eocene sediments are 4-5m of ferruginised coarse to fine sands. Conglomerates at the base contain weathered bedrock clasts. These sediments are either Middle-Late Eocene or Early Middle Miocene, and are presently being investigated by palaeomagnetic methods. No ferruginisation of the bedrock is evident.

Silicification occurred at many levels in the Tertiary sequence. Silcrete appears as white skins on black ferricrete, dislodged blocks of white to cream massive silcrete at base level, and a vari-coloured silcrete cap at the top of the section. A younger, thin, flat-bedded conglomeratic sand containing locally-derived ferricrete and silcrete clasts has been silicified, and to a lesser degree, ferruginised.

The modern outwash sediments in the northern part of the lake are an analogue for the younger silicified sediments. In the same way the saline water flowing from the base of the Tertiary sands may indicate the mechanism for impregnating the sediments with silica and iron oxides.

Campsite nearby at 353km. Final Workshop discussions after dinner led by Graham Taylor, with Colin Chartres and Charles Butt. (Photographs of landscape around camp – see Appendix 5).

From Lake Tallacootra we travel southwards[42] for 70km to "*Colona*" on the Eyre Highway (Hwy 1). The

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[41] At the base of the section there are bleached, steeply dipping Precambrian metasediments overlain unconformably by gravels that are commonly ferruginised (photographs – see Appendix 5). There is also lignite (well preserved coal) in hollows sporadically distributed along the boundary. The coal is not visibly altered.

Ferricretes (ferruginised sandstones), with hematite the dominant oxide, are irregularly developed and commonly exhibit a 'peacock ore' sheen on surfaces. In places these ferricretes have surface skins of silica. Elsewhere there are pods of ferruginised sand adjacent to highly bleached sands containing probable jarosite crystals and crystal clumps. Discussion was around the white, bleached zones being generated by flow-through of acidic waters and the jarosite representing zones of pyrite alteration *in situ*. However the relationships with the ferruginous zones is not clear: it could be that the ferruginised materials correspond with facies changes in the sequence. It is noteworthy that the distribution of lignite is quite variable.

Conglomerates or gravel beds are often on the surface of the bleached sediments and could be much younger infillings of small erosional hollows rather than a component of the sedimentary sequence. There are large nodules of jarosite in the gravels.

In the lake there are outcrops of sedimentary rocks, sometimes in section in small erosional banks and gullies. These often have coatings or orange-coloured iron oxides, as have been seen in other lake sequences.

The lignite horizon is visible in many places at the base of the sequence beneath bleached and ferruginised sands. Where present, it directly overlies the Precambrian bedrock. Burrows and root channels are common in sandy sediments above the lignite, as are pebble beds and conglomerates. Lots of organic matter appears to be preserved in beds above the lignite. On breaking open of the ferruginised sands, there is a strong sulfurous smell.

[42] Travelled south from Lake Tallacootra towards the main Adelaide-Perth highway (Hwy 1). Vegetation is sparse myall with bluebush-saltbush understory – mainly shrub-steppe vegetation. Wombat burrows common. Back on the main Ooldea to "*Colona*" track at around 364km (31.047039^{o} lat; 132.086834^{o} lon; elev. 77m) and turn south. Note large expanses of saltbush and bluebush with very few trees, but the vegetation is changeable. Approaching a sand dune landscape at around 373km and begin to traverse light-coloured east-west sand dunes soon afterwards. These tend to be somewhat isolated structures overlying calcareous plains. The dunes become less conspicuous from about 378km. We cross a vermin-proof fence at around 390km (31.272376^{o} lat; 132.078732^{o} lon; elev. 63m) and then pass through undulating myall woodland with a bluebush understory. An old bore, with tanks, shed and yards occurs at about 400km (31.369764^{o} lat; 132.077552^{o} lon; elev. 54m). A rolling landscape is crossed from about 409km where there are tanks trackside. Some grassy areas with a taller species of bluebush. Broad depressions have samphire vegetation (?*Arthrocnemum* spp.) indicating seasonal swamps. The south coast range is visible in the distance from around 416km. We cross through the major dog fence at 419km (31.530307^{o} lat; 132.059928^{o} lon; elev. 57m). *Eucalyptus* is becoming important in the vegetation (mallee woodland with saltbush-bluebush understorey) assemblage, and many wombat burrows. Soils appear to be U5.12 – coarse, oolitic. Open undulating plains encircled by mallee vegetation in places. At around 426km there is a road sign marked Ooldea pointing northwards. "*Colona*" station is reached at around 430km (31.625422^{o} lat; 132.061891^{o} lon; elev. 39m) and the bitumen road soon thereafter.

landscapes are initially flat and treeless, becoming gently undulating with calcareous aeolian sands and soil (Wiabuna Formation and Loveday Soil of Firman 1975). Myall appears in the south. "Colona" is an Aboriginal pastoral property, and the surrounding land is used mainly for sheep grazing. The region between "*Colona*" and Nundroo lies on the northeastern margin of an unnamed range of calcarenite up to 160m high and shown as Bridgewater Formation on the FOWLER map sheet (Firman 1975). The marginal country between Nundroo and Ceduna[43], a distance of 150km, is used for wheat cropping and sheep grazing.

3. CEDUNA

LOCALITY 7[44]

On the foreshore to the north of the jetty are excellent exposures of ferruginised and silicified Middle-Late Eocene sediments overlain by younger ferruginised Tertiary sediments and Pleistocene aeolian calcarenite with associated calcretes. Near the Jetty 2.5-3m of fine to medium grained sandstones overlie weathered bedrock. They contain siliceous sponge spicules and were probably deposited in a marginal marine environment.

Extensive ferruginisation is evident. Iron-mottles have a horizontal arrangement and an irregular parting which may reflect primary bedding. Silicification of this iron-mottled profile has produced a very hard and brittle silcrete. Pale coloured silica rims occur on some of the indurated iron mottles.

A thin grey sand sequence 0.5m thick overlies the silicified profile and contains scattered clasts of an interesting translucent silcrete. Iron mottling is also developed but the mottles are smaller and much darker coloured than those in the profile below. The mottled sands are overlain by about 2m of aeolian calcarenite referred to the Bridgewater Formation. Two calcrete horizons occur within the calcarenite.

LOCALITY 8[45]

Better exposures of the calcarenite occur on the western side of the shelter shed where the lower calcrete is particularly well displayed. It consists of an upper indurated horizon in which there are clasts with black cores and laminated carbonate rinds. Insect pupal cases are common. Soft mottles of white carbonate occur within pale orange-brown, weakly consolidated calcarenite beneath.

The upper calcrete can be traced along the shore and is associated with a shell bed deposited during one of the Pleistocene sea-level maxima.

Total distance travelled Port August to Ceduna ~1,750k

Return to Adelaide on Highway 1 via Kimba and Port Augusta.

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[43] We follow the bitumen highway to Ceduna at about 604km (32.126126° lat; 133.673764° lon; elev. 10m). Good outcrops occur on the coast north of the jetty.

[44] Mottled goethitic sands thought to be Eocene marginal marine, and containing sponge spicules, overlie Precambrian bedrock at about sea-level. There are also silica-impregnated burrows or rhizomorphs. The upper part of the section contains large blebs and patches of silcrete with goethitic mottles preserved in places. The zones of silicification are quite irregular.

At the very top of the section there are two calcrete horizons with thin interlayers of carbonate silt. (Photographs looking towards jetty – see Appendix 5.)

[45] A good calcrete profile occurs to the north of the shelter sheds. This is not Bridgewater Formation but rather calcretes on what appear to be oolitic sand dunes. A white calcareous mottled zone occurs beneath a horizontally-laminated calcrete crust. Below this is a red clay which overlies a gravel unit, the top of which is marked by a ferruginous gravel layer. All of this overlies Precambrian bedrock. (Some photographs [Appendix 5] of hammer on ferruginous gravel which overlies Tertiary sediments which Benbow earlier described on the other side of the shelter sheds. There is the red clay and the mottled carbonate silts and massive calcrete above.) The ferruginous gravel layer sits on a quite irregular surface over clay, which overlies silicified Tertiary. The red clay has a distinctly blocky structure. Noted a distinctive 'fill' structure in the Tertiary sediments, overlain by clay. The 'fill' structure looks like it might have A- and B-horizon development.

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APPENDICES

APPENDIX 1: 1985 Excursion Guide figures & tables

APPENDIX 2: Route map

APPENDIX 3: Original pre-excursion notes

APPENDIX 4: New figures

APPENDIX 5: Photographs taken during the excursion

APPENDIX 1

1985 Excursion Guide tables & figures

TABLE 1. Soil landscape units of northern South Australia (after Northcote *et al*, 1960-68).

B62	Sand dunes with narrow corridor plains; some seasonal swamps or lakes; some small plain areas: chief soils are red siliceous sands (Uc1.23) and brown sands (Uc5.11, Uc5.12), especially in the southern parts of the unit. Associated are (Uc5.21) and (Gc1.22, Gc1.12) soils of the plain and corridor areas. There is some variation throughout this unit but data are limited
BB2	Hills, dissected tablelands, and valleys: hills of shallow calcareous loamy soils (Um5.11); crusty loamy soils (Dr1.13 and Dr1.33) on tableland remnants; and small valleys of crusty loamy soils (Dr1.33 and Dr1.43) with brown calcareous earths (Gc)
BB32	Ranges and hills with extensive rock outcrop and shallow soils; stony pediments and small basin plains; some remnants of stony downs; narrow valleys, some with gorges: chief soils are shallow calcareous loamy soils (Um5.11) and other shallow soils such as (Um5.41), (Um1.43), and possibly some (Um6) soils. There are small areas of a wide range of soils, including (Dr1.33) and (Ug5.3) on stony downs remnants and pediments; (Dr2.33) and (Gc) soils on plains; and (Um5.12) and other (Um) and (Uc) soils in the valleys
BB33	Dissected low tablelands with mesas and buttes; some seasonal swamps; clay pans; valley plains: chief soils are shallow calcareous loams (Um5.11) on upland plains and mesas and buttes. Associated are (Gc) soils, especially (Gc1.12). There are small valleys similar to unit Mx39
BB34	Gently undulating terrain on limestone, probably with calcrete (kunkar). There are many almost circular depressions often joined together by other narrow linear depressions: chief soils are the shallow calcareous loams (Um5.11). Associated are (Gn2.12, Gn2.13) and possibly some (Uc5.21) soils in the circular depressions
BB35	Uneven plains on limestone, probably with calcrete (kunkar): chief soils are the shallow calcareous loams (Um5.11) of the slightly raised portions of the plain. Associated are the shallow (Gc1.12) and (Gc1.22) soils of the slightly depressed portions of the plain
BG1	Valley plains, some of which have saline deposits: chief soils are calcareous loams (Um5.12) in association with (Gc) soils, especially (Gc1.12). Other soils occur. As mapped, small areas of adjacent units are included
CC112	Narrow valley plains, commonly with many distributary channels; some clay pans and flood-out areas: chief soils are probably grey clays (Ug5.2). Associated are small areas of many other soils (undescribed)
DD1	Dune formations with relatively small plains between: dunes of brown calcareous earths, (Gc1.12) and (Gc1.22) in particular, and (Gn1.13) soils with small areas of brown sands (Uc5.1); plains of brown calcareous earths (Gc1.12) and (Gc1.22) and (Gn1.13) soils, with crusty loamy soils (Dr1.33) and (Dr1.43) in lower-lying portions. The (Gn1.13) soils may be dominant locally and are more common in some DD1 areas than was recorded previously. Areas of other soils, such as (Um5.5) and (Uc1.23), are likely. There are small inclusions of adjoining units.
DD2	Plains with more or less isolated tracts of dunes: broad plains of brown calcareous earths (especially Gc1.12) with areas of exposed caliche and crusty loamy soils (Dr1.33), (Dr1.43), and (Dr1.13), with clay pans, saline soils (unclassified), swamps, and intermittent lakes in the lower-lying portions; also dunes of brown sands (Uc5.1) and brown calcareous earths (Gc1.22)
DD29	Plains broken by hills and ridges; some dune tracts; saline flats; clay pans; seasonal swamps and lakes: chief soils are brown calcareous earths (Gc1.12) and (Gc1.22), with shallow calcareous loams (Um5.11). Associated are dunes of (Uc5.1) and (Gc) soils and also (Uc1.23) and (Gn1.13) soils, particularly in the north of the area; hills and ridges with rock outcrops, (Um5.11), and other shallow (Um) and (Uc) soils; and valley plains in the north of the area with (Gn1.13), (Gn2.13), (Uc1.4), and (Uc1.2) soils. This is a broad complex unit which could be subdivided when more data are available
DD32	Undulating terrain with some sand dunes: chief soils are brown calcareous earths (Gc1.12) and (Gc1.22) with shallow calcareous loams (Um5.11), and (Uc5.1) sands on the dunes. Other soils may occur. Data are limited
Mx39	Broad shallow valleys: chief soils are alkaline red earths (Gn2.13), in association with sandy-surfaced red duplex soils, such as (Dr2.43) and (Dr1.43), and similar soils. Their dominance varies locally. Other soils may occur
Na1	Dissected tableland: undulating stony plains of crusty loamy soils (Dr1.13) and (Dr1.33), which may form gilgais and also gilgai complexes with cracking brown clays (Ug5.3); interspersed with mesas and buttes capped by shallow calcareous loamy soils (Um5.11) and/or residues of past weathering cycles such as remnants of sandstone, gypsum, silcrete, laterite, etc.; traversed by broad shallow valley plains of deep calcareous loamy soils (Um5.12) with saline flats, gypsum mounds, and swamps. Some brown sands (Uc5.1) and brown calcareous earths (Gc) may occur also
Nb27	Dissected tablelands—broad undulating plains with mesas, buttes, scarps, and pedimented areas; block silcrete and possibly laterite on breakaways; siliceous gravels and stones mantle the surface; narrow valleys; clay pans and seasonal swamps: chief soils are crusty loamy soils (Dr1.33, Dr1.32), (Dr1.13, Dr1.12), and (Dr1.43) with some gilgai depressions of (Ug5.38) clays. Associated are (Dr1.16) soils on the pediments and possibly other soils underlain by the red-brown hardpan; but the extent of the hardpan and the (Dr1.16) soils is not known. There are also small areas of many other soils, including (Um1.43) and (Um5.11), which occur in areas of strong relief
Nb35	Stony downs—undulating terrain with some scarps, mesas, and buttes; a mantle of stones and gravels covers the soil surface; narrow valleys: chief soils are crusty loamy soils, especially (Dr1.33) and (Dr1.13), which often occur in weak gilgai complex with brown cracking clays (Ug5.3). Associated locally are (Uf1.13) and possibly (Uf1.23) clays. Other soils may occur, especially (Um5.11) on some mesas and buttes. As mapped, areas of unit Nb36 and narrow valleys of unit BG1 are included
Nb36	Gently sloping pediments and plains mantled by stones and gravels; sand spreads and dunes; mesas and buttes; narrow valleys and some lakes (normally dry): chief soils are crusty loamy soils, especially (Dr1.33) and (Dr1.13), with brown cracking clays (Ug5.3) often associated in weak gilgai microrelief. There are soils of unit DD26 on the sand spreads and dunes, of unit BG1 in the narrow valleys, and (Um5.11) soils on some mesas and buttes. As mapped, small areas of units Nb35 and BB32 may be included
Nb40	Rolling stony downs mantled by a strew of stones and gravels: chief soils are probably crusty loamy soils, especially (Dr1.33), (Dr1.13), and (Dr1.43), in gilgai complex with brown cracking clays (Ug5.3) that may be dominant in some areas. Other soils may occur
Nb41	Rolling stony downs mantled by a strew of stones and gravels; some mesas and buttes; shallow valleys; lakes: chief soils are crusty loamy soils, especially (Dr1.33), (Dr1.13), and (Dr1.43), which may form gilgais and also gilgai complexes with cracking brown clays (Ug5.3). Associated soils include shallow loams such as (Um5.11) and (Um1.43) on mesas and buttes, together with residues of past weathering cycles, sandstone, gypsum, silcrete, and laterite. Small areas of unit DD1 may be included in low-lying sites
Nb42	Remnants of stony downs-often with prominent hills, mesas, and buttes: chief soils are crusty loamy soils, especially (Dr1.33) and (Dr1.13), with (Ug5.3) clays in gilgai complex on the rolling downs areas; shallow calcareous loams (Um5.11) on the hills, mesas, and buttes; and areas of (Gc) soils, especially (Gc1.12) and (Gc1.22), on areas of gentler relief. Any of these may be dominant locally

TABLE II

Analysis for major elements (expressed as oxides %)

Sample No.	Fe_2O_3	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3
54a	1·03	9·50	0·20	0·02	0·05	88·1	0·12
b	0·94	0·48	0·07	0·01	0·01	97·9	0·03
15a	0·98	12·30	0·05	0·04	0·06	85·7	0·84
b	1·01	2·62	0·08	0·08	0·04	93·7	1·35
17a	0·97	18·3	0·31	0·03	0·14	79·5	0·24
b	1·04	1·08	0·71	0·03	0·06	95·5	0·25
16	1·18	26·8	0·78	0·04	0·10	67·6	0·33
50	1·04	7·00	1·04	0·09	0·04	88·1	0·28
22	2·20	3·27	0·15	0·02	0·04	93·9	0·44
10	1·01	3·17	0·08	0·02	0·05	95·6	0·10

TABLE III

Analysis of silcrete and underlying shale from Ellis Gully (expressed as oxides %)

Sample	Fe_2O_3	TiO_2	CaO	K_2O	P_2O_5	SiO_2	Al_2O_3	ZrO_2
Surface pebbles	0·94	1·22	0·37	0·07	0·01	96·7	0·39	·045
Top silcrete	1·19	0·63	0·02	0·02	0·01	97·6	0·08	·028
Lower silcrete	0·66	0·85	0·38	0·03	0·01	98·1	0·50	·040
Weathered shale	0·55	2·55	0·45	0·77	0·08	90·8	2·70	·048
Altered shale	3·00	1·17	0·63	4·2	0·08	64·2	20·20	·027

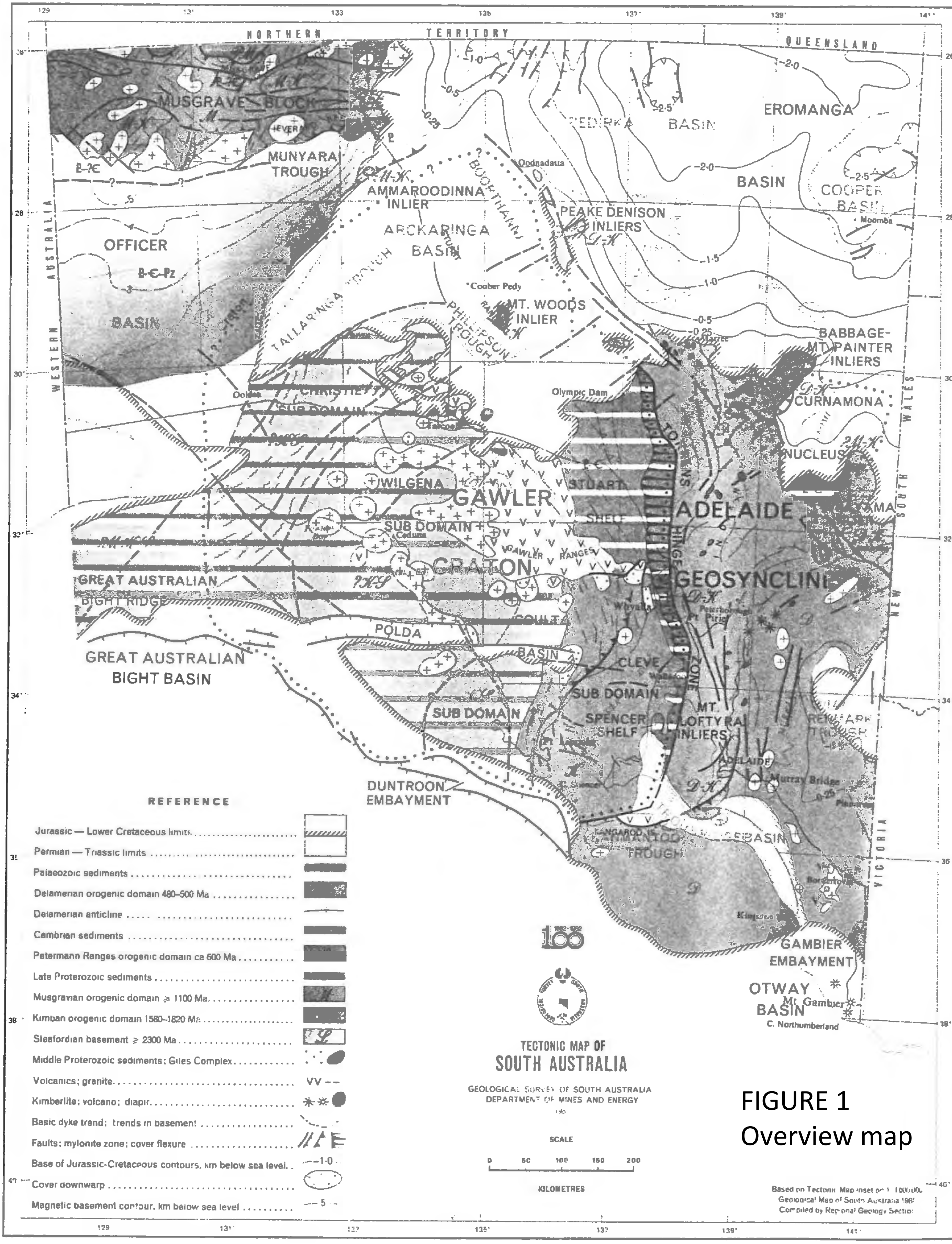


FIGURE 1
Overview map

FIGURE 2. Geological map of the Leg 1 region, from Ambrose & Flint (1981b)

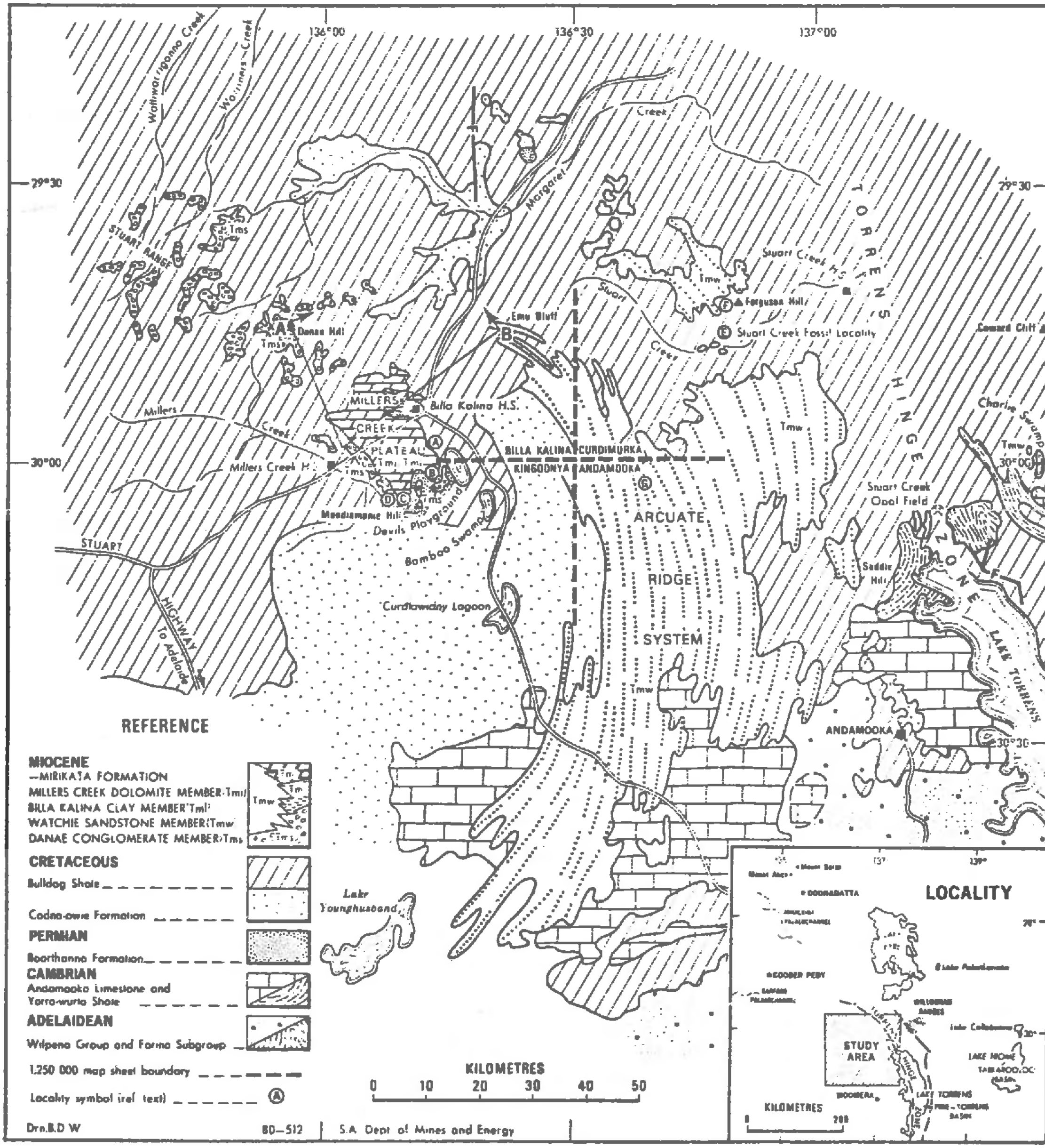


FIGURE 3. Section across the Beda Hill area, from Twidale *et al*. (1970)

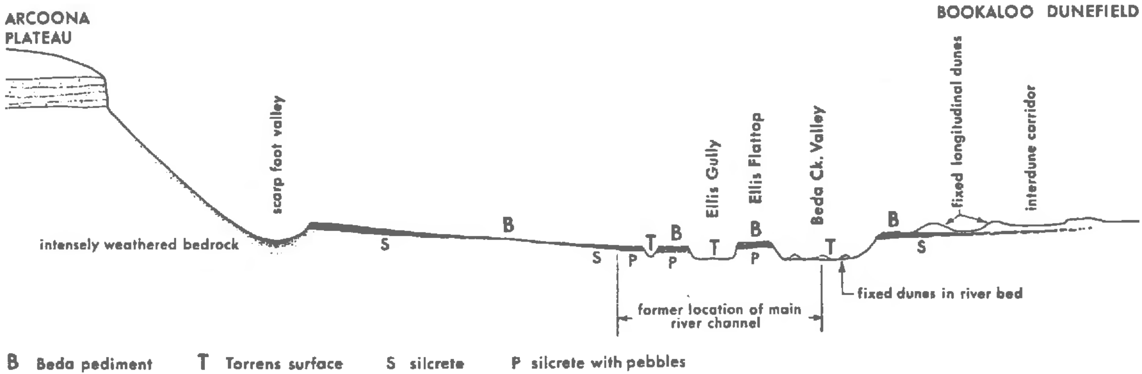


FIGURE 4. Geological plan of the Stuart Creek opal field (from Barnes & Townsend, 1982)

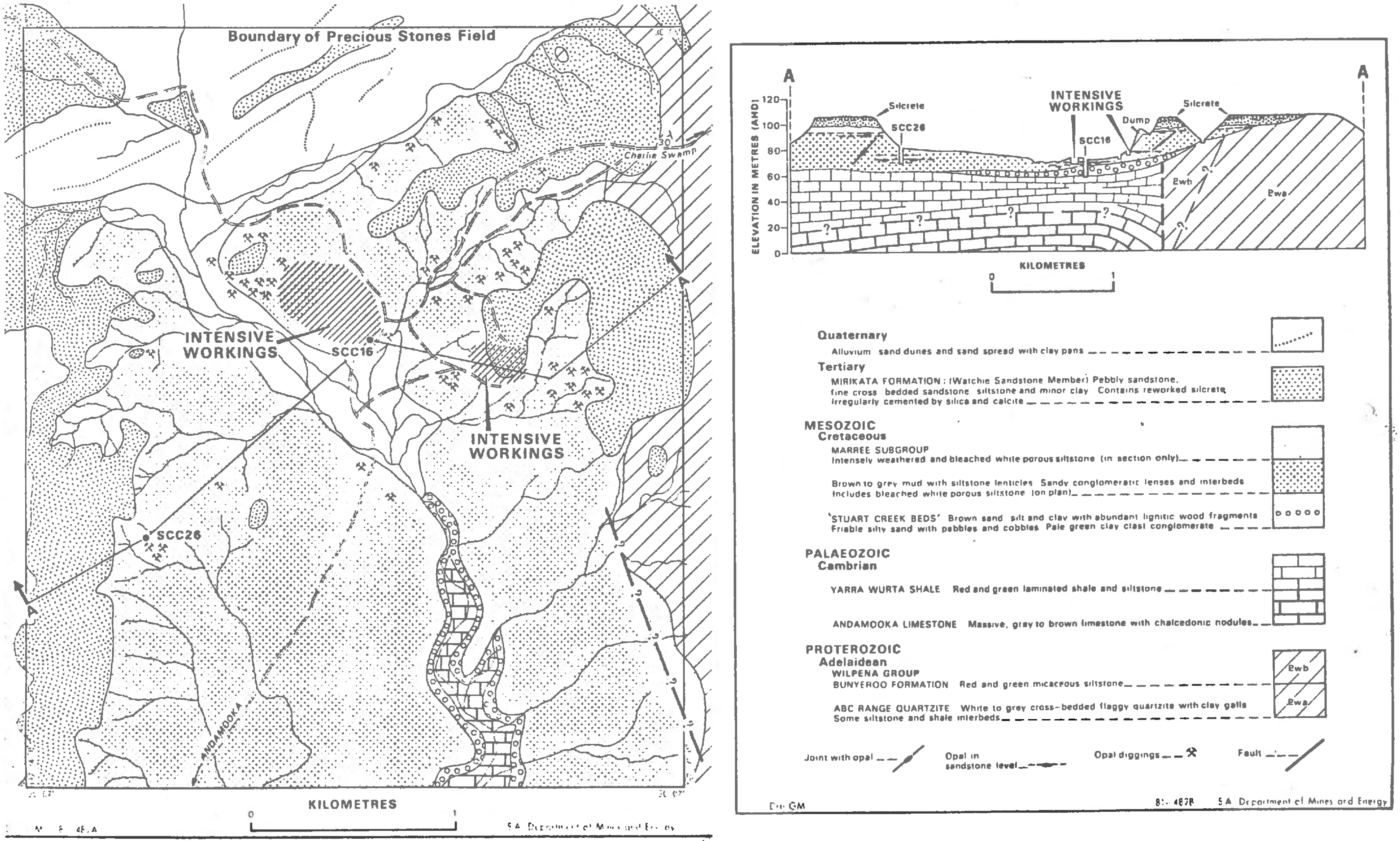


FIGURE 5. Section 379 of Vnuk (1978)

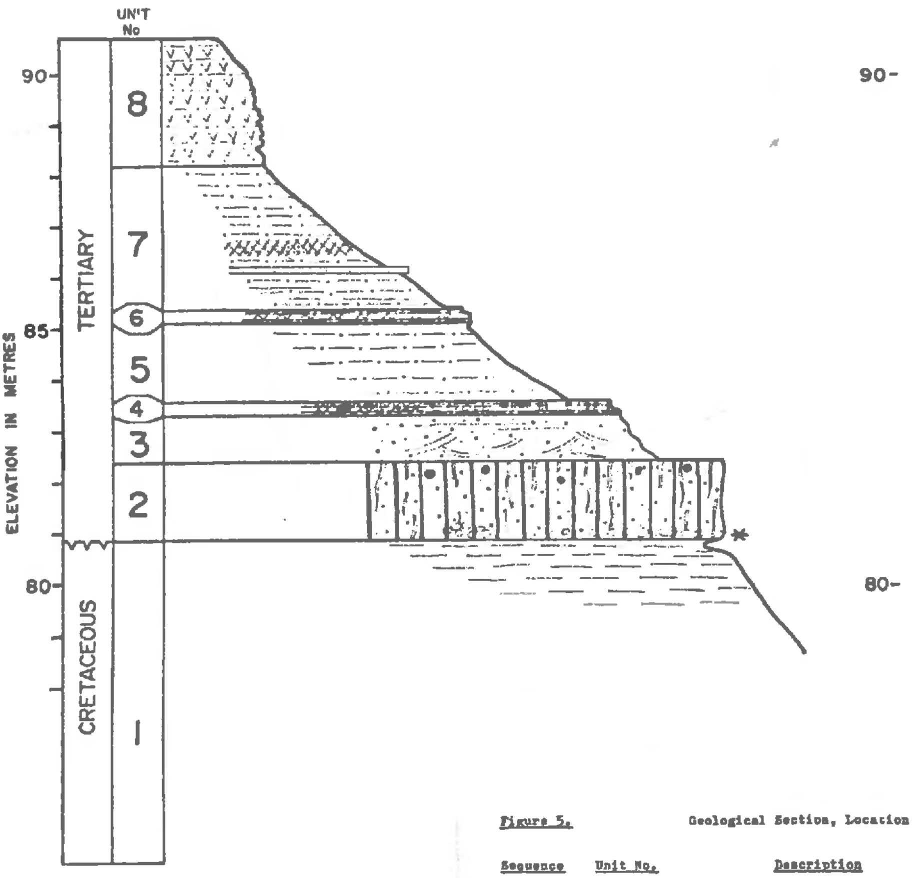


Figure 5. Geological Section, Location No. 379.

Sequence	Unit No.	Description
	1	Fresh grey mudstone. Upper 2m is yellowish.
B	2	Grey silicified sandstone with spherical goethite nodules. Medium quartz grains float in a microcrystalline groundmass. Planar upper surface, reed-like plant impressions in upper part and root channels. Sharp base with silcrete and quartzite lag. (T.S. and silicate analysis 550/-379-1).
B	3	Fining upward, ferruginised friable sand. Yellow, cross bedded medium sand at base to mauve flat laminated fine sand at top. Sharp base on silcrete upper surface.
B	4	Ferruginised and silicified yellow siltstone with granule layers. Planar upper surface and contains goethite nodules and root channels. Base is gradational onto friable fine sand.
C	5	Grey clayey finely bedded silt and very fine sand
C	6	Burrowed interval between two silicified siltstone layers. (T.S. 550/379-5).
C	7	Grey clayey silt and very fine sand. Fine sand and ferruginised, thin, lenticular coarse sand beds.
C	8	Gypcrete, alunite and ferruginous staining developed in silt and very fine sand.

FIGURE 6, Sketch of section in Locality 5 by Roger Callen.

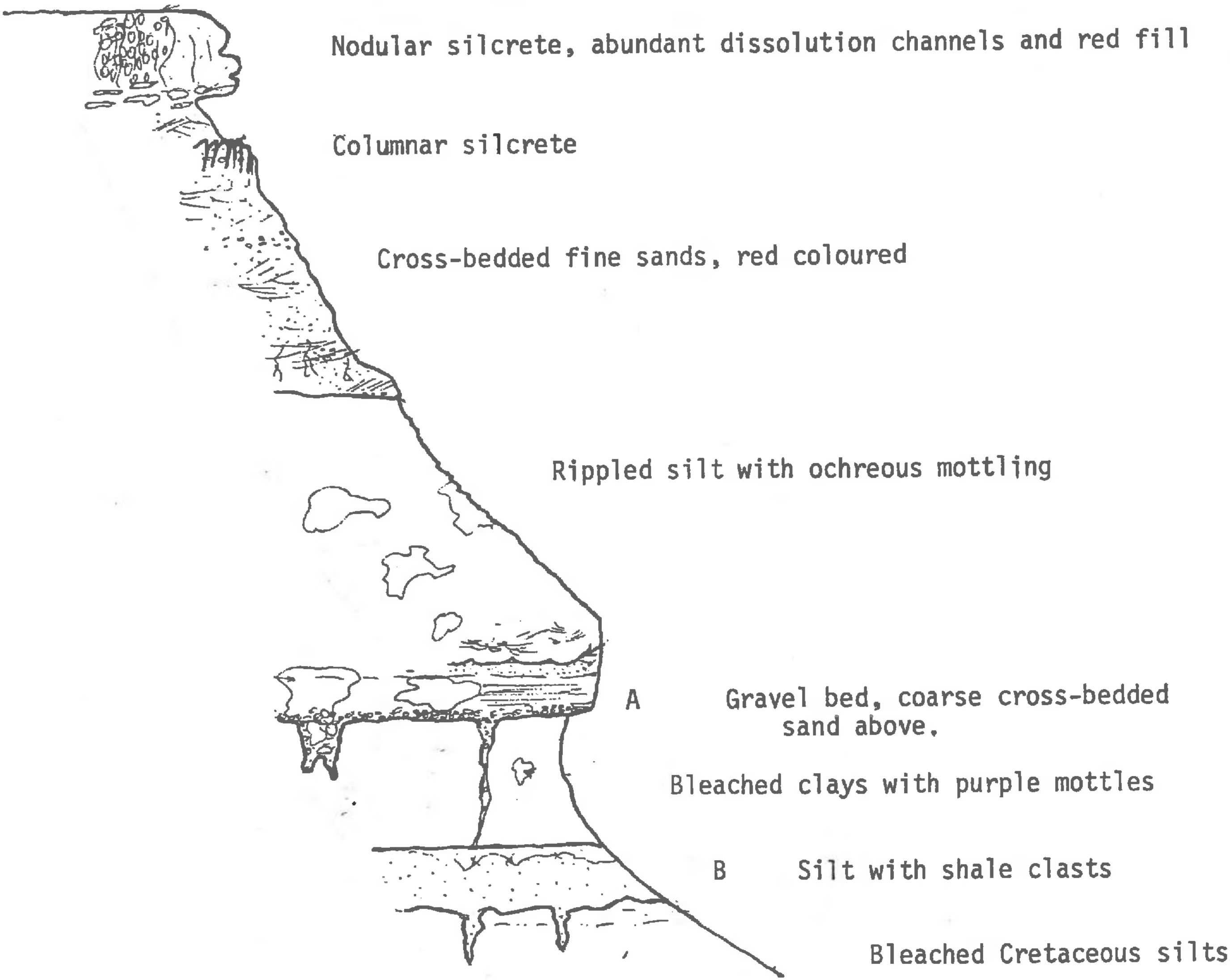


FIGURE 7 **COOBER PEDY OPALFIELDS – SECTION ACROSS STUART RANGE**

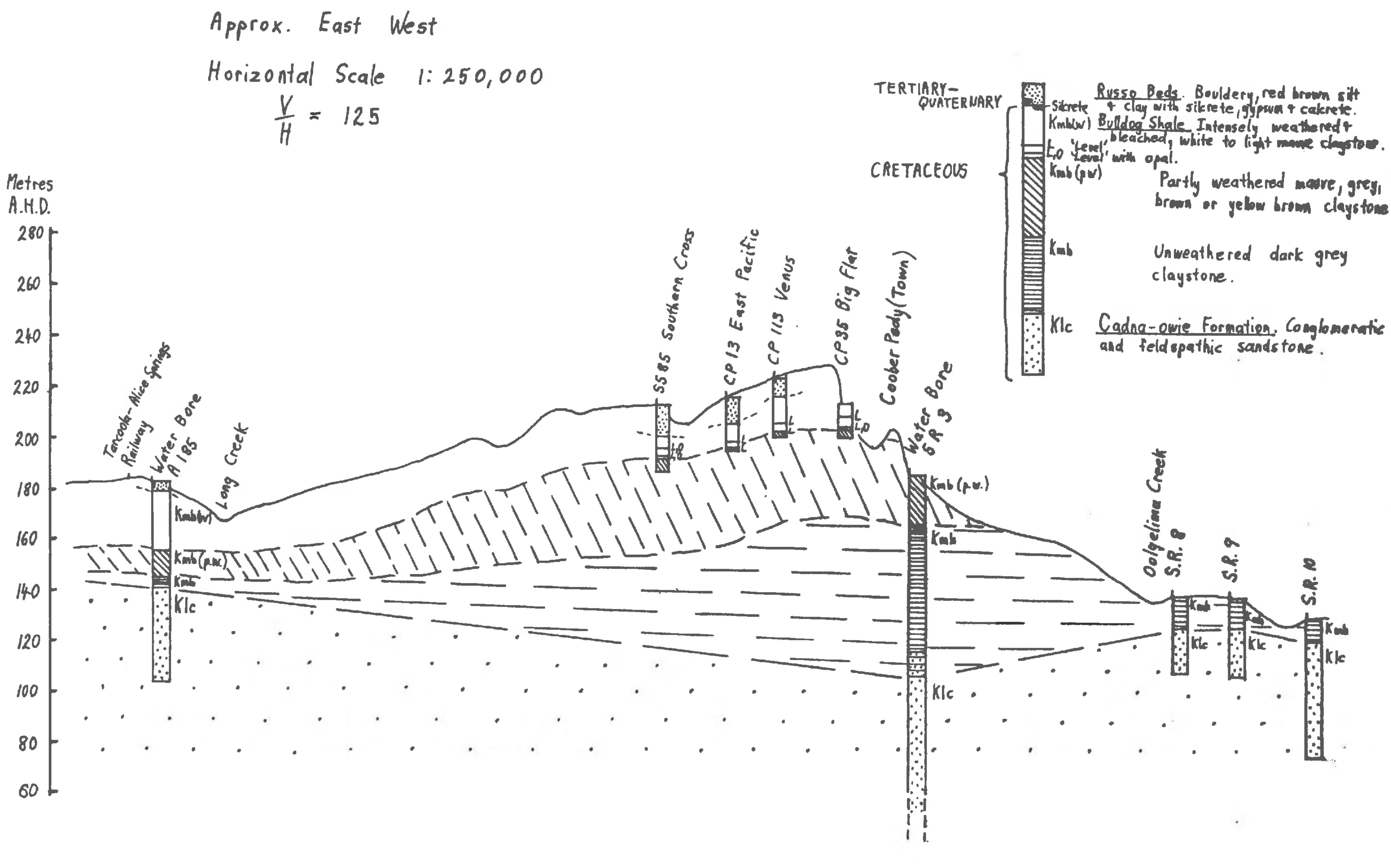


FIGURE 8 Regional Setting, showing palaeodrainage, Eucla Basin margin and localities to be visited. Modified after Pitt, (1980)

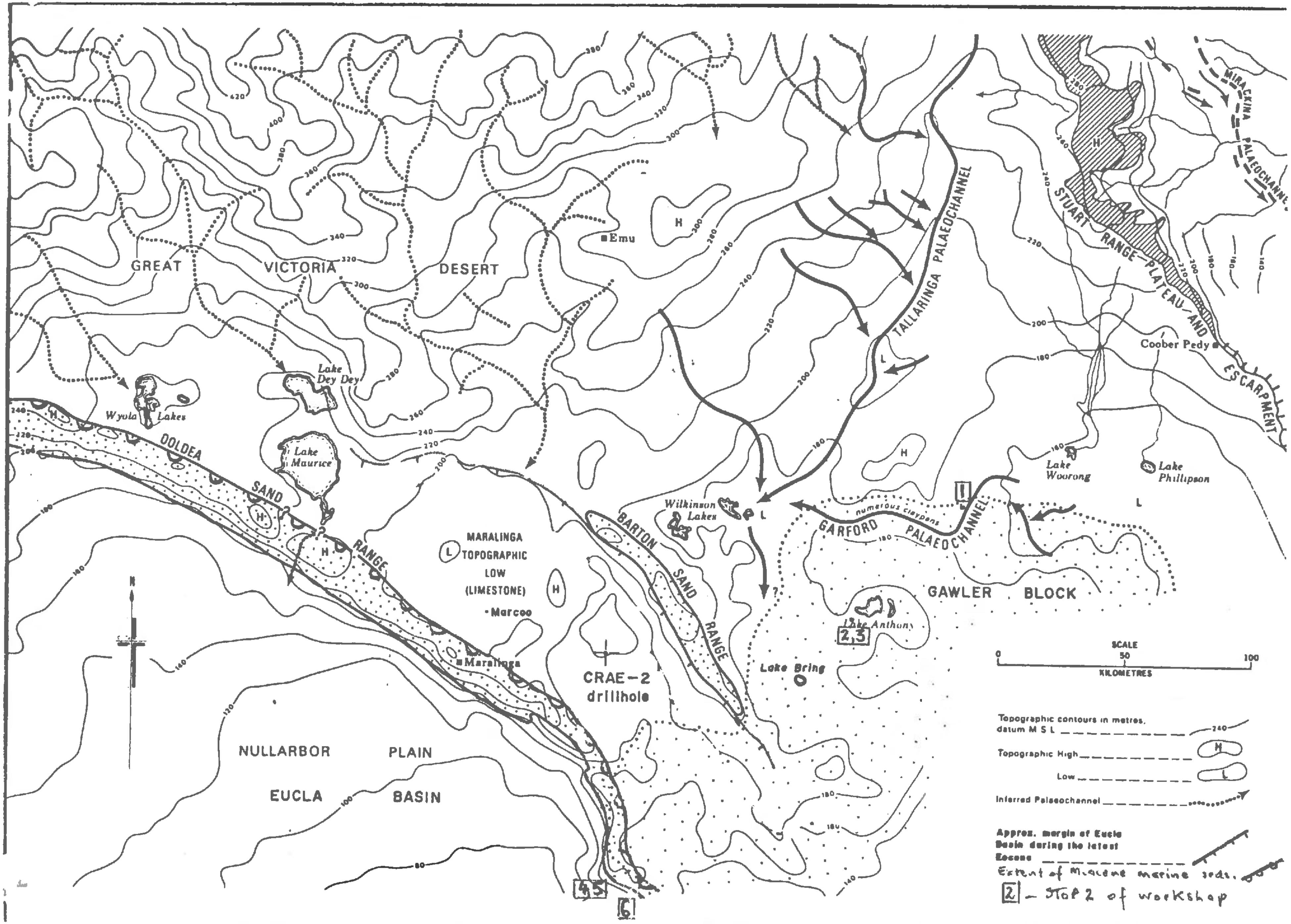
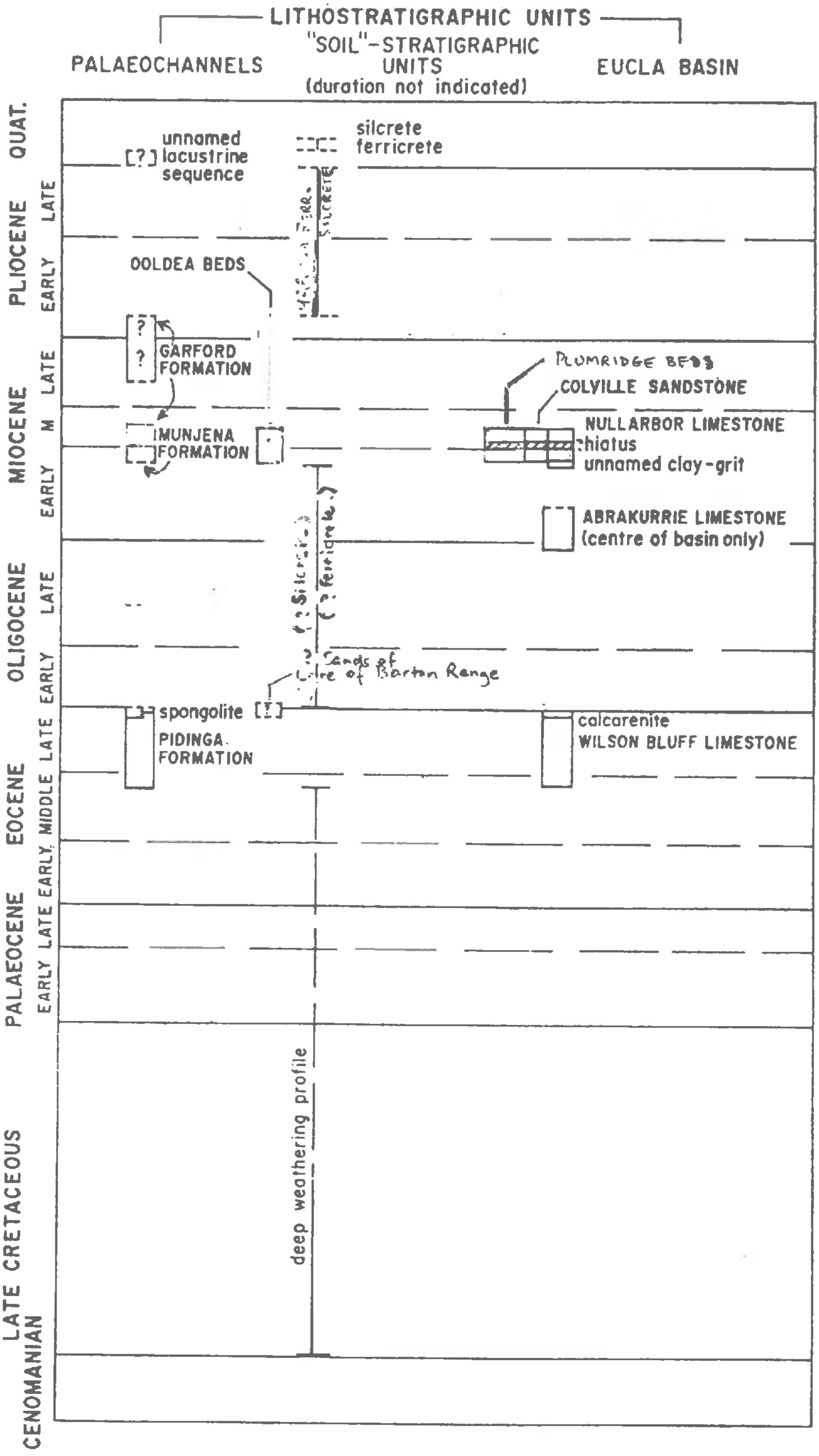
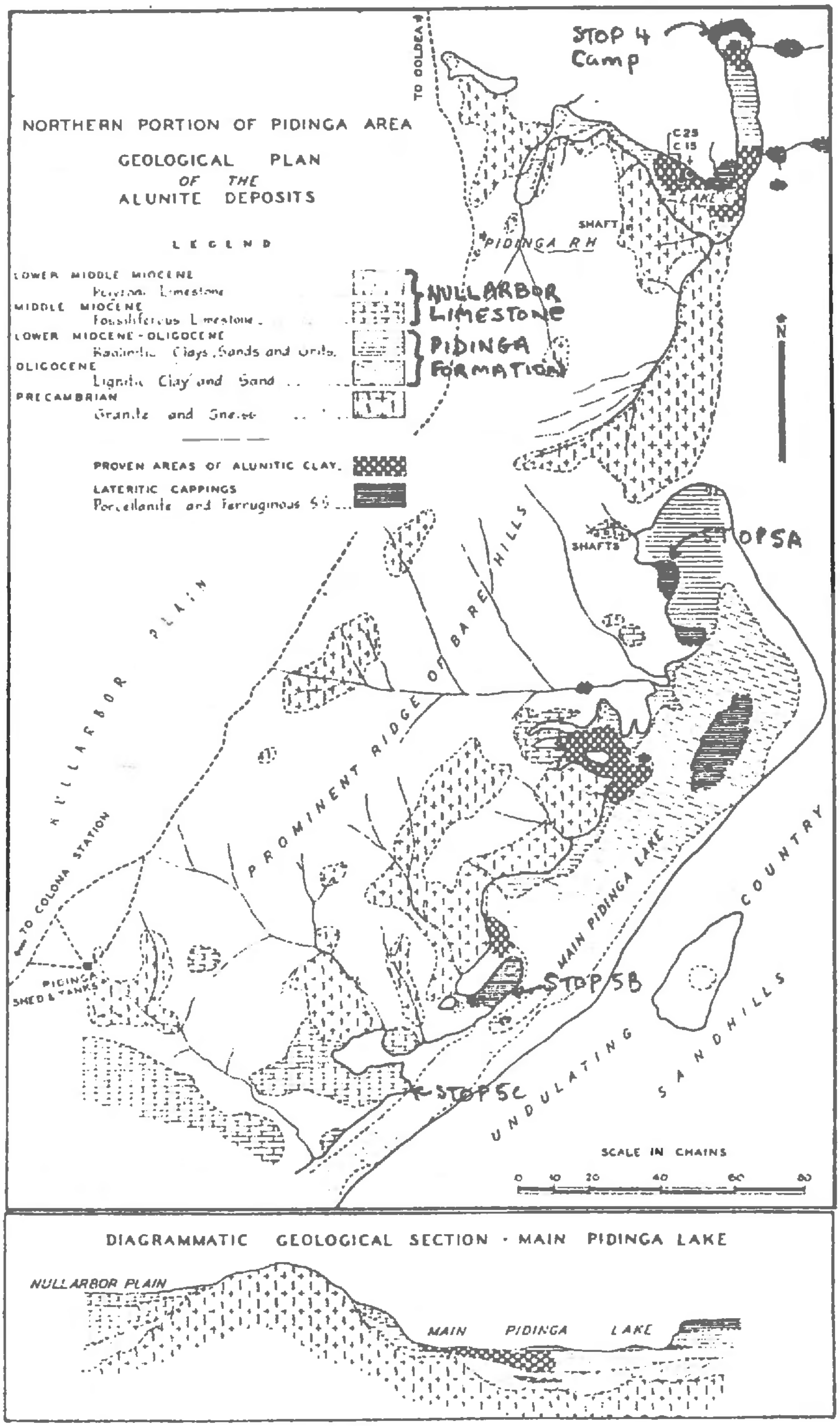


FIGURE 9

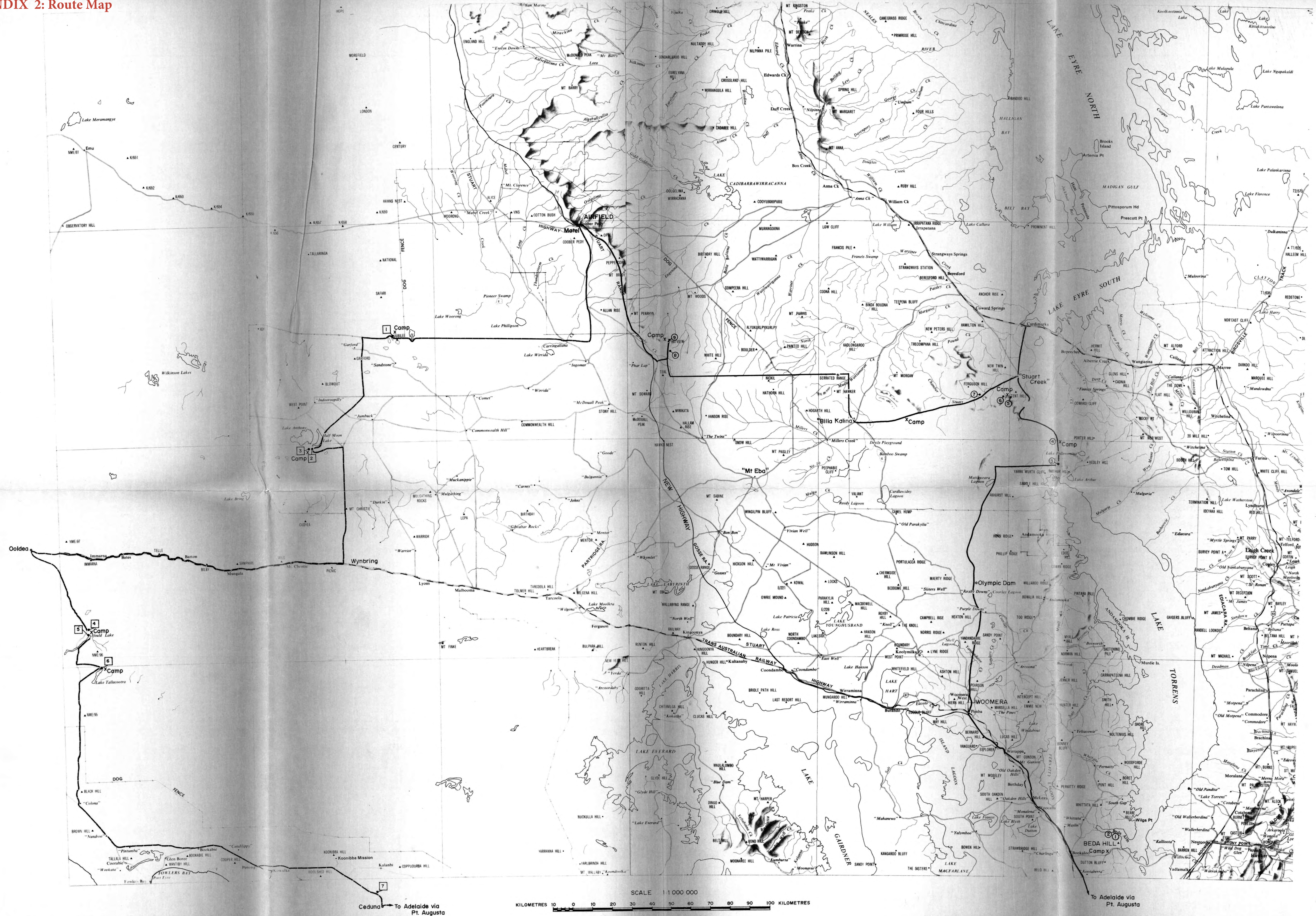


Stratigraphic framework east margin of the Eucla Basin
Modified after Benbow (1983).

FIGURE 10 Fig. 2 of King (1953). Northeast Lake Ifould or Lake Pidinga, showing STOPS 4 and 5.



APPENDIX 2: Route Map



SADME – CSIRO SOILS
SILCRETE FIELD WORKSHOP 1985

SILCRETE FIELD WORKSHOP, SOUTH AUSTRALI A
August 19-30 1985
SECOND AND FINAL CIRCULAR

Organised by SADME and CSIRO Soils

LEADERS : Mr R.A. CALLEN and Mr M.C. BENBOW, Department of Mines & Energy, PARKSIDE.
Dr A.R. MILNES, CSIRO Division of Soils, GLEN OSMOND.

It is proposed to hold a SILCRETE FIELD WORKSHOP in August 1985 at various localities in the arid inland of South Australia where active research on these materials is currently in progress. The aim is to introduce those with a research interest in silcretes to the field situations where stratigraphic, pedological and geomorphic relationships and features can be directly demonstrated and informally discussed.

This will be an excellent opportunity to see the unique rock exposures and geomorphology of the desert regions of South Australia.

The main venues for the WORKSHOP are:-

FIRST LEG (6 days)

- The titanium-rich silcrete skins, associated silicified sediments and related geomorphology of the Lake Torrens area.
- A series of silicified shoreline features in the region between Lake Torrens and Lake Eyre, west of the Willouran Ranges. Stuart Creek, draining into Lake Eyre, cuts through these features to reveal sections related to regression of the ancient lake during the early to middle Tertiary. Beneath this sequence are other Tertiary sediments locally containing abundant plant fossils known as the "silcrete floras", which include Eucalyptus fruits. The relationship of different silcrete types to subtle topographic forms can be observed. The ancient shoreline systems have eroded into a series of unusual arcuate linear mesas.
- The excursion proceeds west to Coober Pedy via 'breakaway' country with silica-iron duricrusts. Coober Pedy lies on a major Tertiary drainage divide, the Stuart Range, which separated drainage into the marine Eucla Basin from that to the Lake Eyre region (Birdsville Basin).
- Whilst at Coober Pedy (motel accommodation) we will examine silcretes and hardpans in the Stuart Range, and visit the opal workings, underground dwellings and the museum.

SECOND LEG (6 days)

- The Tallaringa Palaeodrainage System (which flowed into the Eucla Basin during the Tertiary), with its variety of silcretes in specific stratigraphic positions, and their relationships with ferricretes and deeply weathered rocks. These will be examined at Lake Anthony, southwest of Coober Pedy, and at Ifould Lake, south of Ooldea.
- Silcretes in the Miocene marine Nullabor Limestone at Ifould Lake and in the Eocene Pidinga Formation at Ceduna (motel accommodation) on the west coast.

In-the-field informal talks with slides will be held during some evenings to cover a variety of aspects of silcrete research. (A portable 240v generator, slide projector and screen will be available.) Participants are invited to talk informally about their research at these sessions and to bring transparencies for illustration purposes .

GENERAL

Travel will be by 4-wheel drive vehicles, and should be arranged privately amongst participants, although a limited number of seats may be available for those not able to provide their own transport. Food, cooking and camping facilities will need to be arranged privately on a per-vehicle basis.

The WORKSHOP will commence with departure from Adelaide at 8.00am August 19. Travel will be in convoy after Port Augusta. It will be possible to leave the WORKSHOP after the completion of Leg 1 or to join the WORKSHOP for Leg 2 at Coober Pedy, via an airlink to Adelaide, but this must be arranged by individuals in consultation with others in the host vehicle. The WORKSHOP will end officially on the morning of August 30 in Ceduna, a 8-9 hour drive from Adelaide.

VEHICLES, CAMPING, SAFETY, TERRAIN

All vehicles must have 4-wheel drive, and must have received a thorough mechanical overhaul. Any vehicles which break down will need to undertake their own repairs, or make their own arrangements for repairs, and rejoin the party at a later stage. All vehicles must be self sufficient in water, fuel, food, tyres, puncture kits, etc. Water in the region to be traversed is scarce and of poor quality. Water and fuel availability is as follows:

Port Augusta
Woomera
Olympic Dam
Stuart Creek (doubtful)
Billa Kalina (by arrangement)
Coober Pedy
Wynbring (by arrangement)
Ceduna

The longest stretches without fuel are about 400km: Olympic Dam - Billa Kalina (400km), Coober Pedy - Wynbring (350km), Wynbring - Nundroo (400km). Water is also available after visiting Half Moon Lake and Lake Anthony on the second leg.

Camping gear will be required except at Coober Pedy and Ceduna, where motel accommodation is available. A warm sleeping bag with waterproof cover or a small tent will be necessary because night temperatures can be below freezing and rain is possible. Cold winds are likely through the days: bring parkas and balaklava helmets, in addition to sunhats, sunglasses and sunburn cream.

Water bottles and first aid will be the responsibility of individuals. Each vehicle should carry a full St John First Aid Kit, and 2-3 large elastic bandages for snakebite (although snakes are likely to be scarce). It is also preferable for vehicles to carry a 2-way radio with frequencies 2020, 4010, and 6890, for contacting VNZ Port Augusta.

Much of the journey will be through remote desert terrain. Dunes are not normally a difficulty , though vehicles should be prepared for sand. Rain is possible, and tracks become impassable after about 19mm (3/4") of rainfall. Rugged canyons and creeks strewn with boulders are the norm in the Stuart Creek area. Drivers should take extra care in such terrain, and should also make every effort to avoid puncturing tyres on the low scrubby vegetation common throughout the region.

Wood is usually in plentiful supply, and is excellent for campfires. Rubbish should be burned or returned to vehicles for disposal in Coober Pedy and Ceduna.

Permission for entry to the Woomera Prohibited Area and to Maralinga Lands will be required, and will be organised for participants by SADME. Fuel supplies at Billa Kalina and Wynbring will also be arranged by SADME (see Registration Form where details of vehicle fuel requirements must be specified).

In order to proceed with planning, we need notice of intent to participate and the payment of Registration Fees <u>before June 1st</u>.

I will/will not be able to attend the SILCRETE FIELD WORKSHOP

Please mark with a tick or cross as appropriate:

a. I can provide my own 4-wheel drive transport.

   I have room for [ ] extra people.

   I have arranged for [ ]
[ ]
[ ] to travel in my vehicle.

b. I will require transport.

c. I would like to contribute to the informal evening talks program.

NAME: ………………………………………………………………………………………………

ADDRESS: ………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

TELEPHONE: ……………………………………………………

Suggestions about the proposed WORKSHOP, the venues offered, travel arrangements, etc.

………………………………………………………………………………………

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REGISTRATION

Total registration $60.00 - includes maps and field notes, motel booking fees, organisational costs including costs of arranging fuel supplies.

Leg 1 only registration fee - $33.00.
Leg 2 only registration fee - $27.00.

Please pay by cheque, made payable to:

"Silcrete Workshop",
"Department of Mines & Energy , South Australia".

Enrolment Forms and Registration cheques should be sent to:

Mr M.C. Benbow,
Regional Geology Section,
S.A. Department of Mines & Energy,
P.O. Box 151,
EASTWOOD,
South Australia 5063.

Enquiries should also be directed to Mr M. C. Benbow at the above address, or on Tel. (08) 274 7500.

*For those participants bringing vehicles, please indicate fuel type and amount you anticipate may be required at:

1. Billa Kalina (Leg 1) …………….. …………….. litres
2. Wynbring (Leg 2) …………….. …………….. litres

Final Notice

SILCRETE FIELD WORKSHOP, SOUTH AUSTRALI A
August 19-30, 1985.

Leaders: A.R. Milnes, M.C. Benbow, K.J. Wright & R.S. Robertson.
Unfortunately, Roger Callen has taken up an exchange contract with the Geological Survey in Oman, and will not be with us on the Workshop .

Preliminary runs along the proposed route have now been completed, and final arrangements for the Workshop are in hand. The one major problem with which we cannot cope is widespread rain through the areas we will traverse. If rains do occur, we see no option but to abandon the Workshop, and you will be notified by telephone in the week preceding Saturday August 17.

<u>Participants</u>

The following is a list of registrants. A few have not yet firmed their arrangements with us, and some have not yet paid a registration fee. I ask those concerned to confirm their participation as soon as possible.

List of Registrants

N.F. ALLEY	S.A .Department of Mines & Energy, 191 Greenhill Road, PARKSIDE, S.A. 5063 Tel. (08) 274 7500.
M.C. BENBOW	S.A. Department of Mines & Energy, 191 Greenhill Road, PARKSIDE, S.A. 5063 Tel.(08) 274 7500
M. BIRD	Research School of Earth Sciences, Australian National University, P.O. Box 4, CANBERRA, A.C.T. 2601 Tel. (062) 49 4770
C.R.M. BUTT	CSIRO Division of Mineralogy & Geochemistry, Private Bag, P.O. WEMBLEY, W.A . 6014. Tel. (09) 387 4233
C.J. CHARTRES	CSIRO Division of Soils, P.O. Box 6391, CANBERRA, A.C.T. 2601. Tel. (062) 46 5271
A. CHIVAS	Research School of Earth Sciences, Australian National University, P.O. Box 41, CANBERRA, A .C.T. 2601 Tel. (062) 49 3247
H.M. CHURCHWARD	CSIRO Division of Groundwater Research, Private Bag, P.O. WEMBLEY, W.A. 6014.
N.G. COLLINS	Department of Geology, University of Melbourne, PARKVILLE, VIC. 3012. Tel. (03) 344 4000

R .J. COVENTRY	CSIRO Division of Soils, Private Bag, P.O. AITKENVALE, QLD 4914 Tel. (077) 79 4855
M. CRAIG	Bureau of Mineral Resources, Geology & Geophysics, P.O. Box 3781, CANBERRA, A.C.T. 2601 Tel. (062) 49 9111
R.W. FITZPATRICK	CSIRO Division of Soils, Private Bag No 2, GLEN OSMOND, S.A. 5064 Tel. (08) 274 9311
M .J. FREEMAN	N.T. Geological Survey, P.O. Box 2330, ALICE SPRINGS, N.T. 5750 Tel. (089) 50 3664
A .C. FRENCH	Stockdale Prospecting Ltd, P.O. Box 712, WHYALLA, S.A. 5600 Tel. (086) 45 3889
D. GIBSON	Bureau of Mineral Resources, Geology & Geophysics, P.O. Box 3781, CANBERRA, A.C.T. 2601. Tel. (062) 49 9111
E.B. JOYCE	Department of Geology, University of Melbourne, PARKVILLE, VIC. 3012 Tel. (03) 344 4000
A.R. MILNES	CSIRO Division of Soils, Private Bag No 2, GLEN OSMOND, S.A. 5064 Tel. (08) 274 9311
R.S. ROBERTSON	S.A . Department of Mines & Energy, 191 Greenhill Road, PARKSIDE, S.A. 5063 Tel. (08) 274 7500
G. TAYLOR	Canberra College of Advanced Education, P.O. Box 1, BELCONNEN, A.C.T. 2616 Tel. (062) 52 2031
M. THIRY	Ecole des Mines de Paris, Centre de Geologie Generale et Miniere *c/* CSIRO Division of Soils, Private Bag No 2, GLEN OSMOND, S.A. 5064 Tel. (08) 274 9311
S. VEITCH	8 Eady Street, DICKSON, A.C.T. 2602 Tel. (062} 48 8801
P.H. WALKER	CSIRO Division of Soils, P.O. Box 639, CANBERRA, A.C.T. 2601 Tel. (062) 46 5271

J.A. WEBB Department of Geology,
University of Melbourne, PARKVILLE, VIC. 3012.
Tel. (03) 344 4000

M.J. WRI6HT CSIRO Division of Soils,
Private Bag No 2, GLEN OSMOND, S.A. 5064
Tel. (08) 274 9311

K.H. WYRWOLL Department of Geography,
University of Western Australia,
NEDLANDS, WA. 6009.
Tel. (09) 380 2714

Transport

Pending final notification from some intending participants, transportation arrangements have been set as follows:

Vehicle 1 - BENBOW, ALLEY* & BIRD*
2 - ROBERTSON & JOYCE*
3 - MILNES, THIRY & WRIGHT
4 - COVENTRY, FITZPATRICK & VEITCH
5 - WALKER, CHARTRES & TAYLOR
6 - FREEMAN & CHIVAS*
7 - BUTT, CHURCHWARD & WYROLL
8 - GIBSON, CRAIG & COLLINS
9 - FRENCH & WEBB to meet party at Coober Pedy
10 – another possible vehicle

* Travelling only to Coober Pedy

Pl ease make contact with others in your assigned vehicle. Fuel, food, cooking and camping facilities will have to be arranged privately on a per-vehicle basis. Other vehicle requirements were detailed in the previous circular. Each person must of course be responsible for his own swag and other personal gear mentioned in the previous circular.

Fuel and water supplies have been organised at Billa Kalina HS and at a Stockdale Prospecting Ltd camp at Barton, about 15km beyond Wynbring. As we do not wish to burden the people in each place with administrative problems, you are requested to pay-as-you-receive fuel by cash or cheque.

Registration

We ask participants in the Workshop to meet in Adelaide at CSIRO Division of Soils (Waite Road, GLEN OSMOND) at about 6pm on Sunday August 18. This is not practicable for some people, including the Western Australians and Mike Freeman from the Territory, who will wait for the party in Port Augusta. However, we consider it desirable to meet together prior to departure to facilitate vehicle arrangements and to distribute maps and guides. We will also provide an introduction to the Workshop with details of the route to be taken and the logistics of convoy travel. Snacks and wine will be available. Displays showing some features of the region, and Department of Mines & Energy publications dealing with parts of the region will be on display and for sale.

I can arrange bulk bookings in a nearby motel for those who require Sunday night accommodation. Please contact me by telephone.

Travel

We plan to begin the Workshop officially by departing Port Augusta from the Port Augusta West Shell service station (Woomera road, across the bridge from the town centre) at 12.l5pm Monday August 19. Those leaving Adelaide that morning will need to depart between 7.30-8.00am.

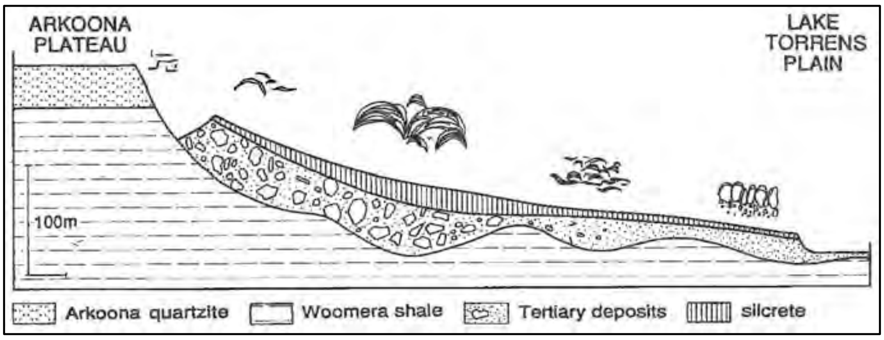


Figure from Schmitt et al. (1991), Milnes & Thiry (1992) showing the distribution of pedogenic silcrete facies on the Beda paleopediment from the scarp-foot zone of the Arcoona Plateau to the distal parts of the pediment where it merges with the modern drainage. Leg 1, Localities 1 & 2.

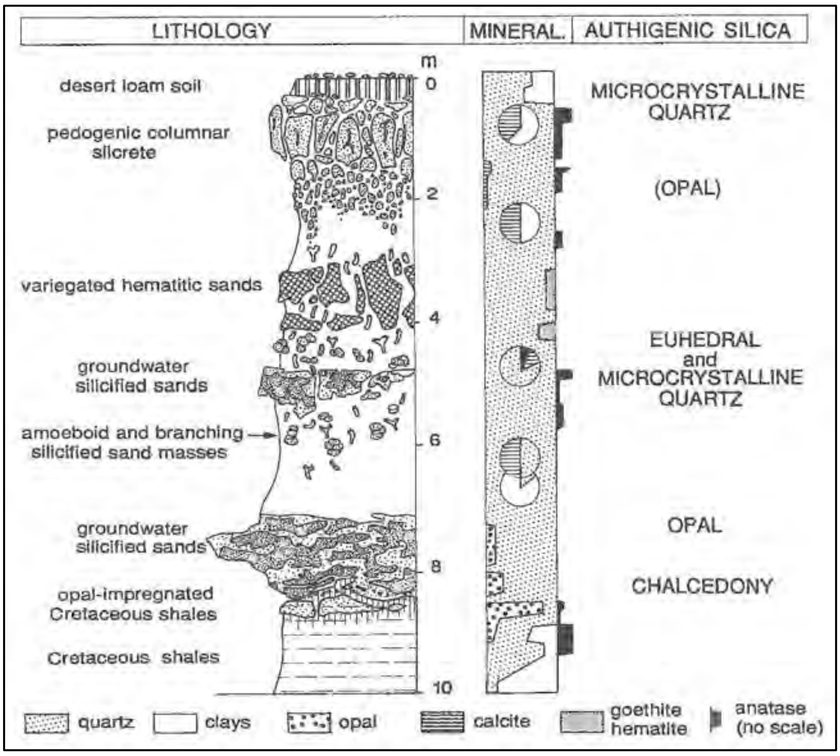


Figure from Milnes & Thiry (1992) showing a schematic profile through the regolith at Stuart Creek opalfield detailing pedogenic and groundwater silcrete s, together with geology and mineralogy. Leg 1, Locality 3.

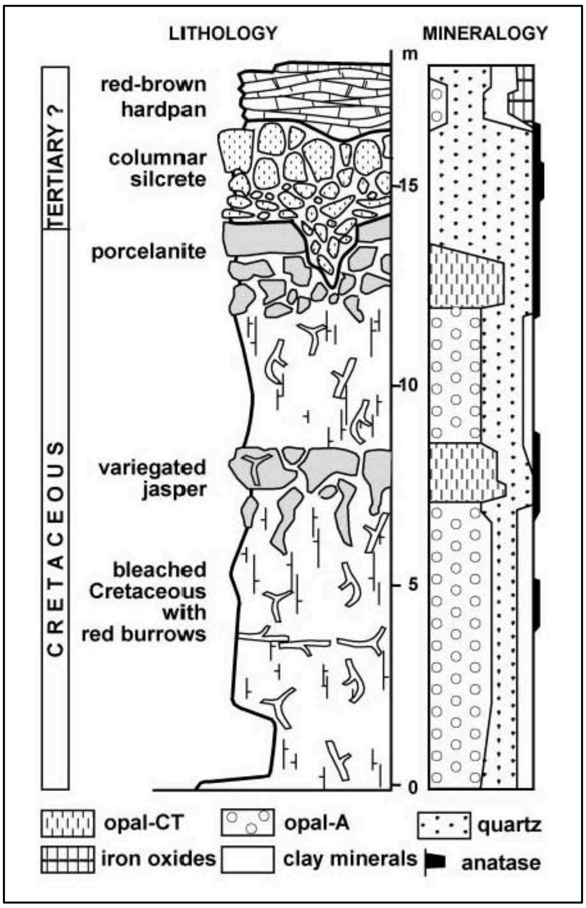


Figure from Thiry et al. (2006) showing a schematic profile through the regolith at Larkins Folly opalfield, Coober Pedy with details of pedogenic and groundwater silcretes, together with geology and mineralogy. Leg 2, Locality 2.

APPENDIX 5

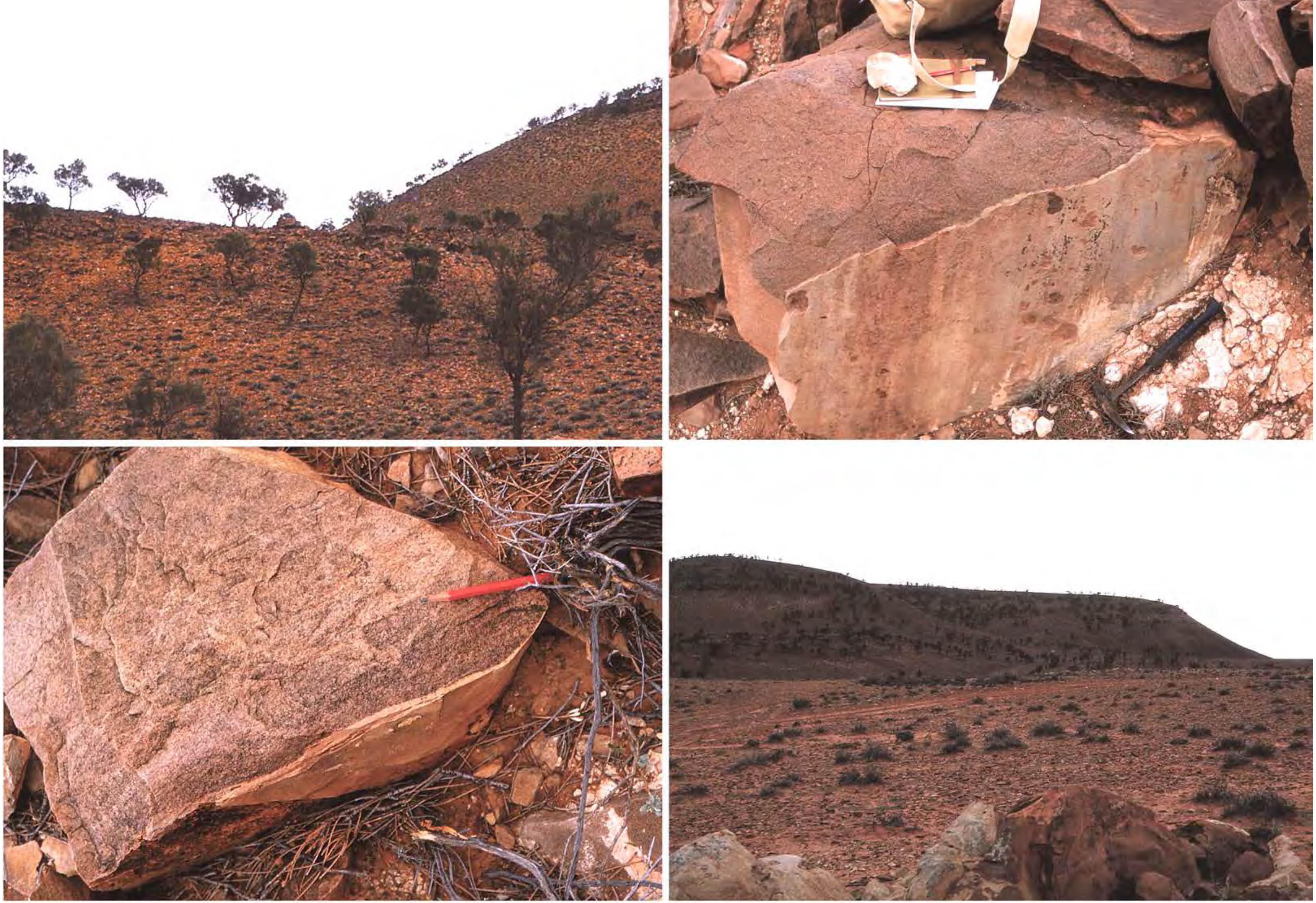
Silcrete Field Excursion

August 19-30, 1985

Photographs taken during excursion (in sequence according to Excursion Notes).

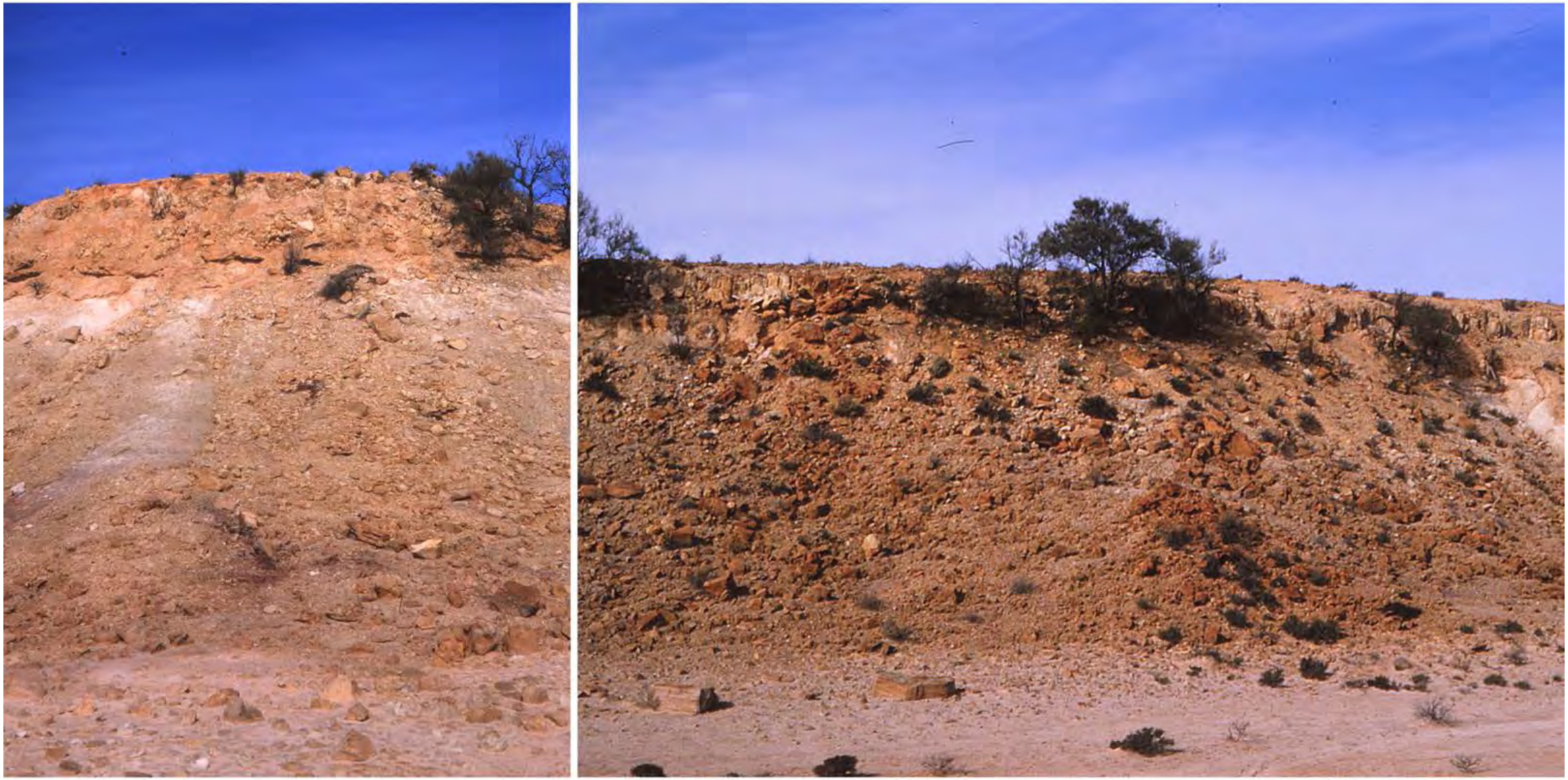
Sequence on page:

1…	*2*	*or*	*1…* *2*	*or*	*1*
3…	*4*		*3*		*2*



Beda Hill showing site of Locality 1 from car parking spot (1). Titania-rich silcrete skins on joints and other surfaces on Proterozoic quartzite blocks on the Beda pediment (2, 3. See also figure, Appendix 4). Quartzite blocks (foreground) remain from collapse and scarp retreat of the high-level plateau surface (4).

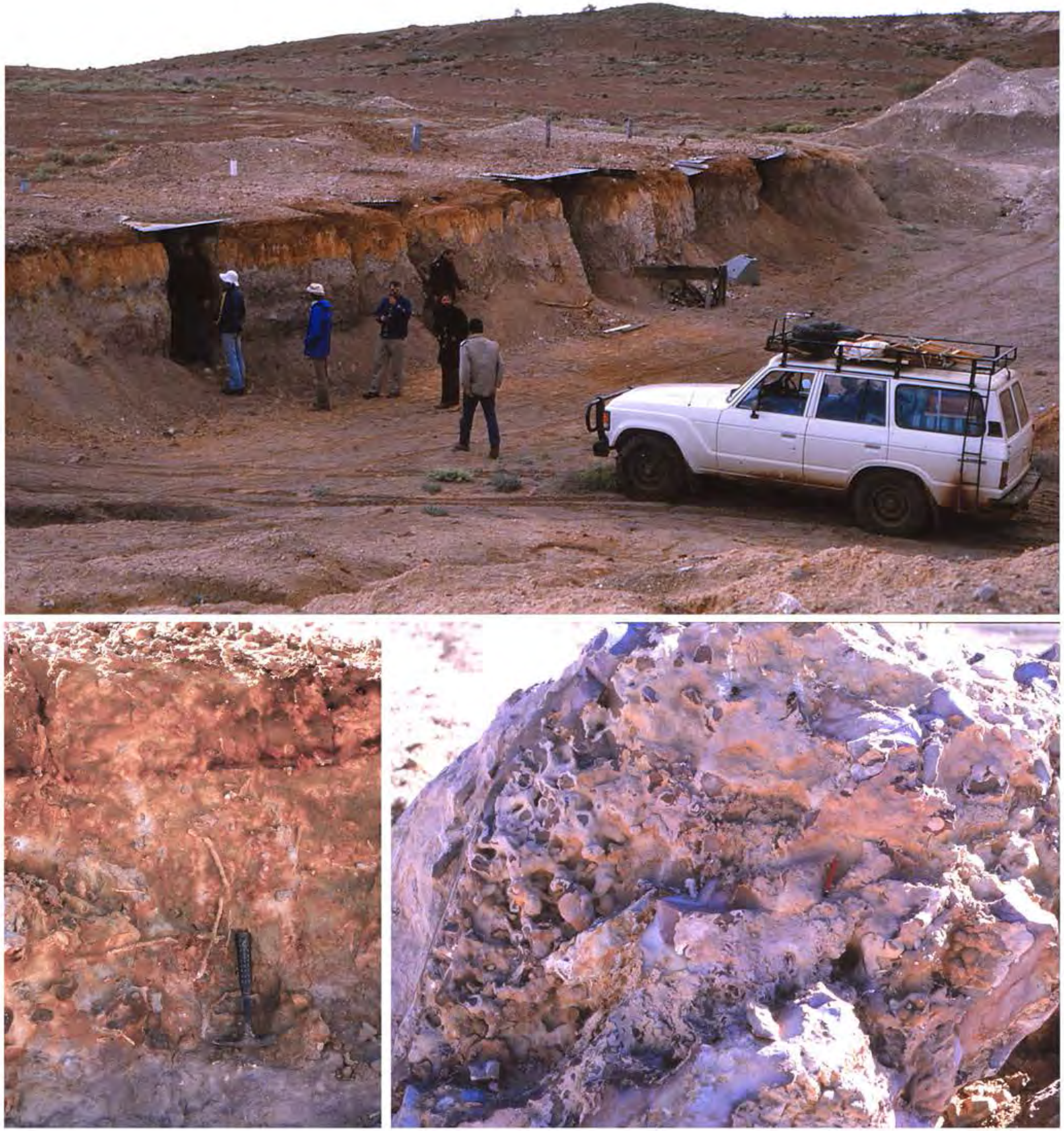
Blocks of bedrock quartzite with light-coloured silcrete cappings (1). Track to Beda Hill crossing debris fans with gilgai structures (stony shelves interspersed with depressions marked by low, shrubby vegetation) (2). Lag gravel marking stony shelf (3). Breakaway sections in Beda Creek (Ellis Gully; Locality 2) showing silicified Tertiary sediments overlying bleached gypsum- and halite-impregnated Proterozoic shales (4).



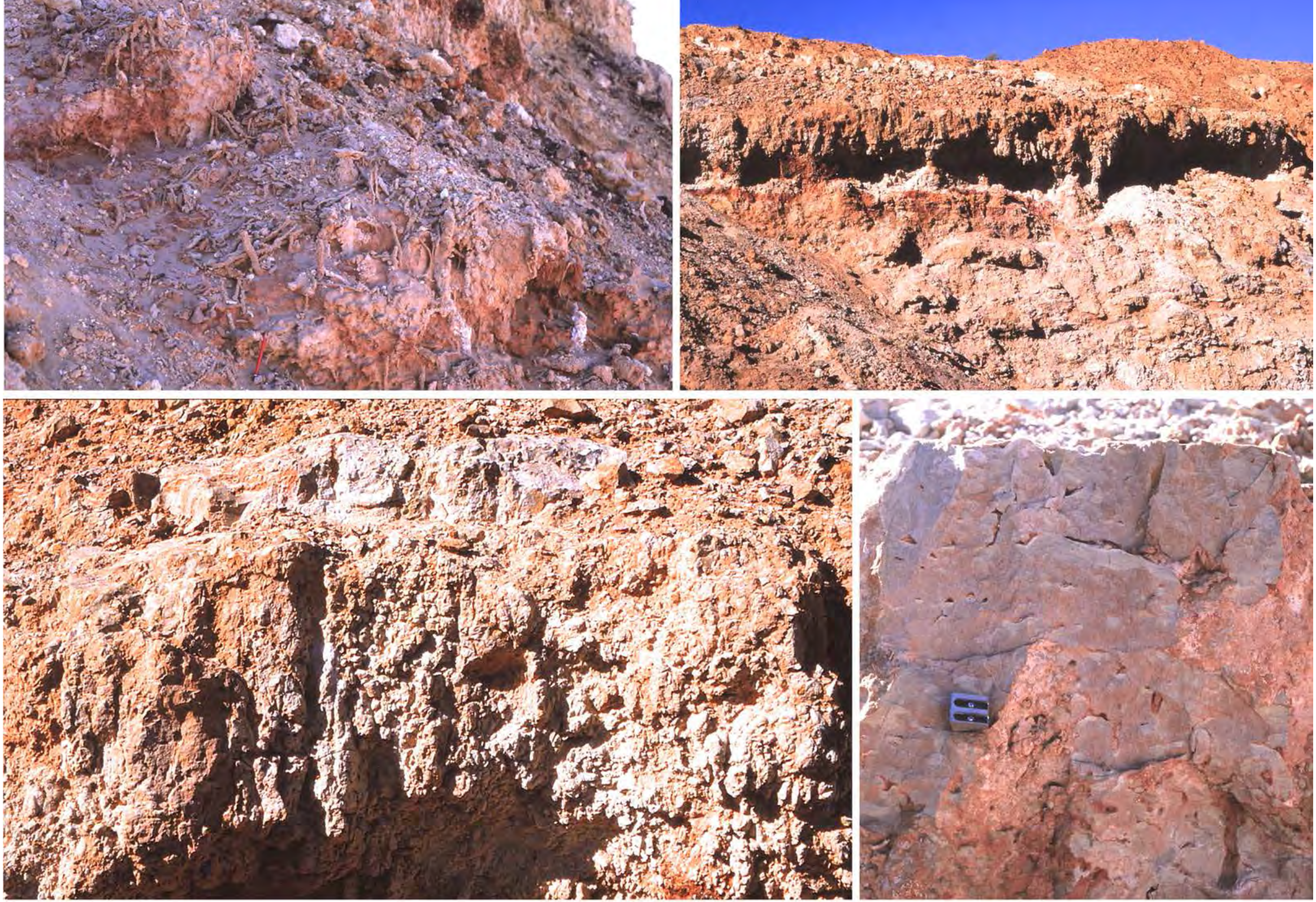
Sections exposed in Beda Creek (Ellis Gully; Locality 2). Silicified Tertiary sands and pedogenic silcrete at the top of the section overlie bleached and weathered Proterozoic shales. A lag of silcrete cobbles mantles the steep face of the breakaway.

Part of the convoy at Andamooka opal field before heading north to Stuart Creek (alternate route than specified in the original field notes because of rain).

Panorama of Stuart Creek opal field (Locality 3) looking west (1). General view of diggings (2). Bulldozer costeans cut through mesa in search of opal (3). Section through mesa showing Cretaceous Marree Subgroup clays overlain by fluviatile sediments of the Miocene Mirikata Formation containing silicified horizons (4).

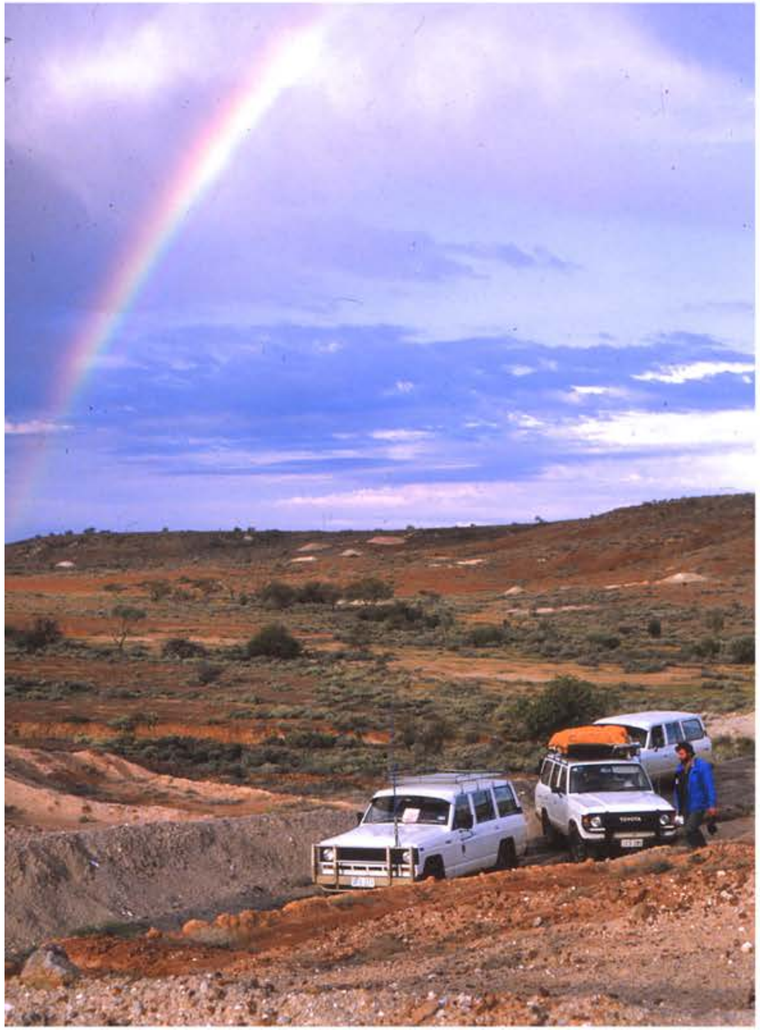


Miner's dugout accommodation at Stuart Creek opal field (1). Part of pedogenic silcrete horizon with gypsum rhizomorphs (2). Mined boulder of groundwater silcrete horizon showing surface features (3).



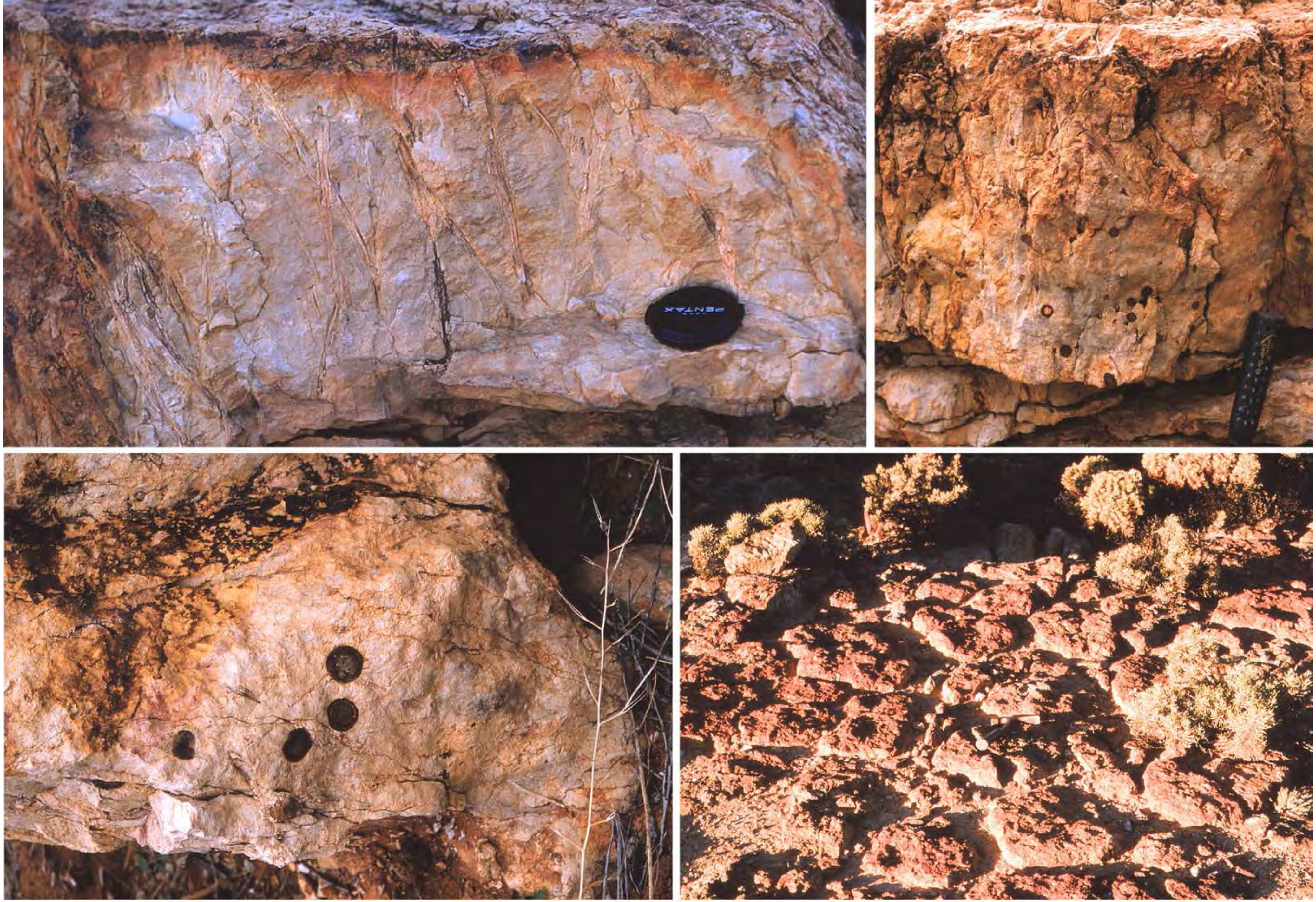
Abundant gypsum and calcite rhizomorphs in the upper part of the section at Stuart Creek opal field (1). Uppermost part of section through complex pedogenic silcrete (2). Details of nodular zone in pedogenic silcrete (3). Cut through re-silicified nodular zone near the top of the pedogenic silcrete (4). Note light-coloured silica-titania cappings on nodular structures. See also figure, Appendix 4.

Panorama over Stuart Creek opal field (1). Presumed explosives stores for miners at Stuart Creek opal field (2).



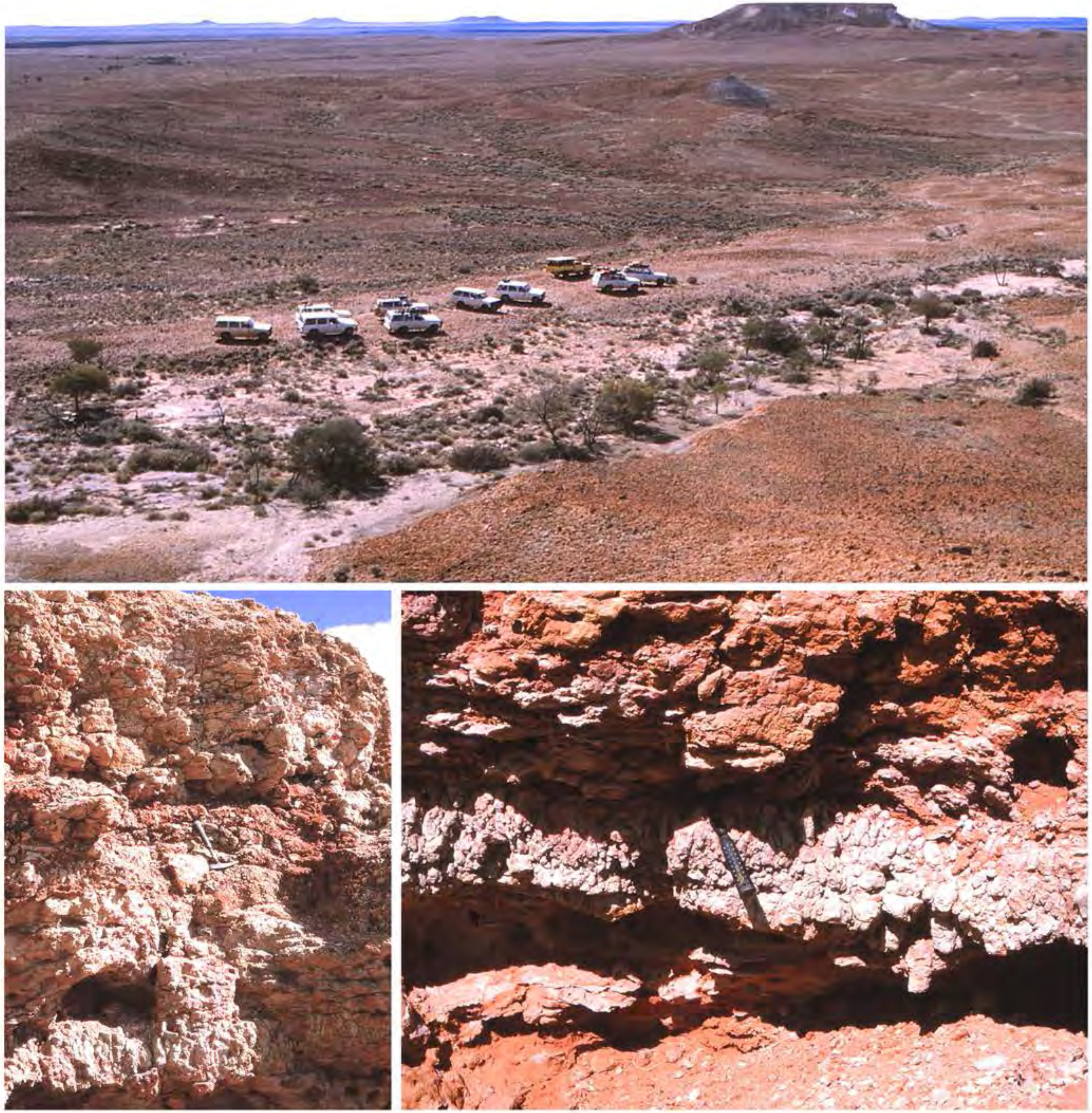
View over Stuart Creek opal field with rain about (1). Evening campsite nearby (2).

Examining shallow excavations for opal at abandoned Charlie Swamp opal field (1). General views of 'reed mould' silcrete locality (Locality 4) (2, 3)

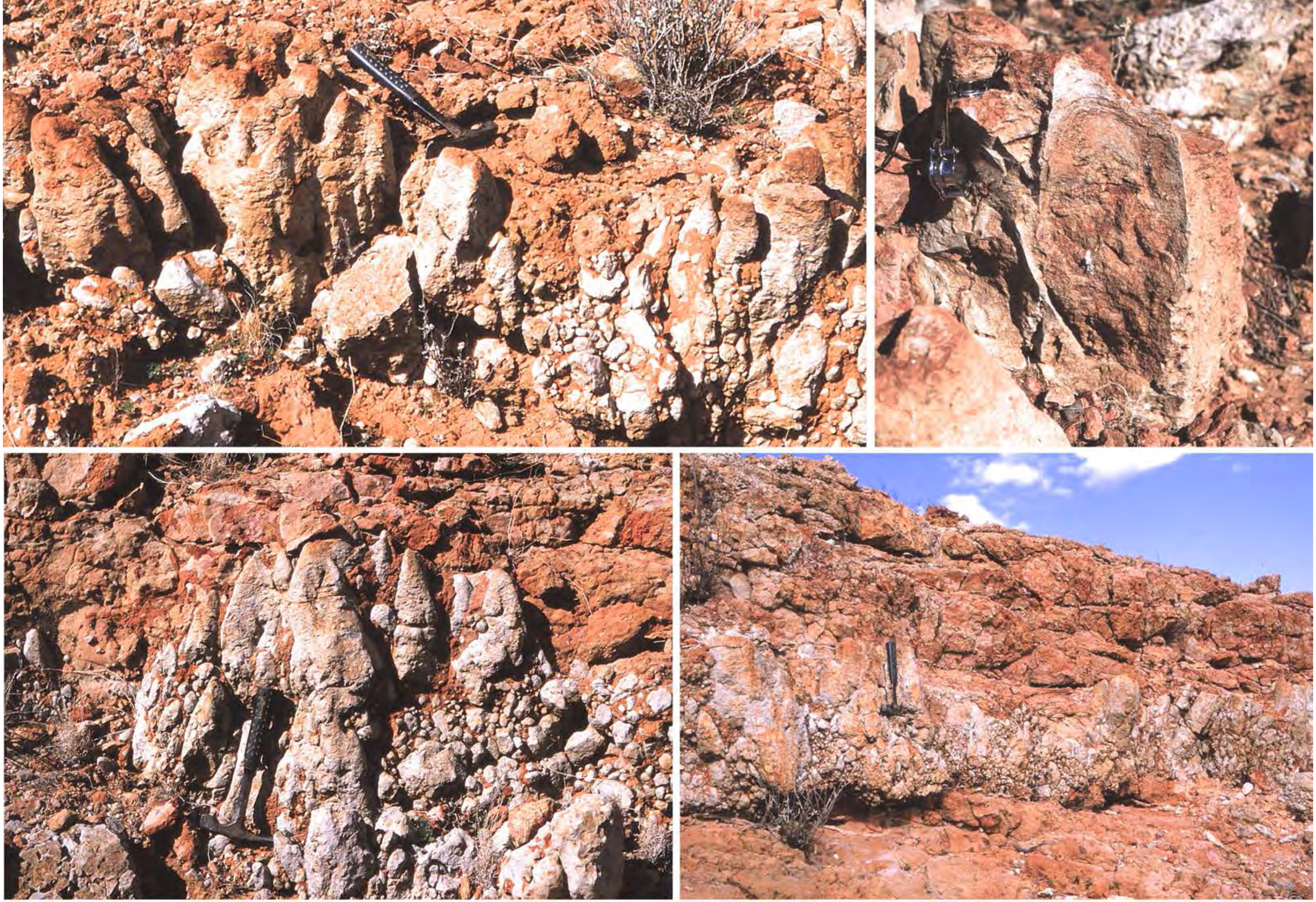


Locality 4: Section through ‘reed mould’ silcrete block (1). ‘Reed mould’ silcrete horizon exposed as a ledge in a watercourse. Spheroidal goethite nodules common (2, 3), but of unknown origin. Upper surface of ‘reed mould’ silcrete horizon showing polygonal pattern of columnar ‘joints’ (4).

Vehicle convoy en route to Locality 5 on the eastern end of the dissected tableland (1). Section exposed at Locality 5 (2, 3).



Locality 5. Landscape view from the top of the section (1). Complex pedogenic silcrete horizons (disrupted nodular zones) near the top of the section (2, 3).



Locality 6. Examples of pedogenic silcrete (nodular, columnar, 'ant nest', and massive) facies.

Locality 6: columnar ('ant-nest') silcrete facies (1, 2). Section exposed at Locality 6a shows Tertiary sequence overlying bleached and weathered Cretaceous sediments (3).

Workshop participants (Leg 1) after lunch near Willalinchina Hut.

Excursion members

Front row kneeling (L to R): Rob Fitzpatrick, Colin Chartres, Pat Walker, Allan Chivas, Nigel Collins, Wayne Cowley, Michael Bird, Tony Milnes, Medard Thiry

Middle row standing (L to R): Ross Coventry, Max Churchward, Mike Craig, Mark Benbow, Tony Martin, Simon Veitch, Graham Taylor, Stuart Robinson, Bernie Joyce

Back row standing (L to R): Karl Wyrwoll, Charles Butt, Neville Alley, unknown, David Gibson, Mike Freeman, Malcolm Wright

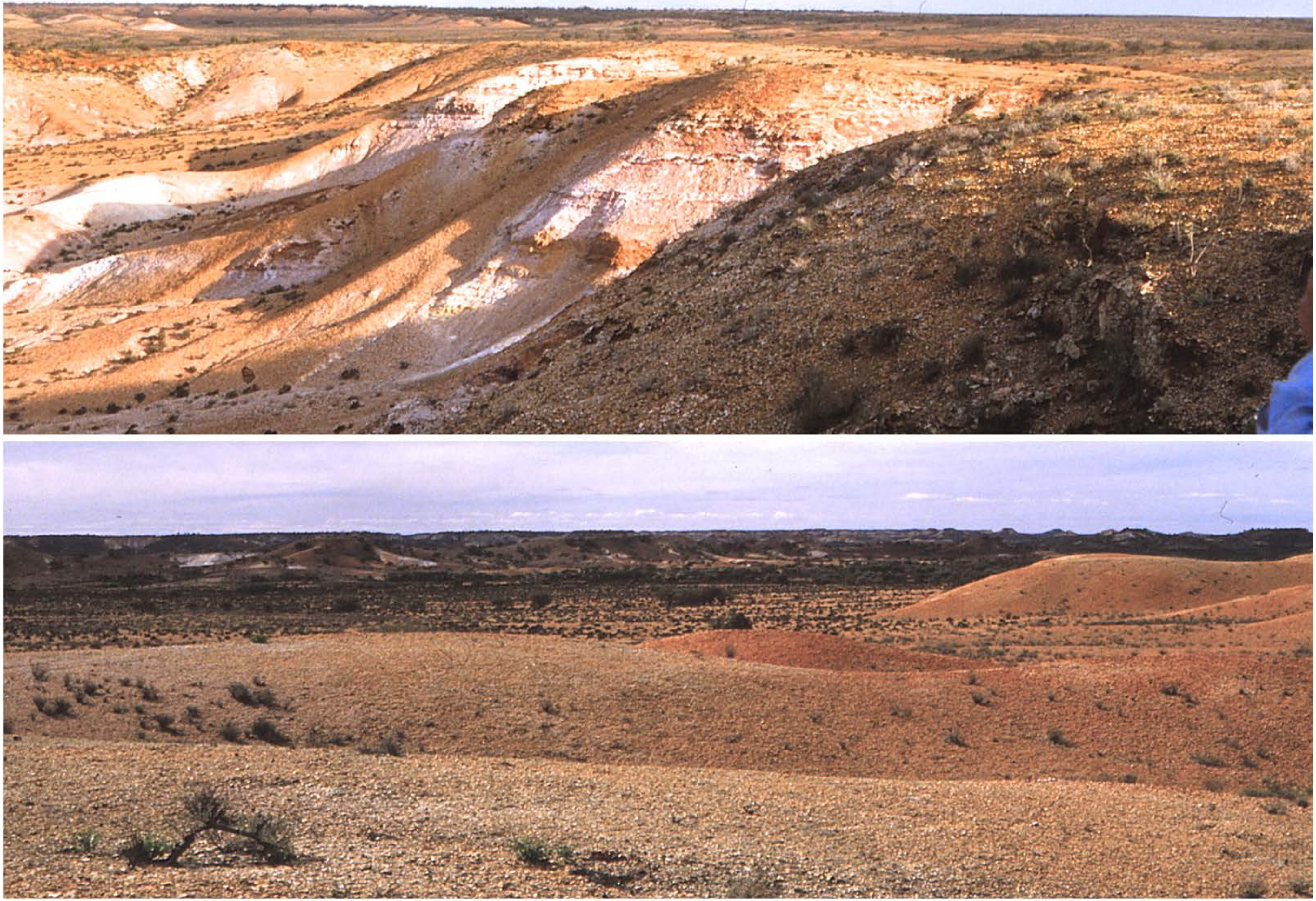
Note: John Webb and A.C. French joined the excursion for Leg 2 in Coober Pedy.

Locality 7: plant fossil site near Willalinchina Hut (1). Plant fossil moulds (including plant stems) in groundwater silcrete, together with goethitic spheroids (2). 'Custard-like' surface accretionary structures typical of groundwater silcretes (3, 4).

Convoy crossing rolling stony downs *en route* to “Billa Kalina” (1). Common and extensive surface lags of black, pisolitic maghemitic gravel (2).

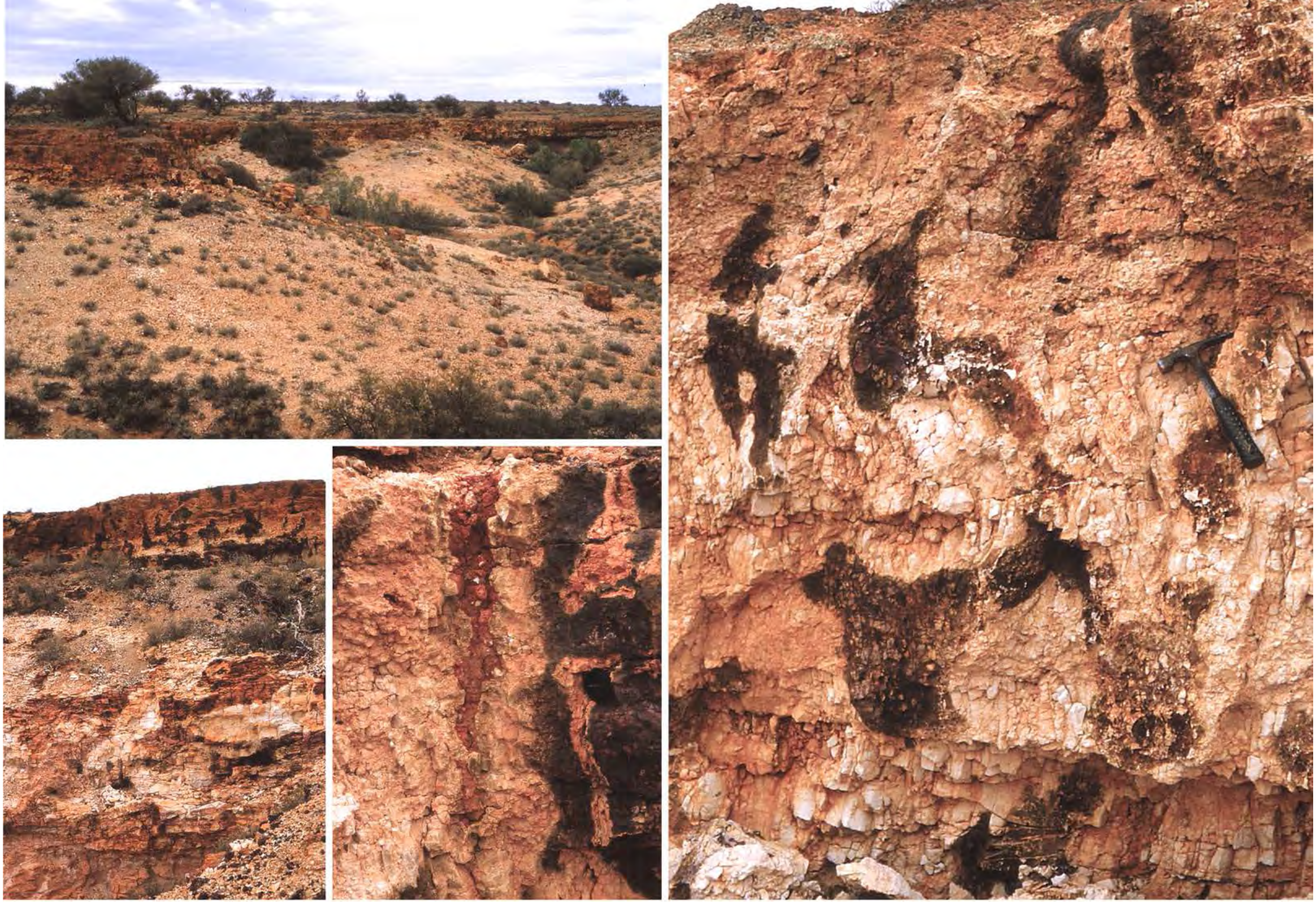
Examining Billa Kalina Clay and overlying Millers Creek Dolomite in mesa breakaways northwest of “Billa Kalina”.

Track along dog-fence, crossing stony downs through the Serrated Range, north of "Billa Kalina". Note deep bleached and weathered profile in Cretaceous sediments exposed in breakaways in remnant highlands (1). There are many gilgai with large stony shelves (ramparts) downslope of 'puffy' soil depressions containing sparse, shrubby vegetation (2,3).



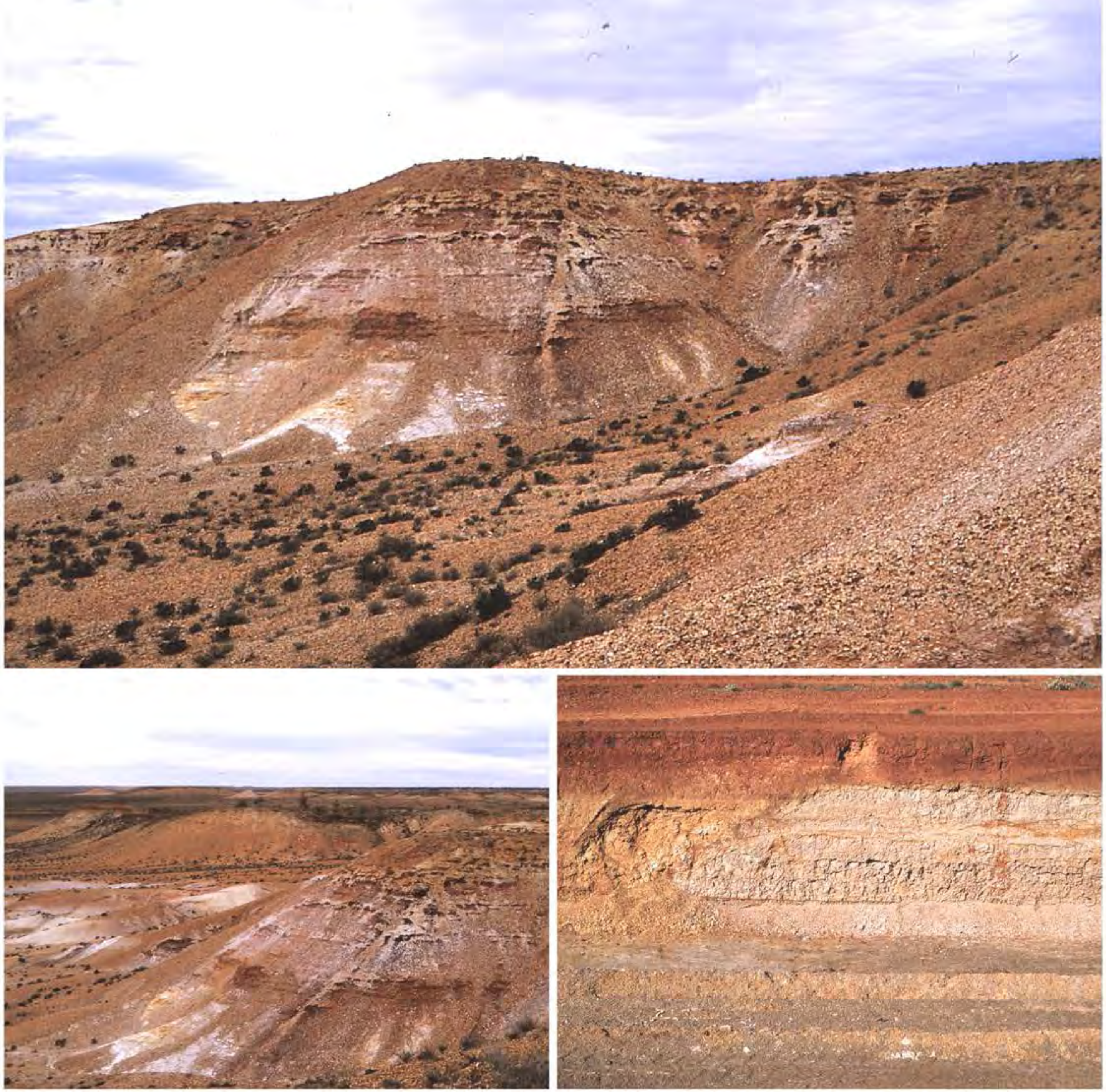
About 40km from “Billa Kalina”. Dissected tablelands with breakaway exposures of bleached and weathered Cretaceous sediments and a silcrete duricrust.

Painted Hills - panorama at evening.

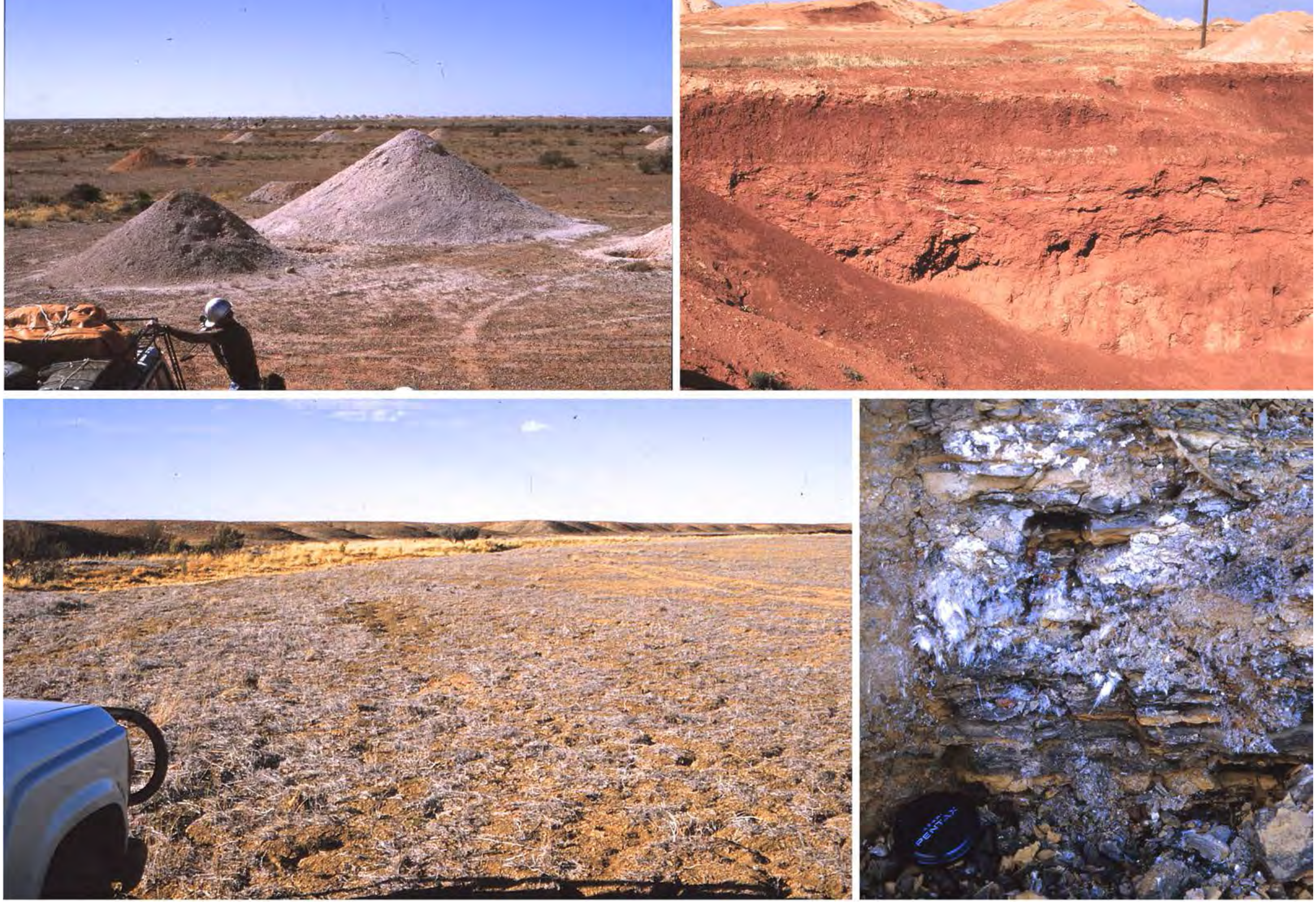


Hat View sections showing well-developed silcrete duricrust, Fe-mottling and disintegration features, including solution pipes filled with red soil.

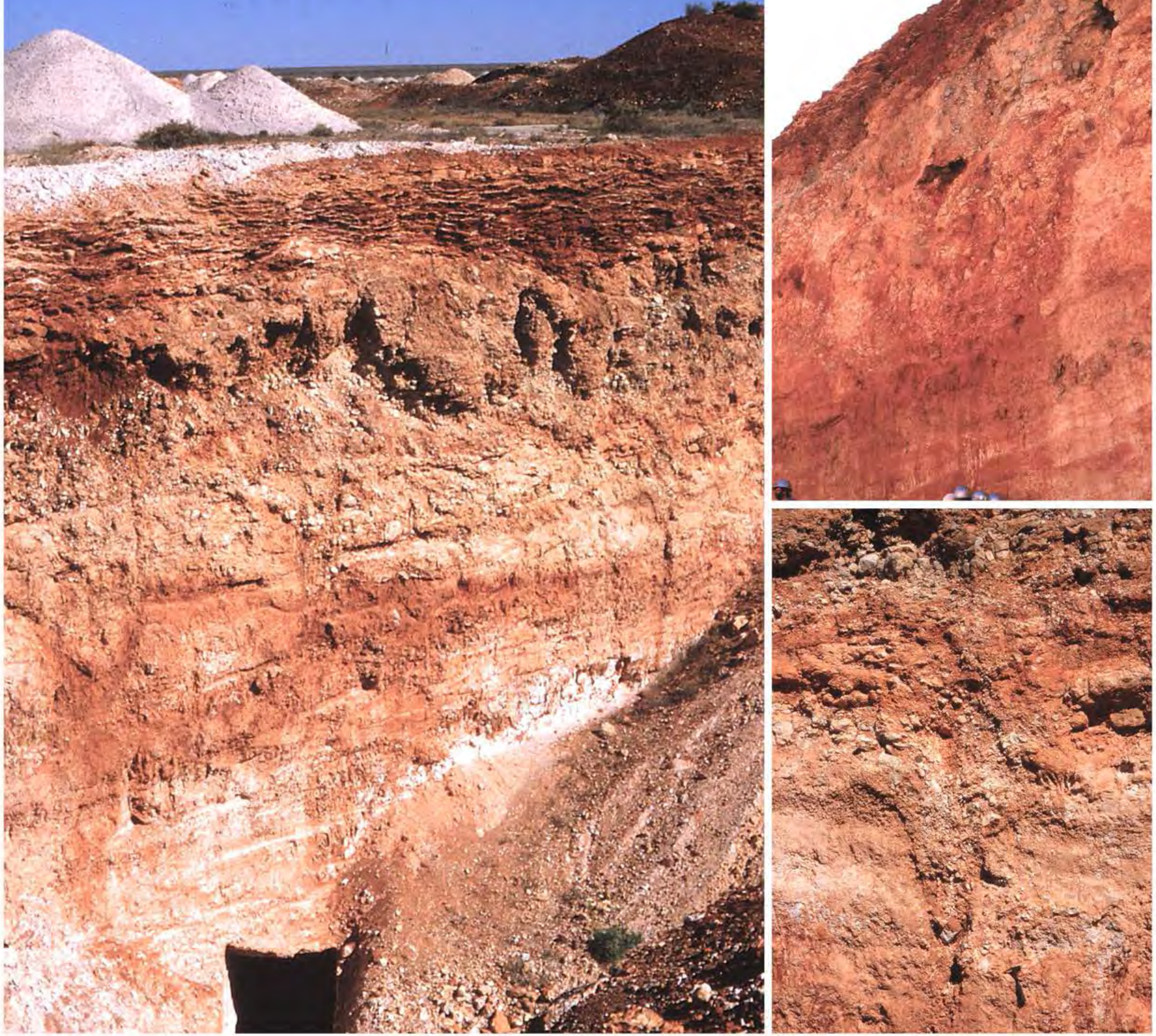
Hat View breakaway section (1). Crazing of silicified zone (likely opaline in composition) in Hat View section (2).



Views of vari-coloured weathered Cretaceous sediments in the breakaway country around Hat View (2, 3). Excavation in Bulldog shale for road-building materials for new Highway 1 alignment to Coober Pedy (3).



Coober Pedy - opal mine mullock heaps on an extensive tableland (1). Typical bulldozer costean exposure of Benitos Clay overlain by the surface stony lag (2). Lowlands east of Coober Pedy terraced into unweathered Bulldog Shale - black cracking clay landscape essentially devoid of vegetation ('Moon Plains') with abundant platy gypsum (3). Gypseous, jarositic Bulldog Shale (4).

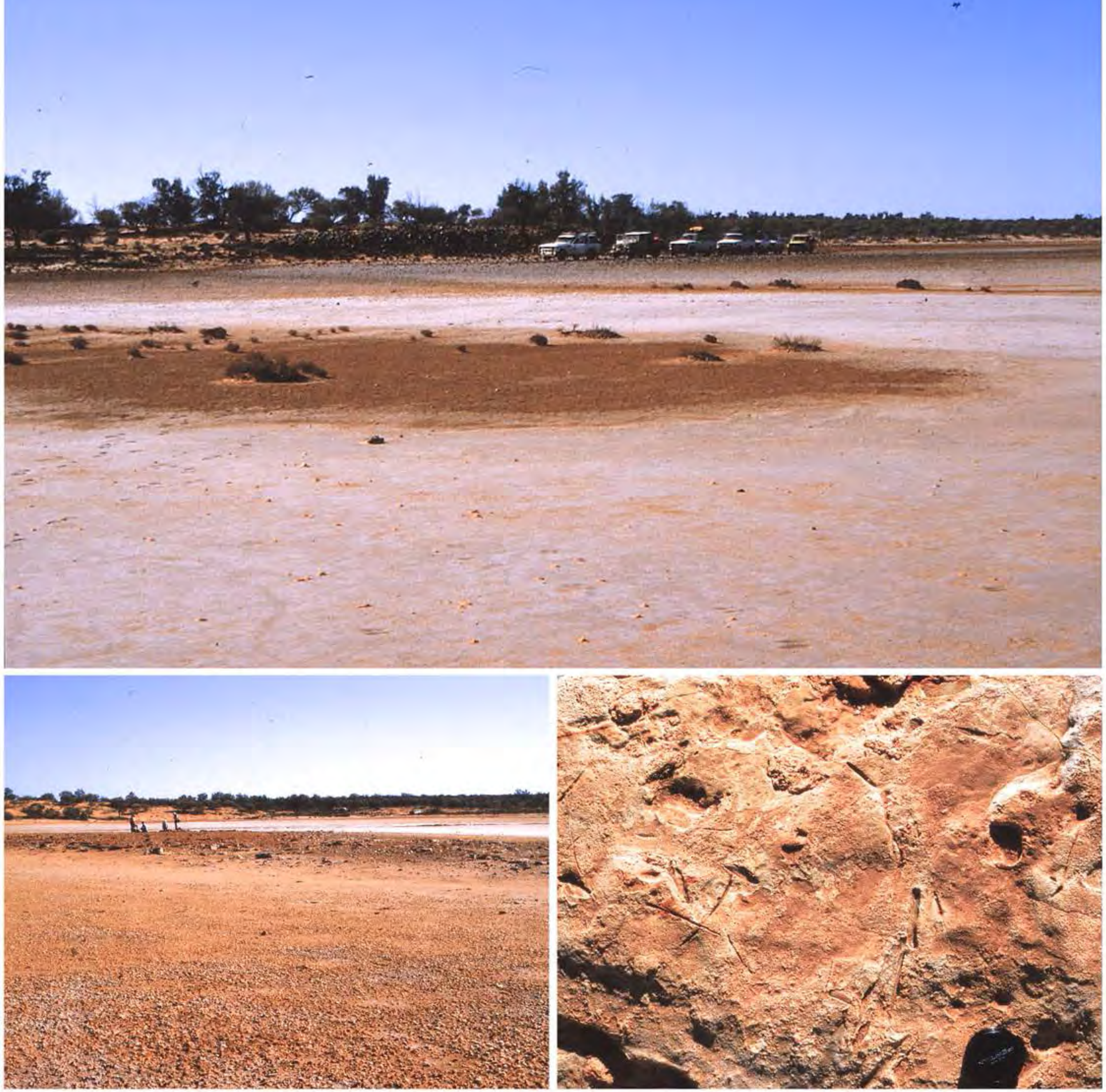


Larkins Folly mine area. Deep bulldozer cut exposing type section of Russo Beds above bleached, opal-bearing Cretaceous shales (1, 2. Note mine tunnel at base. See also figure, Appendix 4). Complex solution-collapse structures (3) form part of the pedogenic silcrete within the Russo Beds.

Unscheduled stop. Low breakaways on the edge of a clay pan have good exposures of Billa Kalina Clay overlain by Quaternary sediments (1, 2). Further north in this locality are good exposures of white dolomitic clays (Namba Formation) overlain by red sands of the Eurinilla Formation with Coonarbine Formation dunes above (3).

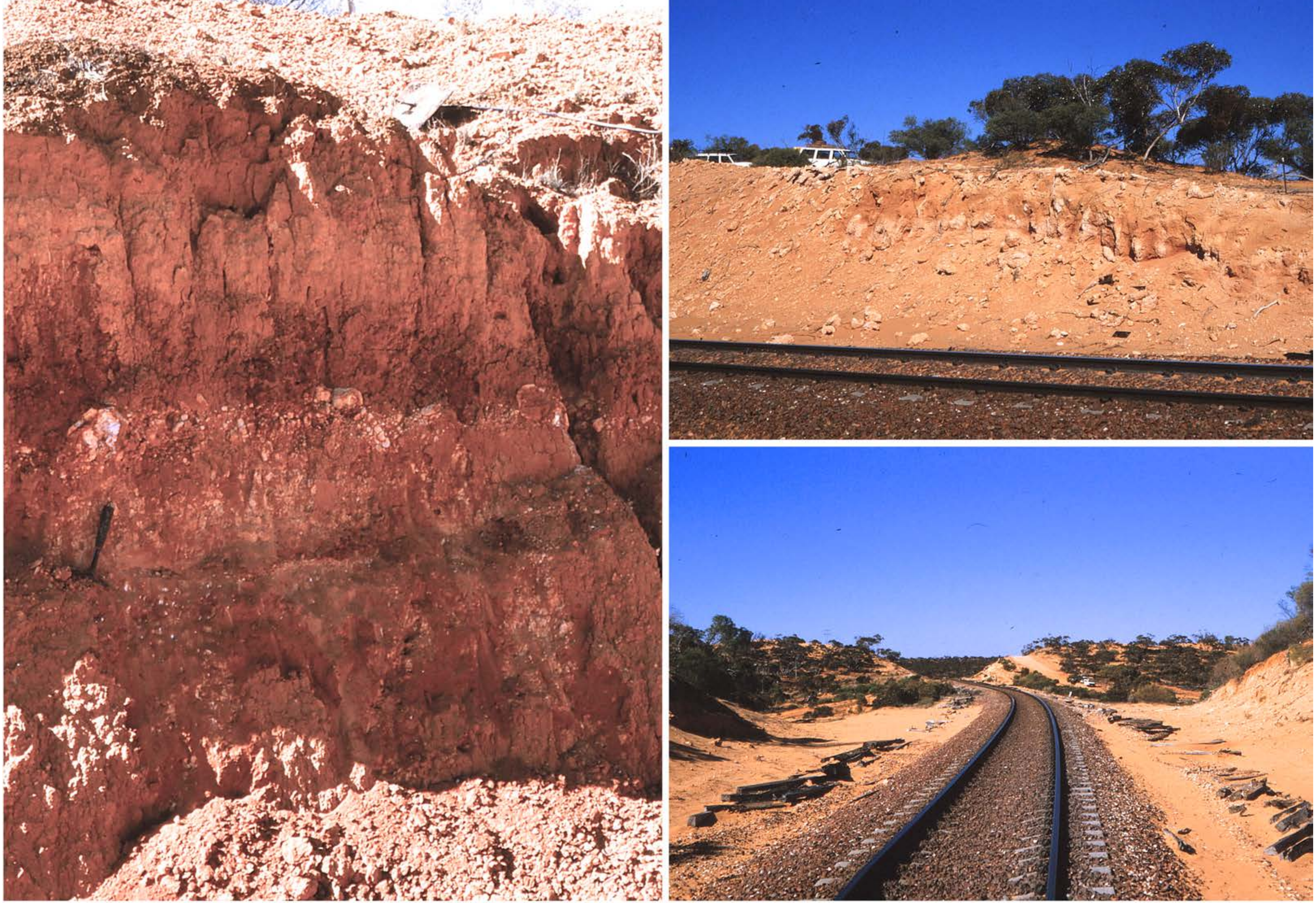
Leg 2 - Locality 1: silcrete capping and boulder lag overlying silicified Permian sediments in breakaway at the edge of a small mesa (1). Locality 2a: complex facies in silicified regolith (2, 3).

Locality 2b. Cappings on silcrete columns (1). Lag of silcrete columns with thick cappings (2).

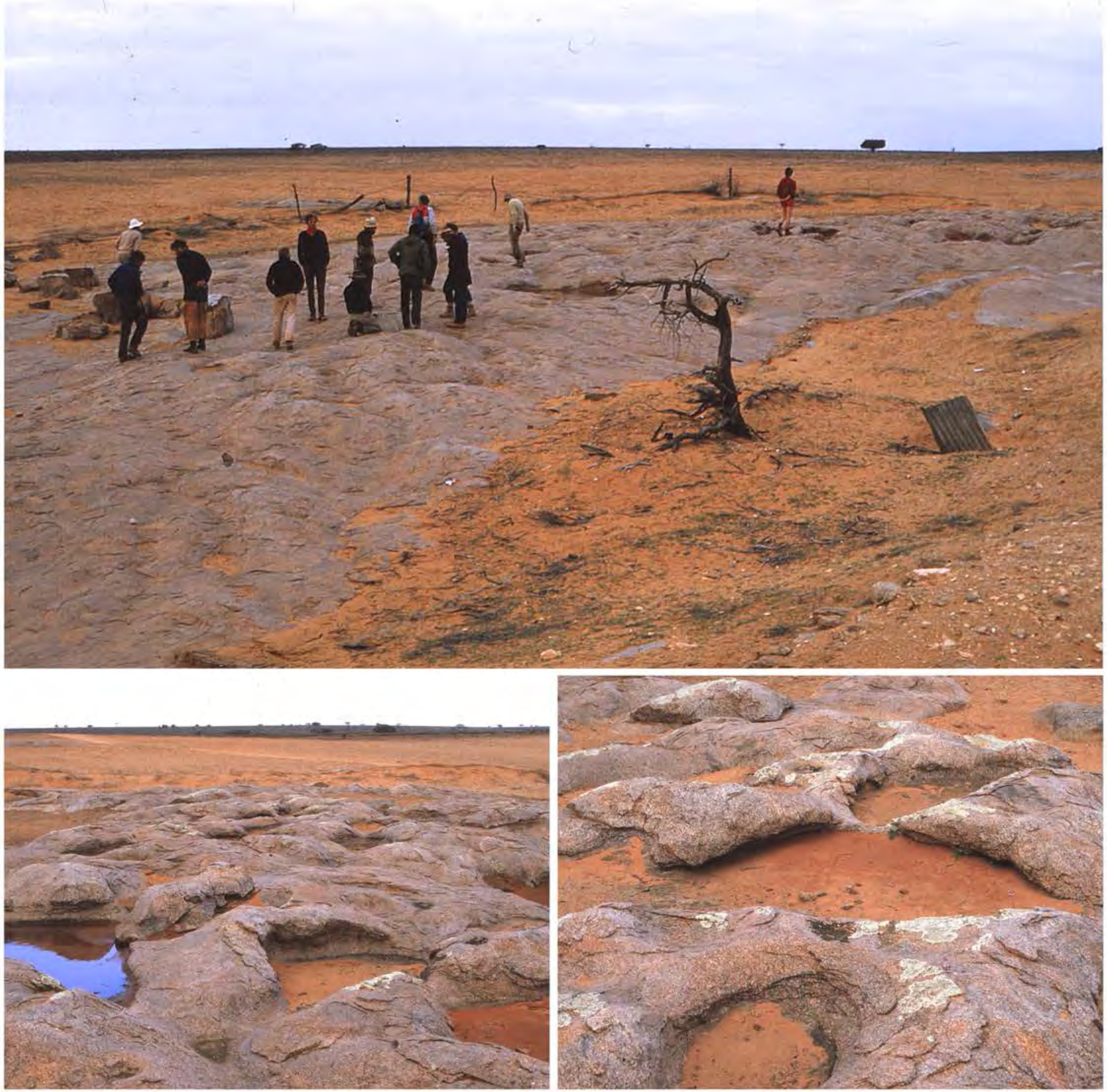


Lake Anthony: Locality 3. General view of the lake floor and margins (1). Low outcrop of silicified ferricrete in the floor of the lake (2). On the opposite side of the lake - silicified, finely laminated silts with plant leaves & micro-burrows (3).

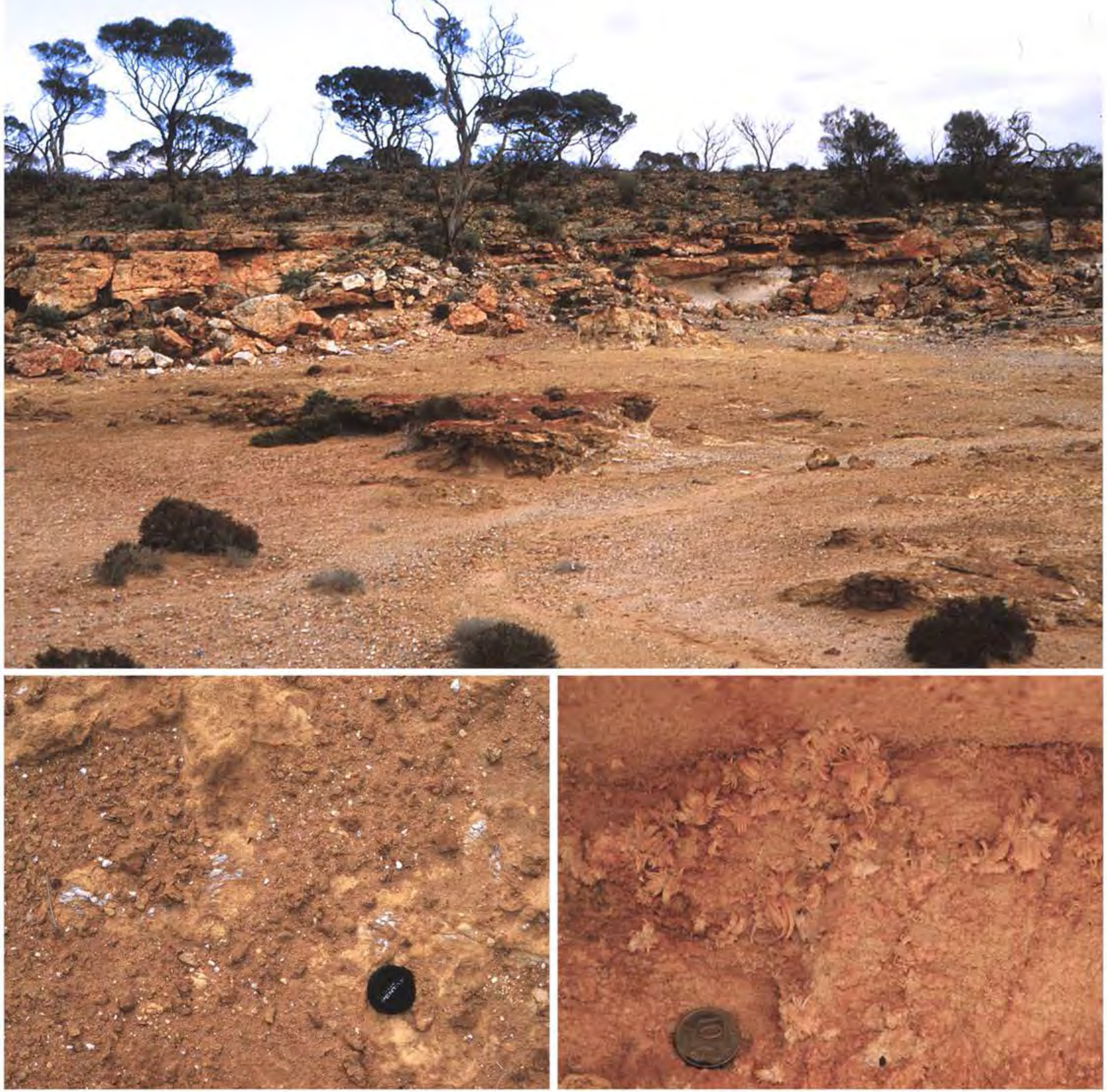
Lake Anthony, Locality 3. Outcrop at lake margins nearby shows ferruginised and bleached Precambrian bedrock (1) overlain by a disrupted nodular and columnar (pedogenic) silcrete (2).



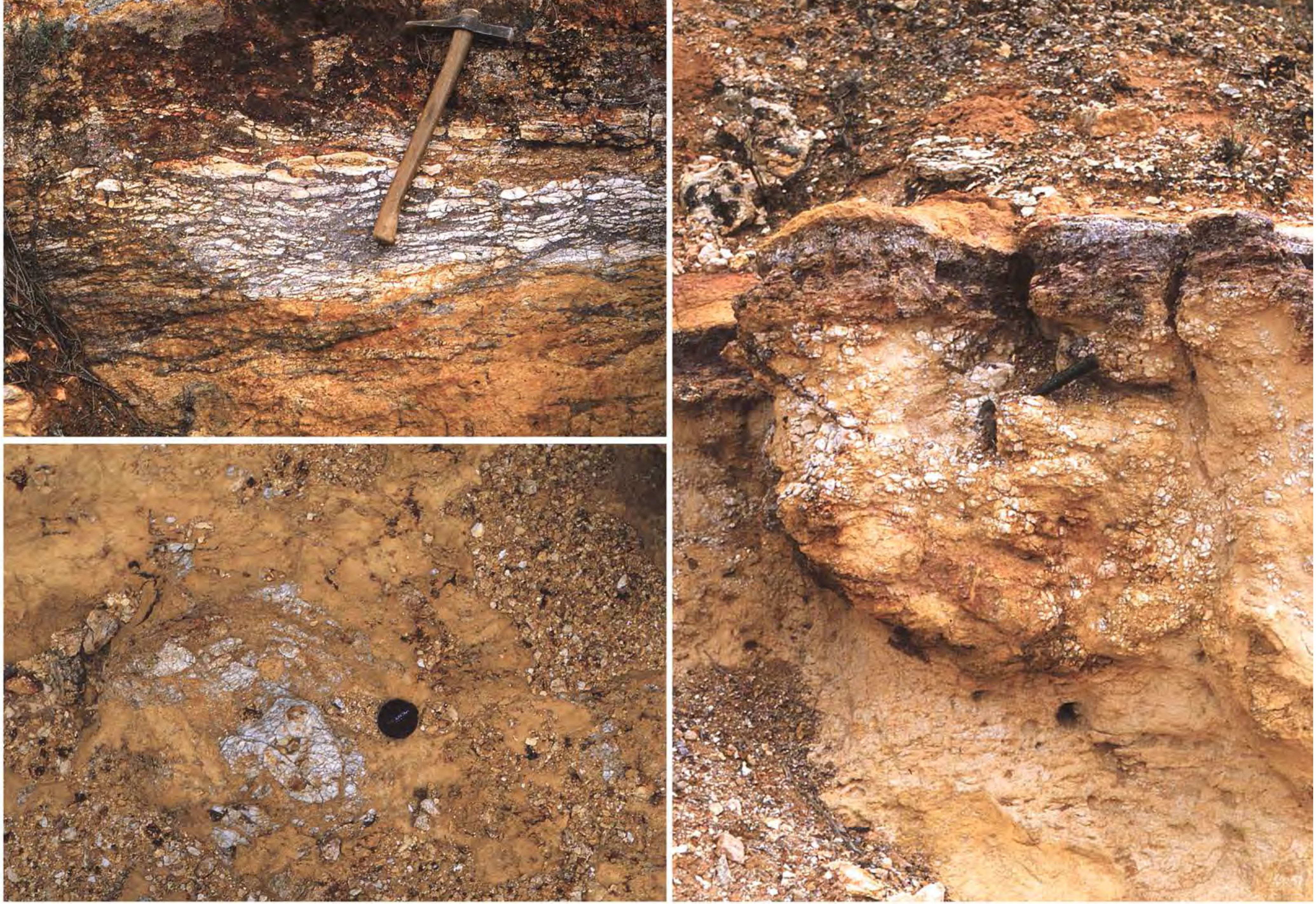
At about 230km travelling west alongside the east-west railway line out of Immarna RS - section with good calcrete profile in trackside excavation (1). Sections through dunes exposed in railway cuttings (2, 3).



Lake Ifould (Lake Pidinga): Pidinga Rockhole (represented by gnammas developed in gneissic bedrock).



Locality 4. Ferruginised & brecciated silcrete formed in possible Cretaceous sediments (1). Alunite pods and brecciated white opal in the lake floor (2). Gypsum/salt crystals in curved masses beneath overhangs (3).



Locality 4. Brecciated white opal masses in ferruginised zones.

Pedestals in gneissic bedrock on the lake floor west of Locality 4.

Locality 5a. Pit in lake floor (foreground) in unconsolidated carbonaceous and pyritic sediments. Outcrop in cliff at lake margin is of Miocene ferruginised sands and sandy limestones, sporadically silificied, with marginal marine calcareous sandstones above (1). Red ferrihydrite-impregnated sands on the lake floor along west side of lake (2).

Marginal facies of the Nullarbor Limestone, silicified in part, overlying transgressive sand and clays unconformably bleached and weathered Precambrian bedrock (view towards lunch spot).

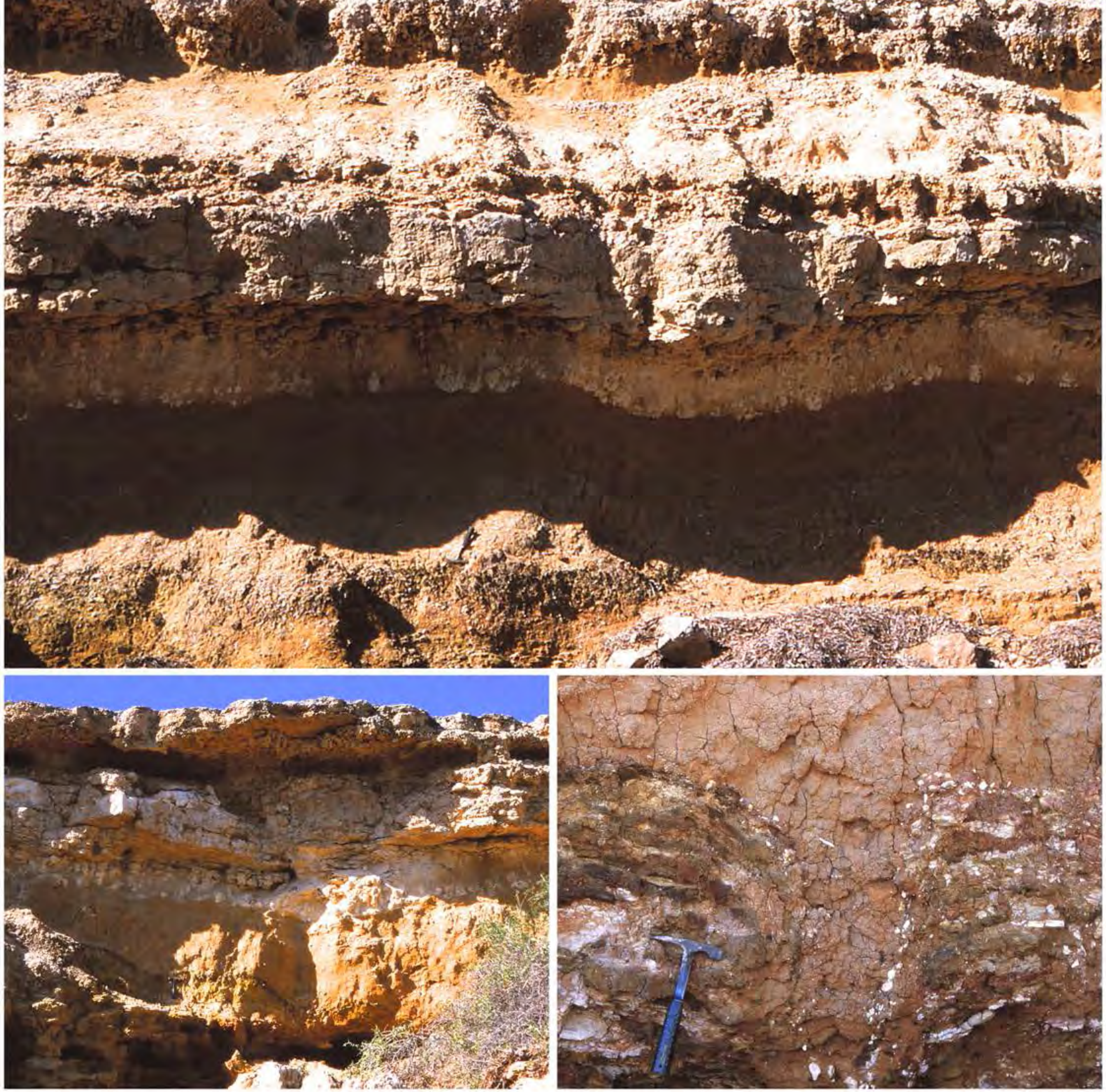
 

Locality 6 on the northern margin of Lake Tallacootra. Bleached Precambrian bedrock unconformably overlain by ferruginised gravels. Note also coatings of orange Fe-oxides on sediments around the lake margins (1). Lignite overlies the bleached and weathered Precambrian bedrock and occurs beneath bleached and ferruginised sands (2).

Setting up final field camp.

Views of lake adjacent to final field campsite.


Locality 7, north of Ceduna jetty. Coastal cliffs in which ferruginised and silicified Eocene sediments are overlain by younger Tertiary sediments and Pleistocene aeolian calcarenites and calcretes.



Locality 8 north of shelter sheds, Ceduna foreshore. Section in (1) shows a hammer resting on ferruginous gravel which overlies silicified Tertiary sediments. Above the hammer there is a red clay horizons with mottled carbonate and massive calcrete horizons above. Upper part of the section (2). Unusual collapse & fill structure in Tertiary sediments with infill of clay and white carbonate (possibly dolomite) mottles (3).

Bogged!