Open File Envelope No. 3463

GEOLOGY OF THE STUART CREEK – CHARLIE SWAMP AREA, NORTHERN SOUTH AUSTRALIA

Submitted by
Department of Geology, university of Adelaide
1980

Enquiries: Customer Services Branch
Minerals and Energy Resources
7th Floor
101 Grenfell Street, Adelaide 5000

Telephone: (08) 8463 3000
Facsimile: (08) 8204 1880

Government of South Australia
Primary Industries and Resources SA

CONTENTS ENVELOPE 3463

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

003

GEOLOGY OF THE STUART CREEK-CHARLIE SWAMP AREA NORTHERN SOUTH AUSTRALIA.

Geological Survey

By

G.J. NICOL

D.M. No.: 484/77

CONTENTS

004

Figures accompanying report

Cont.

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

Rept.Bk.No.
D.M. No. 484/77

GEOLOGY OF THE STUART CREEK-CHARLIE SWAMP AREA NORTHERN SOUTH AUSTRALIA

ABSTRACT

In the Charlie Swamp area, Mesozoic sedimentation commenced with the "Stuart Creek Beds", a transgressional unit of fine sand infilling depressions in the pre-Mesozoic topography. The overlying Marree Formation, of Early Cretaceous age, comprises a marine sequence of mud with sandy conglomeratic interbeds and "erratics". Much of the coarse material has been transported by shore-ice rafting. A major conglomerate bed, closely parallelled by the base of a bleached profile, extends over a distance of 80 km.

Following a period of deep weathering, silicification and erosion, the ?Middle Tertiary Mount Sarah Sandstone, a fluviatile-lacustrine unit of sand and sandy limestone was deposited overlying the Marree Formation.

?Late Tertiary ferruginisation and silicification have produced varicoloured stains and silcrete within the Mount Sarah Sandstone and the Marree Formation.

Late Tertiary or Quaternary events include a further bleaching and the formation of red-brown colluvial sediment and development of silcrete and gypcrete.

INTRODUCTION

This report is the result of research undertaken by the author as a preliminary Honours project in the Geology Department of the University of Adelaide and sponsored by the South Australian Department of Mines and Energy (SADME) during 1978.

An area surrounding Charlie Swamp of nearly 400 square km^2 which includes part of the ANDAMOOKA (Johns, 1966) and CURDIMURKA (Daly and Coats, 1971) was mapped. Charlie Swamp (Fig. 2) is 20 km northeast of the Stuart Creek Opal Field (hereafter called Stuart Creek) which is 60 km north of Andamooka.

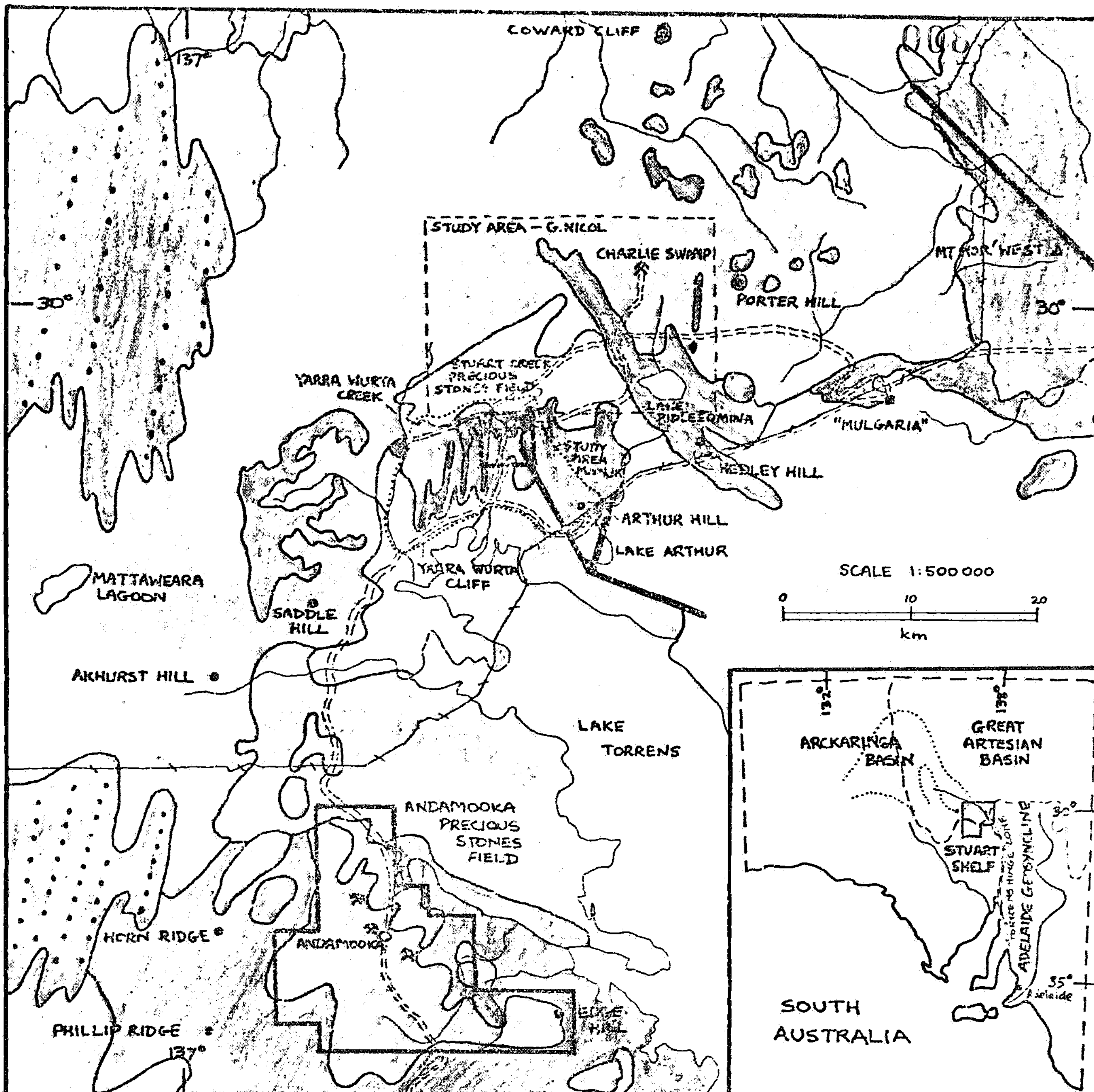


FIGURE 1. LOCALITY MAP.

CAINOZOIC	Quaternary		Sand dunes and spreads. Not shown over older units.
	Tertiary		Mainly sand variably silicified and ferruginized. Old ridge system (schematic).
MESOZOIC	Cretaceous		MARREE FORMATION: Brown and grey claystone with silt lenses. Sandy boulder beds near base.
	Jurassic		ALGEBUCKINA SANDSTONE: Medium to coarse quartz sandstone. Pebbly sandstone.
PALAEOZOIC - Cambrian			YARRA WURTA SHALE: Red and green shale and siltstone.
			ANDAMOOKA LIMESTONE: Massive grey and brown limestone.
PRECAMBRIAN - Adelaidean			Quartzite, siltstone, shale, dolomite.

Fault — Track — Vermin Proof Fence

ADAPTED FROM BARNES AND SCOTT (1979). AND VNUK (1978) G.J. Nicol 1978

Fig. 2. Charlie Swamp (October, 1978)
Looking south from the low rise at TBM 451 over Charlie Swamp. Dumps of shallow diggings can be seen on the far side.

Fig. 3. Backhoe in operation (October, 1978)
Mapping in areas masked by thin cover is greatly facilitated by use of a backhoe. Looking for the contact of the Marree Formation and the 'Stuart Creek Beds' at BHT 42A1.

Investigation of the nature of the Marree Formation, in particular its coarse clastic content, was undertaken in the diggings at Stuart Creek.

A similar concurrent project by M. Vnuk, also of the University of Adelaide, was centred on Stuart Creek.

Mapping was greatly assisted with exposure produced by a backhoe (Fig. 3) hired by the SADME for approximately two weeks. In addition to the 28 backhoe trenches (BHT) described in Vnuk (1978), another 87 trenches to the north and northeast of Stuart Creek are described in this report (Appendix A). All backhoe trenches, except those within the proclaimed Precious Stones Field (Fig. 1) were backfilled after examination.

Levelling of most of the backhoe trenches and many other locations was carried out by the SADME. Temporary bench marks (TBM) were set up along the track from Stuart Creek to Charlie Swamp by A.B. Hack & N.R. Edwards (Technical Officers). Required locations were subsequently levelled from the TBMs. All elevations are relative to Australian Height Datum (AHD).

Several hundred samples from backhoe trenches and outcrop within the map area were collected for laboratory examination, to supplement field notes.

Twenty nine thin sections were prepared by the Australian Mineral Development Laboratories (Amdel). Two thin sections were examined by Amdel and the results are appended in Appendix B. Descriptions of the remaining thin sections will be included in a later report.

Three field trips, totalling twelve weeks in duration, were made during 1978. Laboratory and office work on the project occupied 6 months of the year to March 1979.

The terminology of Folk (1974) is adopted wherever practicable.

Names in inverted commas are informal and used only in this report, or that of Vnuk (1978). Locations are shown on the maps accompanying this report and Vnuk (1978).

GEOLOGY

Exposure within the map area is generally poor. Pre-Mesozoic sediments, with the exception of quartzite, some limestone and dolomite, are deeply weathered, and rarely outcrop. Mesozoic and Tertiary outcrop is generally limited to breakaways and silcrete cappings. For the most part, exposure is obscured by sand spread, sand ridges, soil and alluvium.

Because of the paucity of topographical features, many of the locations described hereunder are related to backhoe trenches (Fig. 22).

Sedimentary units are discussed below in ascending stratigraphic order.

PRECAMBRIAN

Umberatana Group

Amberoona Formation - green to yellow, laminated, micaceous siltstone with some sandstone.
Bands of brown weathering, yellow dolomite, sometimes sandy, dominate outcrop exposure, along with thin (up to 2 cm) bands of dark brown ironstone, the broken fragments of which are abundant in float. Amberoona Formation is present over a large part of the map area midway between Stuart Creek and Charlie Swamp. Very poor outcrop is limited to the southern part of the map with better exposure further south.

Elatina Formation - coarse, poorly sorted sandstone with well rounded quartz and red feldspar (5%) grains. In a poorly exposed section about 300 m south of the map boundary brown calcareous sandstone about 7 m thick crops out immediately below Nuccaleena Formation. The samples examined from this locality are lithologically very similar to those obtained from sample location 550/52 shown as the most easterly outcrop of

Fig. 4. Bunyeroo Formation (October, 1978)
"Kopi" - mud contact in Bunyeroo Formation at BHT 39. Bleached white/grey mudstone ("kopi") overlies soft, moist, pink, fissile mud. Marree Formation is present in BHT 39B on the horizon.

Amberoona Formation on the map. The outcrop, which was not traced or examined in detail, may represent Elatina Formation.

Wilpena Group

Nuccaleena Formation - a lower unit, 5 m thick, of yellow weathering dolomite is overlain by an upper unit of purple shale which passes up into siltstone of the Brachina Formation. The dolomite outcrops boldly as a ridge near the southern edge of the map.

Brachina Formation - laminated, micaceous, green and purple siltstone crops out near the southern margin of the map and is exposed in BHT13, southeast of Coorichina Dam.

ABC Range Quartzite - thinly bedded white to grey quartzite with some interbedded softer sandstone and shale.

The quartzite crops out on the southern map margin marking the western limb of a large anticlinal structure. On the eastern limb, the quartzite forms a prominent ridge in the south but relief becomes subdued toward the north. Outcrop is limited, the ridge being mostly covered with loose, flaggy, brown weathering quartzite slabs.

Bunyeroo Formation - red and green micaceous shale.

Patches of brown ironstone littering the surface near BHT38 have been derived from Bunyeroo Formation. Outcrop is present south of Lake Pidleeomina and south of Charlie Swamp near BHT39. At BHT39, it has been partially affected by a bleached profile developed on the Marree Formation (Cross Section, BDE, Fig. 23). The bleached upper part, comprising grey to white indurated and massive claystone, overlies soft, weathered, fissile, pink clay (Fig. 4).

Wonoka Formation - laminated green and brown micaceous and calcareous siltstone are capped by flaggy green and purple laminated limestone, with intraformational conglomerate.

Patches of ironstone littering the surface in the vicinity of BHT34A have been derived from the Wonoka Formation. Scattered siltstone outcrops are present over a wide area to the west, south and southeast of Charlie Swamp but the limestone is restricted to the area east of Lake Pidleeomina.

Pound Quartzite - brown weathering, thinly bedded, flaggy, white, red and purple quartzite and sandstone, with ripple marks and shale clasts, crops out east of Lake Pidleeomina.

EARLY CAMBRIAN

Andamooka Limestone

Massive yellow to brown limestone, in part oolitic and in part an intraformational conglomerate, preserved as a subdued ridge overlying Pound Quartzite on the western margin of the claypan east of Lake Pidleeomina. Siliceous nodules are present within the limestone and an agate, similar to those found south of Stuart Creek (Crettenden and Barnes, 1978), was seen in float. The limestone is capped by massive fine grained white quartz which may be the result of Tertiary silicification.

STRUCTURE, PRE-MESOZOIC SEDIMENTS

The Precambrian sediments are gently folded into an anticline and a syncline (Cross section ABC, Fig. 23). The anticline trends northwest-southeast, plunging shallowly to the southeast. The anticlinally folded Precambrian sediments crop out extensively in the central portion of the map area. However, the syncline which underlies Mesozoic sediments in the northeast of the map area, is exposed in only one locality, southeast of "Cockatoo Cliff".

Bedding attitudes range from horizontal in the hinge zone to a maximum of 30^{o} on the limbs of the folds.

The Arthur Fault, exposed south of Stuart Creek and which probably continues beneath "Split Hill" (Vnuk, 1978) could not be traced northwards due to extensive Mesozoic to Quaternary cover.

East of Lake Pidleeomina, a fault is indicated by the truncation of the Pound Quartzite and Andamooka Limestone at their northern extremities. Rocks on either side of the fault dip southeasterly, at right angles to usual dips within the Precambrian sequence. The fault is downthrown on the south-eastern side, preserving the upper part of the Wilpena Group and overlying Andamooka Limestone in this area.

Outcrop of the Cambrian Andamooka Limestone is too poor to determine whether or not it was folded along with the Precambrian sediments, as Johns (1966) mapped elsewhere.

MESOZOIC

Two Mesozoic units crop out in the map area. The lower unit, the "Stuart Creek Beds", is described and mapped in the Charlie Swamp area for the first time. It was previously described from the Stuart Creek area by Vnuk (1978). It is overlain by the Marree Formation of Early Cretaceous age.

"Stuart Creek Beds"

White and yellow to pale brown, micaceous fine sand is generally clean and friable, but contains minor brown mud in BHT34 and in outcrop in places, is variably cemented and coloured (brown to yellow) with iron oxide. Small cavities in the sand and mud indicate the possible former existence of woody fragments. Faecal pellets of brown mud produced by sediment feeding organisms, burrow structures and scattered very fine green grains of glauconite(?) are present. No bedding structures or clasts were observed.

Fig. 5. "Stuart Creek Beds" (October, 1978)
Sandstone outcrop east of Pidleeomina Dam, near BHT 29.

"Stuart Creek Beds" were intersected in BHT33 and BHT34 north of Pidleeomina Dam and in BHT 42A, A1 and A2 east of Pidleeomina Dam. The unit crops out in the vicinity of BHT29 (Fig. 5) and BHT29A, and 1.75 km due south of BHT29A. 018

"Stuart Creek Beds" are confined to depressions in the pre-Mesozoic topography, being absent over basement highs. Distribution below Marree Formation is patchy and thickness is expected to be variable being at least 4.5 m thick at BHT29. Elevations range from 74 m (BHT 42A) to less than 60 m (BHT29).

The base was not seen. The contact with the overlying Marree Formation is abrupt but again no definite break was seen. The sand of the "Stuart Creek Beds" passes rapidly up into the basal sandy conglomerate of the Marree Formation. This suggests only a minor time break between the units. The age of the "Stuart Creek Beds" is probably Early Cretaceous, rather than Jurassic.

Although little evidence is available in the Charlie Swamp area to indicate a depositional environment, the "Stuart Creek Beds" are regarded as a transgressional unit. The presence of glauconite indicates marine influence, and the well-sorted nature of the fine sand suggests a littoral environment. Confinement of the unit to pre-Mesozoic topographic depressions and lack of a distinct time break before deposition of the Marree Formation suggests deposition before the onset of uniform marine conditions under which Marree Formation was deposited.

"Stuart Creek Beds" were first described in the Stuart Creek area by Vnuk (1978). The writer correlates the fine sand below Marree Formation in the Charlie Swamp area, with "Stuart Creek Beds", based on the following similarities.

Although Vnuk described a varied lithology friable fine sand constitutes a major proportion of the unit. In the Charlie Swamp area, "Stuart Creek Beds" are entirely friable, fine sand. Scattered small green grains, identified as glauconite in the Stuart Creek area by Vnuk (1978), are present in both areas. Carbonaceous woody material is present in the Stuart Creek area and is thought to have been present in the sands in the Charlie Swamp area, as evidenced by cavities in the sand.

In both areas, "Stuart Creek Beds" are apparently conformable beneath Marree Formation filling depressions in the pre-Mesozoic topography.

Clasts (pebbles and cobbles), commonly present at Stuart Creek, were not seen in the Charlie Swamp area.

A discussion of possible equivalents of "Stuart Creek Beds" within the Great Artesian Basin is presented in Vnuk (1978), but no definite correlation is made. The author agrees with the conclusion reached by Vnuk, that at this stage the "Stuart Creek Beds" are best considered as a transgressional unit, either below or at the base of the Marree Formation, of probable Neocomian to early Aptian age.

Marree Formation

Stratigraphy

Marree Formation overlies "Stuart Creek Beds" or laps directly onto Precambrian rocks. The base of the unit is defined by a distinctive basal conglomerate which is 0.4 m thick at Charlie Swamp (BHT86) but thins elsewhere. The conglomerate contains green siltstone and quartzite clasts of pebble to small cobble size in a sandy matrix.

Above the basal conglomerate is a sequence of poorly bedded, dark brown to grey mud and fine sand, with thin sandy and conglomeratic beds and "erratics".

The mud is poorly sorted, containing a variable proportion of scattered silt to coarse sand grains. Small lenses or layers of sand are present in places. Small structures in the mud have been illustrated, described and discussed in both Barnes and Scott (1979) and Vnuk (1978). They appear in hand specimen as small streaks or patches of either lighter or darker colour than their matrix, giving the mud a mottled appearance. The structures are thought to be the result of intensive bioturbation. They are characteristic of Marree Formation and serve as a valuable means of identification when dealing with very weathered rocks of doubtful age. The two terms 'bioturbation' and 'mottling' were combined to form the word "biomottling", which is used to describe this texture.

In the escarpment adjacent to BHT28, white micaceous fine sand, at least 2 m thick, overlies grey mud. Such sand is uncommon, and has not been seen elsewhere in Marree Formation in this area.

Sandy conglomeratic interbeds are common within the mud. They comprise poorly sorted medium or coarse sand with a variable proportion of clasts, generally green siltstone or quartzite of pebble to small cobble size. Boulders are occasionally present. The sandy beds are generally less than 0.2 m thick but may reach 1.5 m, and their frequency of occurrence appears to decrease with increasing vertical distance above the base of the Marree Formation. "Erratics", generally pebbles to small cobbles are scattered randomly throughout the mud. Their frequency also decreases upwards.

Sandy conglomerate, up to 1.5 m thick, frequently containing boulders, is intermittently exposed for over 5 km along the eastern face of the north-south trending mesa on which

"Cockatoo Cliff" is situated. Rare exposures occur on the western scarps. These isolated outcrops vary in elevation by a maximum of 10 m and appear to belong to one continuous sandy conglomeratic bed (Cross Section FG. Fig. 23). The "kopi-mud" contact corresponds with the conglomerate bed in places as at Andamooka, but elsewhere is at an unknown distance below.

Conglomerate beds, close to the "kopi-mud" contact, and at elevations (90-100 m) similar to the outcrops near "Cockatoo Cliff", are present further afield and may be remnants of the same, once extensive, thin sandy conglomeratic sheet. Examples are present near BHT30, (two conglomerate beds at approximately 88 and 90 m), near BHT83 (approximately 98 m) and at the 'digging', 750 m northeast of BHT37, where a bouldery conglomerate bed occurs at an unknown elevation (but probably within the range of 90-100 m), several metres above the "kopi"-mud contact.

The largest boulder seen in the area is a well rounded quartzite measuring 2.65 x 1.00 x 0.80 m. It has weathered out of the Marree Formation and lies in a creek bed 300 m southwest of TBM473. It may well have weathered from the postulated major conglomerate horizon.

At Charlie Swamp, Marree Formation lies directly on Wonoka Formation which outcrops as a basement 'high' just to the south and is exposed below 2 m of Marree Formation in BHT86 (Cross Section BDE, Fig. 23). Although basement topography is irregular, the maximum thickness of Marree Formation here is probably about 10 m at BHT84.

It was suggested by Barnes and Scott (1979) that Marree Formation exposed at Charlie Swamp may be stratigraphically higher than that at Stuart Creek. The writer does not agree.

Apart from the fact that clasts within the basal conglomerate bed at Charlie Swamp area, do not attain the size of those at Stuart Creek, the nature and frequency of occurrence of sandy conglomeratic beds and "erratics" within Marree Formation are identical in the two areas. Stratigraphic equivalence is also indicated by similarity in elevations of Marree Formation at the two localities (74-84 m), since disturbance of a regional nature appears to be absent. The stratigraphic interval present at Charlie Swamp is believed by the writer to be similar to that at Stuart Creek. Any difference in size or composition of conglomeratic beds is most probably due to differing sources.

Foraminifera were identified in samples from BHT33 and BHT29A, and are possibly present in samples from BHT17A, BHT17B and BHT27. In BHT33 and BHT29A, Haplophragmoides audax is abundant, but only one specimen of Textularia is present (BHT33). They are both agglutinated forms, and indicate an Aptian (Early Cretaceous) age (Hannah and Lindsay, 1977, Harris and Cooper, 1978).

Maximum thickness of Marree Formation in the map area at "Cockatoo Cliff" is probably at least 50 m, 23 m of bleached mudstone ("kopi") over at least 27 m of fresh mud. An elevation of 65.63 m was recorded close to the base of Marree Formation near an outcrop of Wonoka Formation, 1.5 km southeast of Cockatoo Cliff. The maximum elevation of Marree Formation, about 116 m was recorded at "Cockatoo Cliff", and the minimum of less than 63 m at BHT29A. The top of the Marree Formation has been eroded.

Environment of Deposition

A model is outlined involving transport of coarse sediment by shore-ice, to explain the enigmatic occurrence of sandy conglomeratic beds and "erratics" in the dominantly mud sequence of the lower part of the Marree Formation. The conclusions result from observations made in the Andamooka, Stuart Creek and Charlie Swamp areas, and from clast orientation measurements made in sandy conglomeratic beds at Stuart Creek.

Because of the good exposure in opal diggings at Stuart Creek, many of the observations were made there and hence much of the following relates directly to that area. However, it is expected that the model will be equally applicable in detail to both the Charlie Swamp and Andamooka areas, and in general, to the entire southwestern margin of the Great Artesian Basin.

Mud

The bulk of the Marree Formation, (clay to sandy mud), was deposited under a marginal marine body of water, at a depth such that sediments were not subjected to sub-aerial exposure and probably not affected by wave action (Vnuk, 1978). The writer agrees with this hypothesis.

Low energy conditions prevailed, as indicated by the joined shells of bivalves, (Vnuk, 1978) and by the poorly sorted nature of the mud.

The nature of the sediment is consistent with deposition of suspended fine material carried by weak marine currents, except for the coarser sandy fraction, which will be discussed later along with "erratics".

Basal Conglomerate Bed

This bed, varying from a metre or more thick to only scattered cobbles or boulders, is considered to be of different origin than stratigraphically higher sandy conglomerate beds within the mud. Unlike the higher conglomerate beds, clasts within the basal conglomerate are 95% rounded quartzite with the remainder of underlying bedrock. The basal bed is a framework supported conglomerate with a sand matrix, whereas higher beds are often sand containing varying proportions of clasts. The basal bed contains numerous large boulders, sometimes poorly rounded but smooth, with dimensions in excess of one metre, whereas in higher beds these are much rarer.

The predominance of quartzite clasts indicates removal of other lithologies. Since quartzites are the most stable lithology with regard to chemical weathering and mechanical abrasion, it is proposed that a considerable amount of time and energy were available for the rounding of the quartzites and the breakdown and disappearance of other lithologies before the final transgression of the Early Cretaceous sea over the pre-Cretaceous land surface.

The basal conglomerate bed is regarded as a lag deposit, having been reworked by the advancing shoreline, but not transported any considerable distance. Transport of clasts is regarded as having taken place prior to the marine transgression that marked the beginning of Marree Formation. The clasts were probably derived from reworking of "Stuart Creek Beds", or directly from the basement.

Higher Sandy Conglomeratic Beds and "Erratics"

1. Previous Suggestions

The coarse sediments, particularly boulders, in the Marree Formation have provoked much discussion, and ideas for their origin have been summarised by Barnes and Scott (1979) and Vnuk (1978).

These are:-

- <u>glacial action</u>; Brown (1894 and 1902) and Woolnough and David (1926).

  The rounded nature of clasts and the lack of other diagnostic features such as striated clasts and pavements, and till pellets, as well as sufficiently cold climatic conditions and high topographic relief do not support this idea.

- organic rafting; Emery (1955).
  The coarse sediment is much too abundant to have been transported solely by floating vegetation (trees, kelp, etc.).
- reworking of Permian till; Howchin (1928) and Parkin (1956).
  This mechanism is indicated by the presence of rare exotic clasts such as porphyry and Devonian quartzite (Vnuk, 1978). This does not account for the transportation and deposition of the coarse clastics within Marree Formation or for the rounded nature of clasts and their local derivation.
- downslope movement by slow sediment creep adjacent to basement highs; Wopfner et. al. (1970).
  The shallow marine nature of the sediment and the fact that the conglomerate beds are horizontal over large areas negate this suggestion.

Barnes and Scott (1979) suggest deposition of the sandy conglomeratic beds by fluvial processes and of "erratics" by wind gliding across frictionless mud surfaces. This implies sub-aerial exposure for which no evidence (channels, mudcracks, ripple marks) is present. The nature of the thin sandy conglomeratic beds is inconsistent with fluvial deposition. Sufficient distance of transport is implied to consistently round all clasts, but they have been derived in some cases from almost adjacent rock. "Erratics" range in size from sand grains to small cobbles, rarely being larger. It is unlikely that wind could move material of that size over long distances. Nor can wind gliding account for their abundance and widespread areal extent.

2. Structure

At Stuart Creek, bedding in the Marree Formation as defined by sandy conglomeratic interbeds is essentially horizontal.

Fig. 6. <u>Stuart Creek Opal Field (August, 1978)</u>
Marree Formation.
South wall of bulldozer cut adjacent to SCC 16.
Sand bed with pebbles in the fresh brown mud.
Pebbles were measured to determine any imbrication.

Low angle dips (less than 5^{o}) are present in confined exposures, but such low angles were not able to be measured, nor were they considered significant, since local dips of up to 5^{o} are produced by the numerous "slips" in the area.

In a dugout in which pebble orientations were measured, sandy conglomeratic beds dip 14^{o} west-southwest. This may be an initial dip of the sediments or it may result from post-depositional tectonism, possibly related to the nearby Arthur Fault.

Over a larger area, the extensive sandy conglomeratic bed in the Charlie Swamp area, is correlated with the conglomerate beds outcropping on the "Second Mesa" west of Stuart Creek, Yarra Wurta Cliff and Andamooka (Fig. 21). At Stuart Creek, it is correlated with the sandy conglomeratic bed near the base of the Tertiary sequence (94-95 m) at "Split Hill". The elevation of this sandy conglomeratic bed is everywhere between 90 and 100 metres. It can then be seen that no post-depositional regional disturbance has taken place and bedding is horizontal.

3. Clast Measurements

(i) Method

To establish the mode of deposition of the sandy conglomeratic beds (Fig. 6) within the dominantly mud sequence of the lower part of the Marree Formation preferred orientation of clasts was measured.

Clasts of the size from pebbles to small cobbles were selected for the following reasons:

- small enough to have been moved by water currents.
- comprised the majority of clasts.
- insufficient larger clasts were present.
- larger clasts were difficult to extract to measure.

Measurement of sufficient numbers was difficult owing to:

- discontinuous outcrop.
- low clast populations.
- extremely weathered nature of many clasts, particularly shales, which prevented extraction.
- extraction from partially cemented sand beds was time consuming and unsuccessful.

Measurements were made on the plane of the long and intermediate dimensions of the clasts. The few equidimensional and elongate clasts (perhaps 5%) were not considered. Many clasts (30-40%) were horizontally or near-horizontally disposed and were not taken into account. The attitude of non-horizontal clasts in four separate exposed pebble beds in the central area of the diggings at Stuart Creek were measured. (The number of measurements ranged from 34 to 67 on the four beds). Measured attitudes of the clasts were plotted on stereonets (Figs. 7, 8).

(ii) Results

With the exception of the clasts from the 'dugout', non-horizontal clasts from the other three localities have a seemingly random direction of dip, with a low angle of dip of less than 30^{o} (Figs. 7a, 7b, 8a).

The random dip direction of clasts suggests the absence of a dominant current direction and excludes the possibility of deposition of the beds by fluviatile means, or by strong unidirectional marine currents or in a littoral environment. The lack of any initial bedding dips excludes the possibility of deposition by any down-slope processes.

Measurements of clasts from the 'dugout' (Fig. 8b) show a moderately strong preferred orientation of dip direction consistent with the bedding dip direction, but of a considerably higher angle. If the bedding dip is assumed to be tectonic in

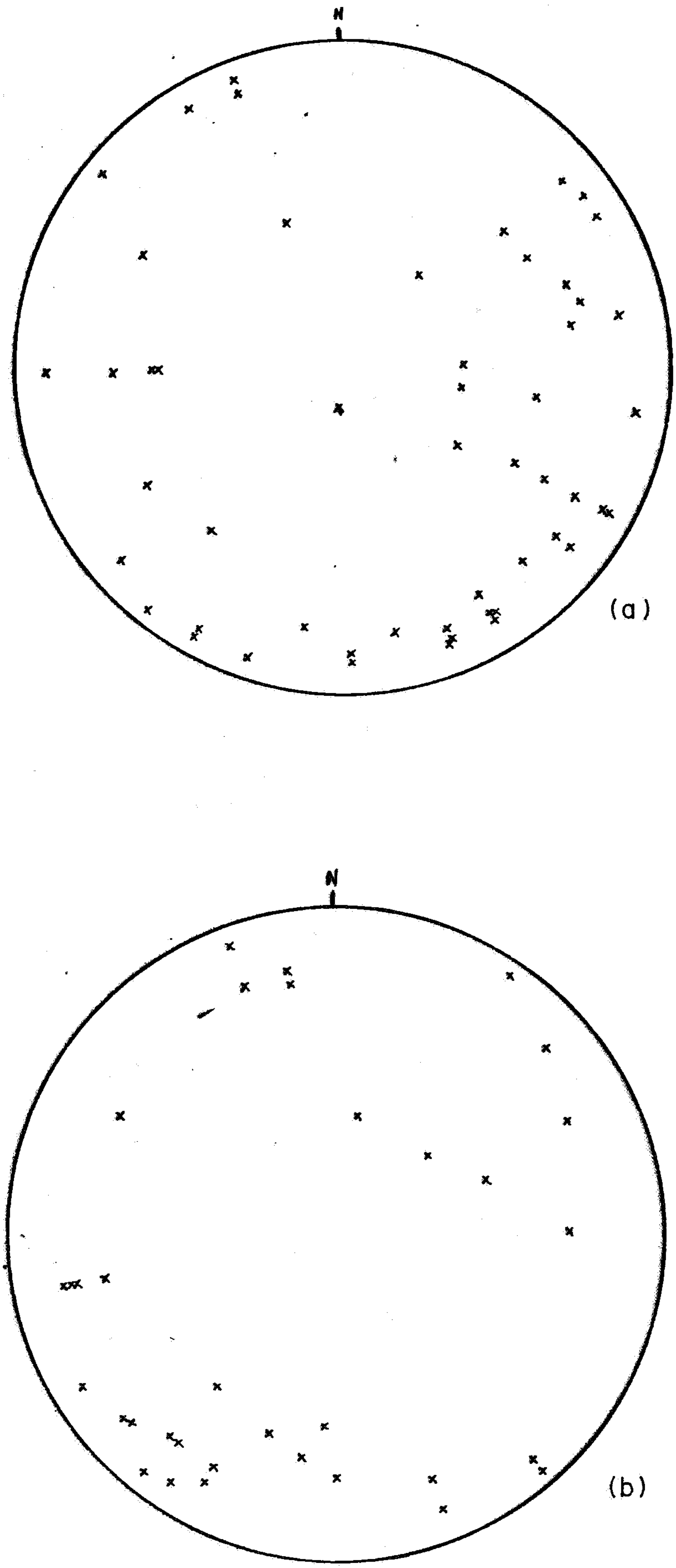
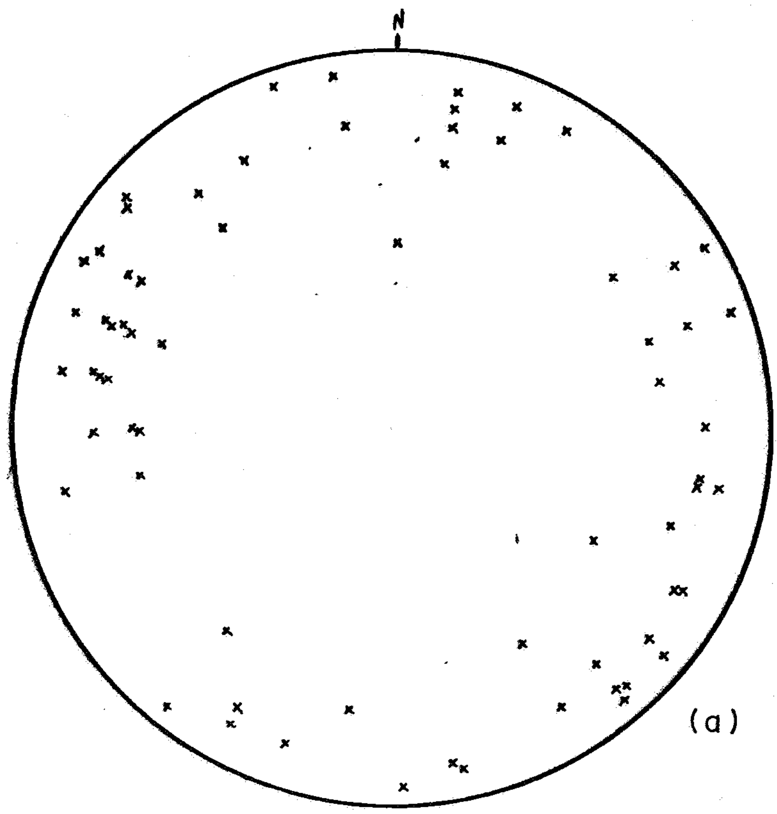


Fig. 7 Stereonet plot of orientations of pebble to small cobble sized clasts in two sandy conglomeratic beds at Stuart Creek.



'Dugout'

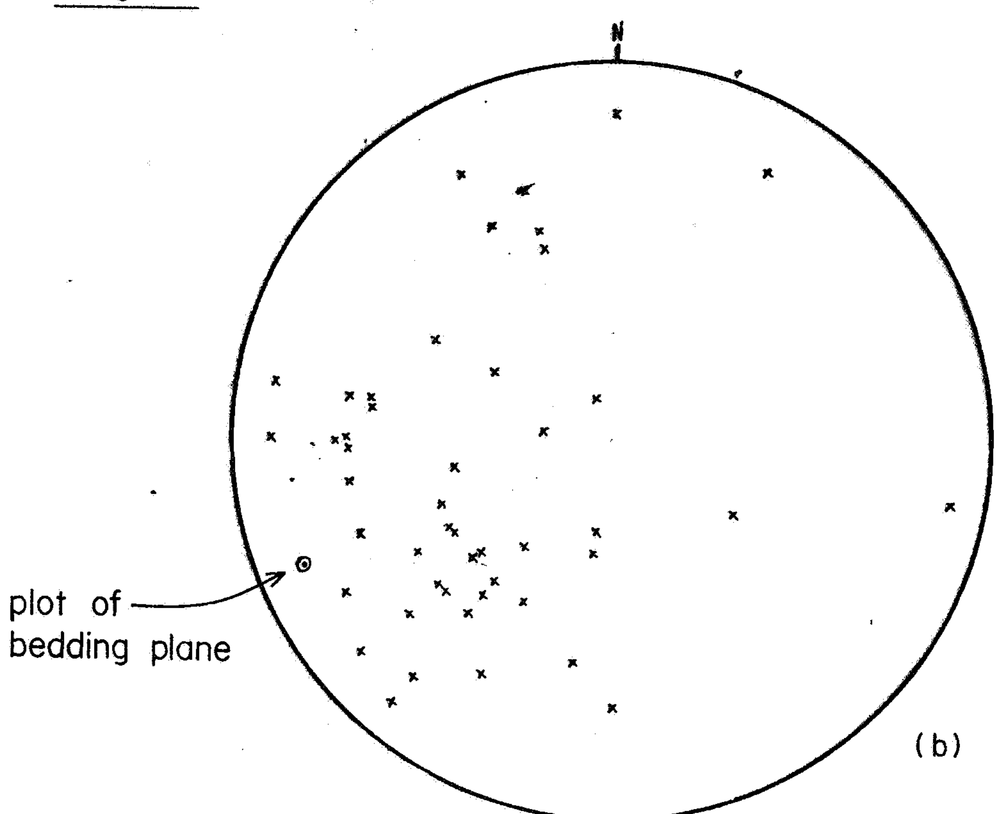


Fig. 8 Stereonet plot of orientations of pebble to small cobble sized clasts in two sandy conglomeratic beds at Stuart Creek.

origin and not an initial dip, then the angle of dip of most of the clasts is reduced slightly but their preferred orientation remains. If the bedding dip is regarded as an initial dip, the downslope imbrication, which would require an upslope movement of water to produce it, is most likely to have been produced in a littoral (beach) environment.

The poorly sorted nature of the sandy conglomeratic beds suggests either a quiet or a turbulent environment, or rapid deposition. The size range of sediment in these beds, together with the indication that some movement and arrangement of the pebbles and cobbles has taken place (a large proportion are inclined to the horizontal and in some cases heaped against larger clasts (Fig. 9)) indicates deposition under turbulent conditions. This is supported by the observation that, in cases of limited gravel content, the gravel sized component is concentrated near the base of the sand bed.

Having established the depositional environment of the sandy conglomeratic beds as being under turbulent or stormy conditions, in a marine body of water, probably at sufficient depth such that sediments were below wave base under normal (quieter) conditions, the questions of source area and transport method arise.

4. Source

Lithologies were recorded of 200 clasts when measuring pebble orientations. Of these, 37% were quartzite, the rest being mainly siltstone to fine sandstone, with some shale. The tendency for shaley pebbles to disintegrate on extraction, results in a low count. Hence, it is estimated that the clast content more closely approached 30% quartzite, 10-15% shale, and 55% siltstone to fine sandstone. Porphyry clasts were rare (about 1%).

The lithologies point to local derivation of clasts from nearby Precambrian and Cambrian rocks. The quartzite clasts, often with clay galls and cross bedding, along with the sandstone clasts, have their obvious source in ABC Range Quartzite. The siltstone and shale clasts were probably derived from Cambrian Yarra Wurta Shale or from Precambrian Bunyeroo Formation, Brachina Formation or Amberoona Formation. In the Charlie Swamp area, clasts other than quartzite, comprise green siltstone identical to Wonoka Formation. The sand content could have been derived from the breakdown of sandstone of the ABC Range Quartzite, Elatina Formation and Amberoona Formation, as well as from "Stuart Creek Beds", and possibly Algebuckina Sandstone.

The consistent roundness of clasts indicates that they underwent a period of abrasion prior to deposition. Since the abrasive action of transport over such short distances is deemed insufficient to produce such rounding, another explanation must be sought, the most likely being that the clasts were rounded on the shores of the Cretaceous sea, by the action of waves. Whether some transport with consequent abrasion took place, or whether the clasts were rounded only by shoreline action, is not known, but probably both processes took place.

It is suggested that much of the Precambrian anticline presently exposed east of Stuart Creek, was above sea level at the time of deposition of the lower part of the Marree Formation. South of Stuart Creek, Andamooka Limestone and Yarra Wurta Shale may also have been above sea level at this time. The shoreline of the Cretaceous sea, impinging on these "highs", would have eroded them, providing a source of coarse material, well rounded by the abrasive shoreline wave action.

5. Transport

The next step is to consider the transport of sand and rounded gravel, presumed to have accummulated along shorelines,

Fig. 9. <u>Stuart Creek Opal Field (August, 1978)</u>
Marree Formation.
Thin sandy pebble bed, containing an angular sandstone boulder.
Pebbles are heaped against the left hand side of boulder, but are sparse on the right hand side, indicating movement of pebbles by a current after the boulder had been positioned. Note depression of bedding below boulder.

to thin beds on the sea floor.

Under stormy conditions, flood water runoff from adjacent land, together with turbulent seas, could have washed coarse material offshore, and deposited it in beds of varying composition and thickness, and limited lateral extent. This may be a plausible transportation mechanism for the clastics of sandy conglomeratic beds in close proximity to a basement high, such as those at Stuart Creek. However, this model does not account for all of the features of the sandy conglomeratic beds, notably the presence of large "erratics" and the lateral continuity of some of the beds. Consequently another method of transportation must be invoked.

It is proposed that shore-ice rafting was responsible for the transportation of the coarse clastics. Water, freezing along shorelines, picked up well rounded coarse gravel, sand and possibly finer material from shallow depths and the shoreline. Under stormy or turbulent conditions, the ice broke up (Gostin, 1968), and floated out to sea, where slow melting released rafted material to drop on to the seafloor. Fine material in the rafted load was winnowed out by current activity. Some reworking of the coarse material under turbulent conditions may have taken place.

Some features of the coarse sediments, apparently inexplicable by any model of transportation and deposition other than that of ice rafting are discussed here. The first of these is the occurrence of "erratics"; pebbles to cobbles generally, occurring as isolated clasts distributed randomly or in horizontal, discontinuous lines in the mud. Since bedding is not clear in the mud, no penetration of bedding can be seen. It is suggested that the "erratics" were dropped into position in the mud on the bottom of the sea from floating ice, along with sand and silt, now present as scattered grains in the poorly sorted mud. 035

The second feature is the presence of isolated large cobbles and boulders in the sandy conglomeratic beds. There is no evidence that currents of sufficiently high energy necessary to transport such clasts existed. However, weak currents are indicated by the heaping of sand and pebbles to one side of large clasts (Fig. 9). Cobbles and boulders rarely rest at the base of the sandy conglomeratic beds, usually being separated from it by a thin sandy or pebbly layer. This suggests deposition of the large clasts by dropping from above into the sandy bed. Deformation of the underlying mud-sand contact beneath large clasts is common, but is probably due to general compaction of the sediments. Equal deformation is present at the upper contact of the sandy conglomeratic bed with the mud.

The ubiquitous presence of "erratics" and sandy conglomeratic beds over large areas is a third feature that can only be readily explained by ice rafting. Clasts, generally pebbles or small cobbles (but in places boulders), are present considerable distances from any possible contemporaneous shoreline and source. Within the study area, this distance amounts to 5-10 km, but is expected to be much greater elsewhere, since clasts are common in the lower part of the Marree Formation over a large area around the southwestern margin of the Great Australian Basin (Barnes and Scott, 1979). The long distance transport of large clasts supports rafting by ice.

A fourth feature is the discontinuous,lensoidal nature and generally flat bottom bedding surfaces of the sandy conglomeratic beds. The discontinuity of the beds is demonstrated remarkably well in the Calweld drill holes at Stuart Creek

Fig. 10. Stuart Creek Opal Field (June, 1978)
Marree Formation.
An eye-shaped nest of pebbles and cobbles with a sandy matrix is present above the hammer. The pink sandstone boulder is 1 m long. Gypsum and yellow alunite vein the fresh brown mud.

(Barnes and Scott, 1979). The beds appear of extremely limited lateral extent and have an erratic vertical distribution. Some of the lenses have a distinct eye-shape in cross section (Fig. 10), as though the sediment has been dumped in a heap. Such a feature is commonly produced by the breaking up and overturning of icebergs (Ovenshine, 1970). No scouring is evident along the base of the sandy conglomeratic beds, the base being quite flat. These features appear incompatable with any model of underwater transport and deposition, including that of transport under turbulent conditions, proposed earlier, and strongly suggest that ice rafting played a prominent part in the transport and deposition of the bulk of the sediment contained in the sandy conglomeratic beds.

Thin sandy conglomeratic beds that are continuous over large areas, such as those at Andamooka, near Stuart Creek and near Charlie Swamp, also indicate ice rafting of the coarse sediments. This is particularly so if they are all part of the same "sheet" as seems highly probable. The beds which contain numerous large clasts, are rarely more than 0.5 m thick, and although show minor local relief are horizontal over large areas (Fig. 21). The only possible means by which such widespread, horizontal, thin "sheets" of coarse sediment may have been produced, is by deposition from floating ice. Such extensive "sheets" (or "sheet") may be the result of a major widespread episode of ice break-up and melting.

Summary

The basal conglomerate bed of the Marree Formation where present, is a lag deposit containing clasts of only the most resistant lithology, or that of rocks directly underlying it, and marks the onset of a uniformly marine period of deposition.

The bulk of the mud was deposited under quiet conditions, at a depth of water probably unaffected by wave action, from a suspended load of fine material carried by normal marine currents. Coarse sediment, eroded and rounded by shoreline wave action was picked up as water froze along the shore. During storms, the ice broke up and drifted out to sea where it either dumped its rafted load in thin lenticular beds or dropped occasional "erratics". Reworking of the coarse sediment under turbulent conditions took place.

Post-depositional Alteration

Pre-Tertiary sediments above an elevation of 90-100 m have been bleached (Cross Sections BDE, FG, Fig. 23). Sediments below the bleached profile are generally weathered and soft.

Marree Formation is generally the pre-Tertiary sediment above 90 m elevation in the map area and therefore commonly affected by bleaching, resulting in an indurated, porous mudstone ("kopi"). This is confined to the higher ridges and the mesas. It is assumed that an original bleached profile, at least 30 m thick, was present at the top of the Marree Formation prior to its erosion (Barnes and Scott, 1979) and that it would have covered the entire area mapped.

The bleached profile is generally brilliant white. However, some exposures are yellow whilst some are mauve coloured. Horizontal bands of yellow and mauve colouring can be seen at "Cockatoo Cliff (Figs. 11, 12, 13).

In this section, a second bleaching is superimposed on the upper part of the first varicoloured bleached profile. It is uniformly present at the top of the cliff, but has penetrated downwards through ?termite tubules, joints and cracks, forming large lobes and isolated bleached patches

Fig. 11. 'Cockatoo Cliff' (October, 1978)
Marree Formation.
Variably stained "kopi", with sandy bed containing boulders at the base, overlies fresh brown mud, exposed at lower right of photograph.

Fig. 12. 'Cockatoo Cliff' (October, 1978)
Marree Formation.
Bleached and variably stained "kopi". The topmost white bleaching has penetrated down cracks and tubules and been superimposed on the stained (coloured) section. Horizontal gypsum veins permeate the upper part.

C40

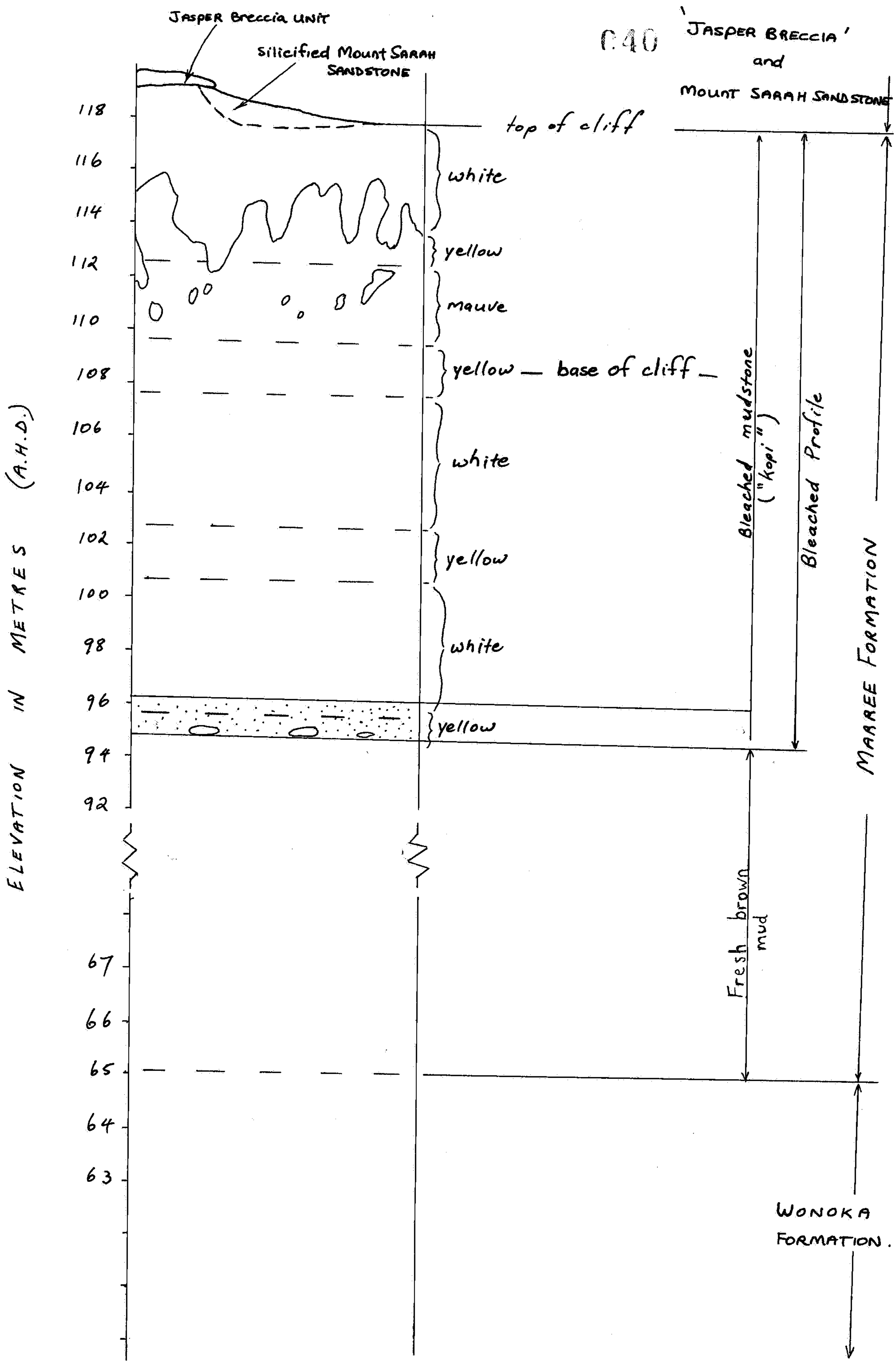


Fig 13.

"Cockatoo Cliff" Section.

Vertical Scale 1:200

G.J. Nicol.

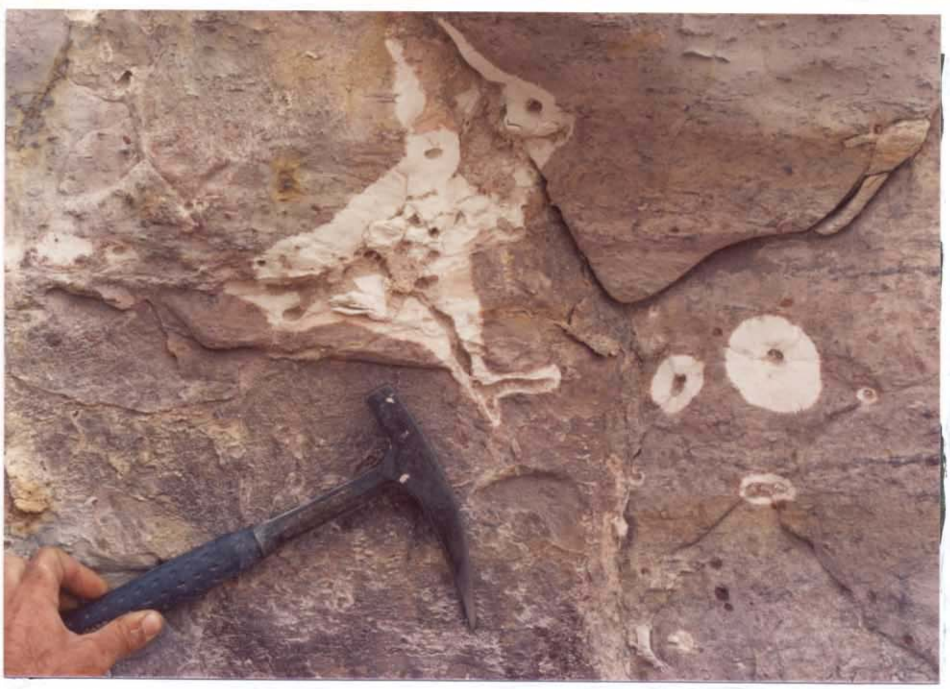


Fig. 14. 'Cockatoo Cliff' (October, 1978)
Marree Formation.
Mudstone surrounding the lowermost ?termite tubules has been bleached white. The tubules are partially infilled with gypsum. "Biomottling", accentuated by the staining, can be seen clearly.

(Figs. 12 and 14). This is the only known exposure in the area of the second bleaching event.

The upper part of the bleached profile (probably the first one) in some localities has been silicified, forming a white or grey chert-like material, quite similar in appearance to the opaque, white common opal found in the Charlie Swamp area.

The only other pre-Tertiary sediments above 90 m in elevation, are the Bunyeroo Formation at BHT39, where it has been bleached, and quartzite of the ABC Range Quartzite, which is apparently unaffected by bleaching.

?MIDDLE TERTIARY

Mount Sarah Sandstone

Friable sand and sandy limestone (or calcareous sandstone), contain polished granules to pebbles of silcrete, quartzite, milky quartz, clear quartz, agate and black ?chert. Rare fragments of white, bleached and silicified mudstone from the Marree Formation are also present. Lag deposits are common at the base and include rounded quartzite derived from Marree Formation (Fig. 15). Tertiary sediments capping the ridge of ABC Range Quartzite contain angular quartzite fragments at the base and in layers, with polished pebbles, within the sand.

Polished pebble assemblages vary in size between certain locations, suggesting a further reworking from large to small, and hence more than one Tertiary unit. However, no other evidence was found to substantiate the suggestion.

Alteration

Ferruginisation and silicification have altered the Mount Sarah Sandstone, producing varicoloured friable and partly silicified sand (Figs. 16, 17). Complete silicification results in an olive green-grey silcrete.

Fig. 15. BHT 27 (October, 1978)
Sand of the Mount Sarah Sandstone with lag cobbles (near hammer) at the base overlies mud of the Marree Formation. (See log of BHT 27 in Appendix A).

Fig. 16. Stuart Creek Opal Field (October, 1978)
"Split Hill". Mount Sarah Sandstone.
The friable sand shows large scale cross-bedding.
Purple silicified layers are present above and below the hammer. Both silcrete layers and the colour banding are horizontal, crosscutting the cross-bedding.

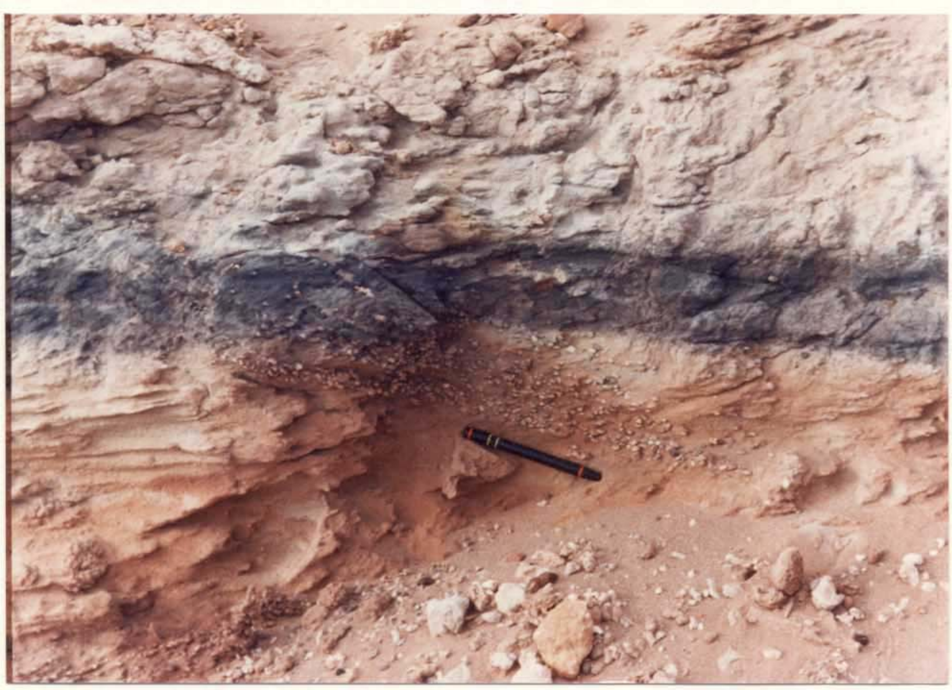


Fig. 17. Stuart Creek Opal Field (October, 1978)
"Split Hill". Friable cross-bedded sand of the Mount Sarah Sandstone. Horizontal colour banding crosscuts the inclined milky quartz pebble layer.

Carbonate in sandy limestone was studied to determine if it is a primary or secondary feature. The sandy limestone is partially silicified and the relationship between the carbonate and silica is of particular interest. Examination of thin section 550/55B (Appendix B) shows remnant carbonate included in the silica cement suggesting that silicification has proceeded by replacement of the carbonate, but it could not be established definitely whether the carbonate was primary and deposited with the terrigenous sand grains or whether it filled the pore space of an open framework sand as a later event. However, the fact that the sand grains are matrix supported in places suggests that the carbonate is a primary feature of the rock. There has been alternation in the crystallisation of the carbonate and the silica (550/49B, Appendix B), suggesting that there is no great age difference between calcite crystallisation and silica crystallisation - crystallisation is not to be confused with emplacement. Hence, it is probable that the sandy limestone was deposited as a sandy carbonate mud, which later recrystallised at the time of silica replacement. This accounts for alternating calcite-silica-calcite crystallisation. The time between carbonate deposition and recrystallisation/silica replacement is unknown.

Friable sand with a silcrete capping is patchily present over the entire area mapped. Silcrete caps the mesas and some small hills, as well as forming the valleys of a few of the present creeks. Massive, yellow sandy limestone caps the mesa 3 km southeast of Lake Pidleeomina and large jumbled blocks of grey sandy limestone cap the mesa 2 km due east of Charlie Swamp. Limestone is present in several other localities amongst outcrops of silicified sand.

A fluviatile environment of deposition for the Mount Sarah Sandstone is indicated by cross-bedding, the coarseness of the sands and the presence of frequent pebble bands. The sandy limestones may also be of fluviatile origin, but are more probably lacustrine deposits. They contain pebble bands and fine bedding laminations.

The use of the name Mount Sarah Sandstone, follows from the correlation made by Barnes and Scott (1979) and Vnuk (1978), who suggest a probable Miocene age.

Fossil leaf and wood impressions in flaggy, brown weathering, cream to grey, variably silicified, fine sand, were found scattered on top of the mesas to the north and south of TBM472. Silicification has proceeded in such a fashion as to produce exterior surface moulds of the fragments, mostly of the underside of leaves. The rock has broken along beds crowded with leaf and wood impressions and weathering has enhanced the effect. Similar occurrences of fossil leaf beds in Tertiary silicified sand have been reported in the north of the state (Lange, 1978). Since no outcrop of sand containing leaf impressions was found, and no evidence was seen to link it to the Mount Sarah Sandstone it is possible that these sands are remnants of a younger unit.

The Mount Sarah Sandstone was deposited unconformably over the Marree Formation and Adelaidean sediments. The base of the unit has a relief in excess of 30 m, ranging in elevation from less than 85 m at BHT64A to more than 116 m at "Cockatoo Cliff". The top is an erosional surface, with a maximum elevation of 119 m south of TBM472. A thickness in excess of 10 m is present near BHT64A and BHT64B but generally the Mount Sarah Sandstone is less than 5 m thick. The original thickness is unknown.

LATE TERTIARY-QUATERNARY

"Jasper Breccia" Unit

The "jasper breccia" unit is a colluvial accummulation of red-brown sand and silt with a high proportion of angular clasts of silicified sand and mud derived from Mount Sarah Sandstone and Marree Formation. The unit is often strongly cemented with silica or gypsum. Silica cemented material has the appearance of terrazzo (Fig. 18) and is referred to here as "jasper breccia". The unit of red sand and silt, whether silicified or not, is referred to here as the "jasper breccia" unit.

Surface remnants of "jasper breccia" are present as scattered fragments or blocks on the tops, and along the upper edges, of most mesas (Fig. 19). Red sand and silt permeate the brecciated, bleached upper part of the Marree Formation, where they overlie it penetrating downward into tubules, joints and cracks. At "Cockatoo Cliff", the red sand and silt infills tubules in the Marree Formation to a depth of 6 m, leaving deeper tubules empty.

The "jasper breccia" unit contains clasts of the Mount Sarah Sandstone hence post-dating it. "Jasper breccia" pre-dates a gypsificiation event, for which no age can be established. Hence, it can only be said to be younger than the ?Miocene Mount Sarah Sandstone. The "jasper breccia" unit may be equivalent in part to the Russo Beds of Coober Pedy (Barker et. al., 1979), the age of which is believed to be late Tertiary or early Quaternary.

Gypcrete Breccia

Brecciation of the upper part of Marree Formation with infiltration of sand and silt and cementation by gypsum has produced a gypcrete breccia. Gypcrete breccia outcrops in a

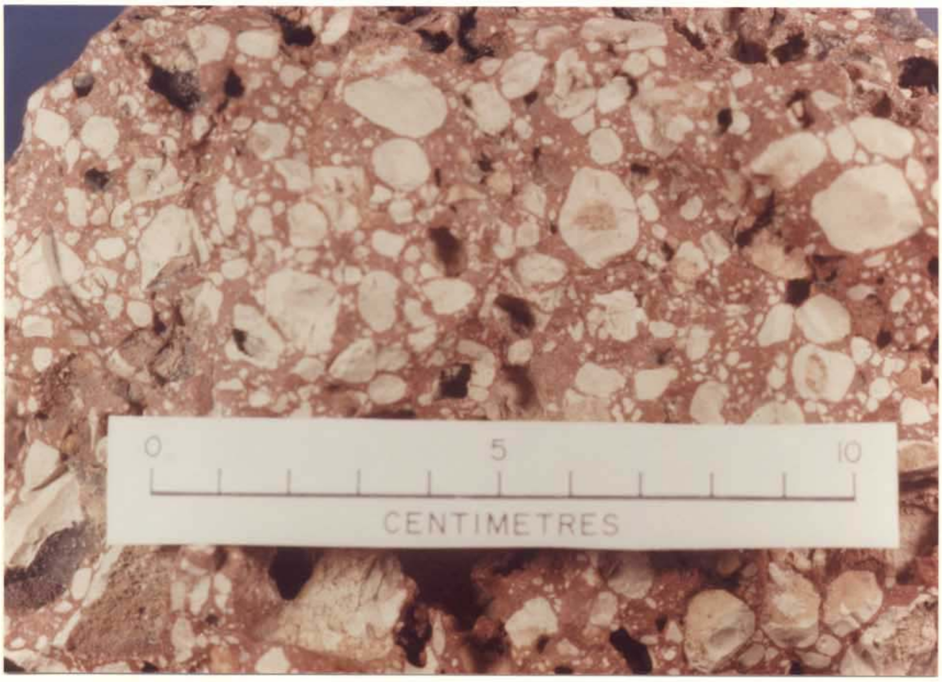


Fig. 18. "Jasper Breccia"
Silica cemented red-brown sand containing pale coloured clasts of silicified sand (Mount Sarah Sandstone) and silicified, bleached mud (Marree Formation).

Fig. 19. "Jasper Breccia"
Float on upper scarp of mesa. Red-brown silicified sand, "jasper breccia", containing clasts of grey silicified sand (Mount Sarah Sandstone) and small fragments of white, silicified, bleached claystone (Marree Formation).

small cliff near the top of a mesa 300 m south of TBM472.

Horizontal gypsum veins permeating the upper part of the Marree Formation and cross-cutting all other features at "Cockatoo Cliff" (Fig. 12) may be related to the gypcrete breccia. The lowermost tubules at "Cockatoo Cliff" are partially infilled with gypsum (Fig. 14) which may be related to the same gypsification event.

Veins of silicified red sand ("jasper breccia") within the gypcrete breccia have been brecciated, hence formation of the gypcrete breccia post-dates silicification of "jasper breccia". The age of the gypsification event is therefore probably Quaternary.

Recent Sediments

Other thin Quaternary sediment and soil which effectively mask older rocks include:

- red-brown soil and silcrete gibber, well developed on the flanks of mesas,
- alluvial sand and gravel within ephemeral creeks,
- gypseous sand and mud within lakes and claypans,
- northeast-southwest trending sand ridges and associated sand spread of pale red, medium grain size quartz, well developed over a large part of the area,
- aeolian, white siltstone to very fine sandstone developed on low ridges and mesa flanks; encountered in several of the backhoe trenches.

OPAL

Black common opal is abundant in the shallow diggings in Charlie Swamp itself, and in the base of the bulldozer cuts (BHT84) (Vnuk, 1978, Fig. 8) on the low rise at the northwestern edge of Charlie Swamp. Similar material can be found on the dumps of the bulldozer cut at BHT83 (2.5 km east of Charlie Swamp) and the shallow diggings just southwest of BHT83. No common opal was seen 'in situ' in either of these diggings, even though BHT83 deepened the bulldozer cut by 3 m.

Scattered common opal fragments, varying in colour from black through blue/grey to white, are present on most of the dumps of diggings marked on the map. Most of the diggings are in fresh Marree Formation mud, but some are in bleached mudstone. A thin, almost vertical, vein of common opal is present in a digging in the side of a scarp of bleached mudstone about 1.5 km southeast of BHT83.

Common opal was found in Precambrian rock (Bunyeroo Formation) in BHT39A, (Fig. 20) as vertical and horizontal veins up to 7 mm thick. The common opal, amber coloured, badly cracked and opaque was identified as opal CT by M. Vnuk using XRD. Fragments of common opal of white to black colour are present on the dumps of diggings nearby.

Fig. 20. Common opal in Bunyeroo Formation (October, 1978)
Horizontal and vertical veins of amber coloured common opal in pink mud-shale of the Precambrian Bunyeroo Formation in BHT 39A.

SEQUENCE OF EVENTS

The geological history of the area is summarised in Table I. Folded and faulted Adelaidean and Early Cambrian sediments were subjected to peneplanation prior to transgression of the Early Cretaceous sea. Following deposition of "Stuart Creek Beds" and Marree Formation, the shallow Early Cretaceous sea is presumed to have retreated leaving a relatively flat land surface.

Although there is little record of post-Marree Formation events prior to the deposition of the ?Miocene Mount Sarah Sandstone, the following sequence is suggested:-

1) Weathering.
2) Bleaching - clasts of bleached Marree Formation are reworked into the Mount Sarah Sandstone.
3) Yellow and mauve colouration.
4) Silicification - present as silcrete pebbles in the Mount Sarah Sandstone (also possibly derived from the Eyre Formation).

To the events shown by the clasts included in the Mount Sarah Sandstone, can be linked the first major bleaching shown at "Cockatoo Cliff" and probably represented by most of the bleached sections of the Marree Formation seen in the area. For simplicity, the yellow and white banding effect shown in the major bleached portion of Marree Formation at "Cockatoo Cliff" is taken to be a single event. However, it may well indicate a series of events, or the yellow colouring may even be related to the later ferruginisation event. Bleaching and silicification may be related events.

Extensive erosion, removing most of the first bleached profile, preceded deposition of Mount Sarah Sandstone which was later variably ferruginised. This ferruginisation event

TABLE I

SEQUENCE OF EVENTS

FORMATION OF SOIL, COLLUVIUM, ALLUVIUM AND AEOLIAN DEPOSITS

GYPSIFICATION

FORMATION OF GYPCRETE BRECCIA COLLUVIUM

3RD SILICIFICATION

FORMATION OF "JASPER BRECCIA" UNIT COLLUVIUM

2ND BLEACHING
TERMITE TUBULES

EROSION

OPALISATION?
2ND SILICIFICATION
FERRUGINISATION. Colouration of Mount Sarah Sandstone and bleached Marree Formation sediments.

DEPOSITION OF MOUNT SARAH SANDSTONE

EROSION

1ST SILICIFICATION (now present only as silcrete pebbles in younger sediments).
1ST BLEACHING

DEPOSITION OF MARREE FORMATION. Followed by retreat of shallow seas, leaving a relatively flat surface.

EROSION

FAULTING
FOLDING

DEPOSITION OF CAMBRIAN SEDIMENTS

DEPOSITION OF ADELAIDEAN SEDIMENTS

(or events) may be linked with the mauve staining of the bleached Marree Formation. Silica then cemented ferruginised Mount Sarah Sandstone, forming layers of silcrete which cap much of the present topography. Formation of precious opal is believed to be related to this silicification (Barnes and Scott, 1979). A bleached profile associated with this silicification cannot be recognised.

Erosion of the top of the Mount Sarah Sandstone was followed by formation of tubules. The tubules are present within the upper part of the Marree Formation and are best exposed at "Cockatoo Cliff" where they extend downward from the top of the cliff for about 8 m. It has been postulated by Barker (1979) that similar tubules at Coober Pedy result from termite activity. The top of the tubules, and their relationship to Mount Sarah Sandstone are not clearly exposed.

A second bleaching event then took place, superimposed on the first varicoloured bleached profile and utilising the tubules. It is unrelated to silicification of Mount Sarah Sandstone. To be related, the tubules would have had to exist prior to erosion of the silicified Mount Sarah Sandstone and would thus have been infilled by debris eroded from this unit. However, they are not, and therefore did not exist at the time Mount Sarah Sandstone was silicified.

Following the second bleaching event, the tubules were infilled by the colluvial "jasper breccia" unit, marking the end of ?termite activity. The "jasper breccia" unit was then partially silicified; the silicification again being unrelated to the second bleaching event, for two reasons. Firstly, "jasper breccia" has brecciated and permeated rocks already affected by the second bleaching event, including penetration of tubules and cracks. Secondly, had the "jasper breccia" been present in the tubules prior to bleaching, the reddish colour would have been removed.

Following silicification of the "jasper breccia", brecciation and colluvial accummulation of sand and silt again took place. Gypsum impregnation formed gypcrete breccia and extensive gypsum veining.

Soil, colluvium and alluvium are developing at the present time, along with extensive aeolian deposits.

CONCLUSIONS

The "Stuart Creek Beds" are a transgressional unit of fine sand either at the base of, or below the Marree Formation. Further mapping toward the north and east may provide more evidence for correlation of this unit with others already described.

The Marree Formation is a marine sequence of mud with sandy conglomeratic interbeds and "erratics". The coarse sediment was locally derived, rounded on the shoreline of the Early Cretaceous sea and transported by shore-ice rafting to the sea floor. Most coarse sediment is in lenticular beds, but a continuous, horizontal, thin sandy conglomeratic bed is postulated to extend from Andamooka to Charlie Swamp, a distance of 80 km. Post-depositional bleaching has affected sediments above an elevation of 90-100 m over a wide area, and the base of the bleached profile corresponds roughly with the major sandy conglomeratic horizon.

Common opal is present at Charlie Swamp in both fresh and bleached Marree Formation, and in weathered Adelaidean sediments.

Tertiary and Quaternary events include the deposition of the fluviatile-lacustrine Mount Sarah Sandstone and later colluvial units, two bleaching events, three silicification events, and the introduction of iron and gypsum into the sediments.

GJN:ZV

G.J. NICOL

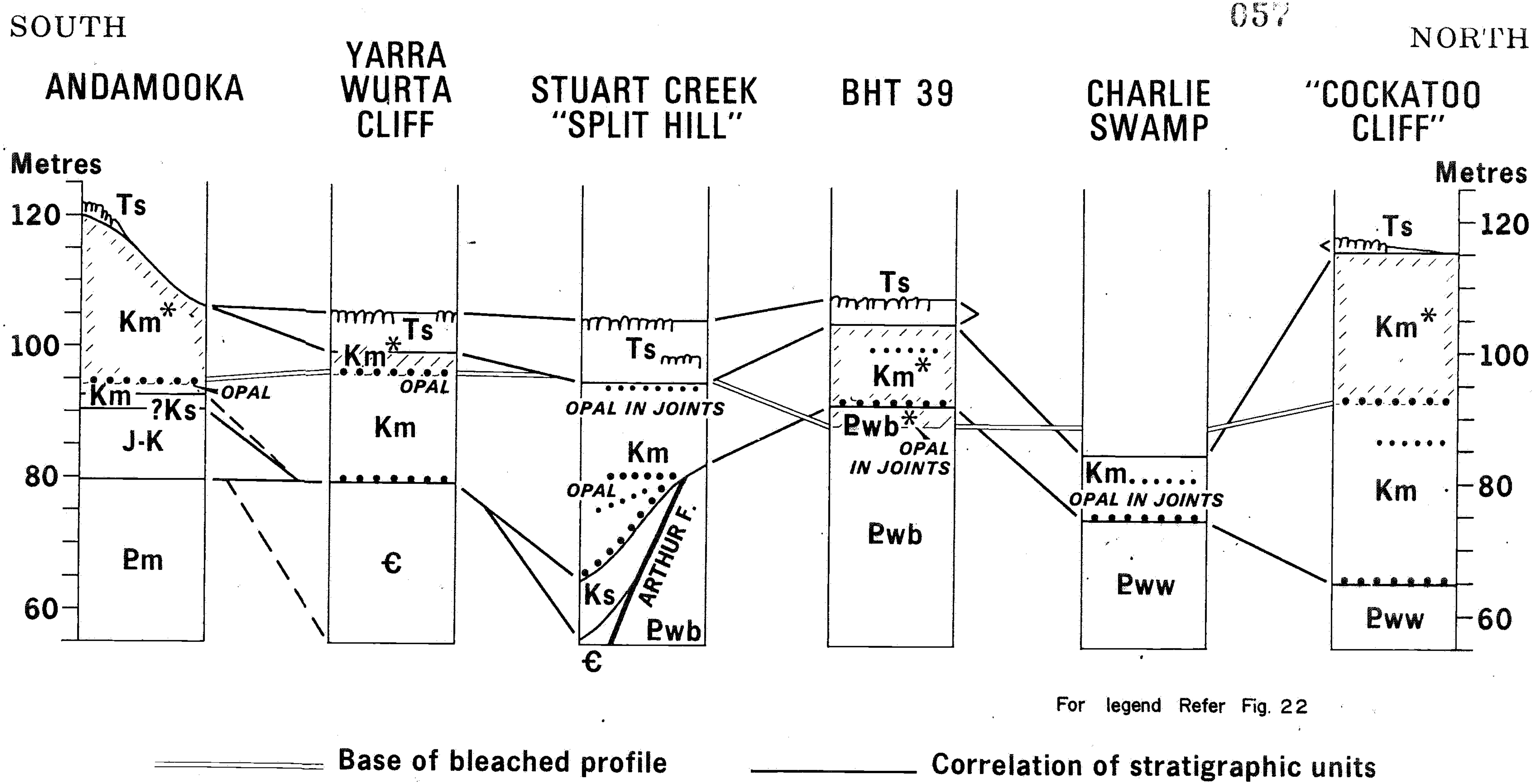


Fig. 21 Schematic Cross Section — Andamooka to Cockatoo Cliff

ACKNOWLEDGEMENTS

The author is indebted to the following people who contributed to the investigation:

- Officers of the Department of Mines and Energy.
  . L. Barnes (Senior Geologist) - for supervision, guidance and discussion in the field and office.
  . D. Scott (Geologist) - for invaluable assistance in the execution of the backhoe trenching program.
  . P. Crettenden and S. Ewen (field assistants) - for levelling of the backhoe trenches and sections.
  . J. Olliver (Supervising Geologist) - for organisation of the project and discussion in the field.
  . G. Kreig (Senior Geologist) - for discussion in the field.
  . G. Ambrose and R. Callen (Geologists) - for discussion in the office.
  . R. Betterman (Andamooka Area Officer) - for assistance while in the field area.
- Staff of the University of Adelaide, Geology Department.
  . Dr. J. Jones - for organisation of the project and discussion in the office.
  . Dr. B. Daily - for discussion in the field and office.
  . Dr. V. Gostin - for discussion in the office.
- Michael Vnuk, whose assistance and discussion throughout the project in both the field and office was invaluable.
- Many people in both Andamooka and Stuart Creek, particularly Ted Havers (backhoe operator) and his brother Mike, Rudi and Inge Duke, Clarry Findlay, and the miners of Stuart Creek, whose co-operation was appreciated.

BIBLIOGRAPHY

Anonymous, (1949). Charley Swamp or Stuart Creek Opalfield. Min. Rev., Adelaide, 87:23.

Barker, I.C., 1979. The Stratigraphy and Opal Occurrences of the 14 and 17 Mile Opalfields, Coober Pedy, South Australia. M.Sc. thesis, University of Adelaide, (in preparation).

Barker, I.C., Barnes, L.C. and Benbow, M.C., 1979. The Russo Beds. Q. geol. Notes, geol. Surv. S. Aust., 71 (in press).

Barnes, L.C. and Pitt, G.M., (1976). Silcrete, sediments and stratigraphy. S. Aust. Dept. Mines report 76/119 (unpublished).

Barnes, L.C. and Pitt, G.M., (1977). The Mount Sarah Sandstone. Q. geol. Notes geol. Surv. S. Aust., 62:2-8.

Barnes, L.C. and Scott, D.C., (1979). Opal at Stuart Creek, Charlie Swamp and Yarra Wurta Cliff. Report No. 1: Geological investigations and Calweld drilling of the Stuart Creek Precious Stones Field. S. Aust. Dept. Mines report 79/5 (unpublished).

Brown, H.Y.L., 1884. Report on the geology of the country along the route from Strangways Springs to Wilgena, and on the gold discovery near Wilgena: Adelaide, South Australian Govt. Geologist Ann. Rept. 10-12.

Brown, H.Y.L., 1904. Opal. A short review of Mining Operations in S. Aust. 2, 12.

Brown, H.Y.L., 1908. Record of the Mines of S. Aust., (4th Ed.) p. 360.

Campbell, K.S.W., Rogers, P.A. and Benbow, M.C., (1977). Fossiliferous Lower Devonian boulders from the Cretaceous of South Australia. Q. geol. Notes, geol. Surv. S. Aust., 62:9-13.

Carr, S.G., Olliver, J.G, Conor, C.H.H. and Scott, D.C., 1978. Andamooka Opalfields. The Geology of the Precious Stones Field and the results of the Subsidised Mining Programme. S. Aust. Dept. Mines Report of Investigations 51.

Crettenden, P.P. and Barnes, L.C., 1978. Agate occurrence near Stuart Creek Opalfield. S. Aust. Dept. Mines report 78/154 (unpublished).

Daly, S.J. and Coats, R.P., 1971. CURDIMURKA map sheet, Geological Atlas of South Australia 1:250 000 series (Preliminary edition) Geol. Surv. S. Aust.

Dorman, F.H., and Gill, E.D., (1959). Oxygen isotope palaeo-temperature measurements of Australian fossils. Proc. Roy. Soc. Vict., 71:73-98.

Emery, K.O., 1955. Transportation of rocks by driftwood. Jo. Sed. Petrology. 25(1):51-57.

Folk, R.L., 1974. Petrology of Sedimentary Rocks. Hemphill Publishing Co., Austin, Texas, 182 pp.

Forbes, B.G., (1966). The geology of the Marree 1:250 000 map area. S. Aust. Dept. Mines. Report of Investigations 28, 47 pp.

Freytag, I.B., (1966). Proposed rock units for marine Lower Cretaceous sediments in the Oodnadatta region of the Great Artesian Basin. Q. geol. Notes, geol. Surv. S. Aust., 18:3-7.

Gostin, V.A., 1968. Stratigraphy and Sedimentology of the Lower Permian Sequence in the Dunnas-Ulladulla Area, Sydney Basin, New South Wales. Unpublished Ph.D. Thesis, Australian National University, Canberra.

Gostin, V.A. and Herbert, C., 1973. Stratigraphy of the Upper Carboniferous and Lower Permian Sequence, Southern Sydney Basin. J. Geol. Soc. Aust. 20:49-70.

Hannah, M.J. and Lindsay, J.M., 1977. Foraminiferal Biostratigraphy of the Andamooka Opalfields. S. Aust. Dept. Mines report 77/10 (unpublished).

Harland, W.B., Herod, K.N. and Krinsley, D.H., 1966. The Definition and Identification of Tills and Tillites. Earth-Sci. Rev., 2:225-256.

Harris, W.K. and Cooper, B.J., 1978. Micropalaeontology of selected samples from Stuart Creek Opalfields. ANDAMOOKA 1:250 000 map shett. S. Aust. Dept. Mines report 78/95 (unpublished).

Howchin, W., 1928. The Building of Australia, and the succession of life, Pt. II, British Science Guild; Govt. Printer, Adelaide.

Johns, R.K., 1966. ANDAMOOKA map sheet, Geological Atlas of South Australia 1:250 000 series. Geol. Surv. S. Aust.

Johns, R.K., 1968. Geology and Mineral Resources of the Andamooka-Torrens Area. Bull. geol. Surv. S. Aust., 41:103 pp.

Lange, R.T., 1978. Carpological Evidence for Fossil Eucalyptus and other Leptospermeae (Subfamily Leptospermoideae of Myrtaceae) from a Tertiary Deposit in the South Australian Arid Zone. Aust. J. Bot., 26:221-233.

Lindsay, J.M., 1975. Foraminiferal biostratigraphy of an Aptian Shale from Giddinna, MURLOOCOPPIE 1:250 000 sheet. Dept. Mines report 75/176 (unpublished).

Lisitsyn, A.P., 1958. Types of Marine Sediments connected with the Activity of Ice. Akad. Nauk SSSR Doklady, Earth Sci. Sect. (English Transl.). 118:373-377.

Lisitsyn, A.P., 1966. Recent Sedimentation in the Bering Sea. Israel Program for Scientific Translations, Jerusalem. 614 pp.

062

Ludbrook, N.H., 1966. Cretaceous Biostratigraphy of the Great Artesian Basin in South Australia. Bull. geol. Surv. S. Aust., 40:223 pp.

Murrell, B., (1977). Stratigraphy and Tectonics across the Torrens Hinge Zone between Marree and Andamooka, South Australia. Ph.D. thesis, University of Adelaide, (unpublished).

Olliver, J.G., Carr, S.G., Conor, C.H.H. and Scott, D.C., 1978. Andamooka Opalfields. A geological guide for the Opal Prospector. S. Aust. Dept. Mines report 78/86 (unpublished).

Ovenshine, A.T., 1970. Observations of Iceberg Rafting in Glacier Bay, Alaska, and the Identification of Ancient Ice-Rafted Deposits. Geol. Soc. America Bull., 81:891-894.

Parkin, L.W., (1956). Notes on the younger glacial remnants of northern South Australia. Trans. Roy. Soc. S. Aust., 79:148-151.

Parkin, L.W., ed., (1969). "Handbook of South Australian Geology". Geol. Surv. S. Aust., Adelaide, 268pp.

Vnuk, M.F., 1978. Aspects of the Geology of the Stuart Creek Area, North of Lake Torrens, South Australia. B.Sc. Hons. Thesis, University of Adelaide, (unpublished).

Woolnough, W.G. and David, T.W.E., 1926. Cretaceous glaciation in Central Australia. Quart. Journ. Geol. Soc. London 82:332.

Wopfner, H., Freytag, I.B. and Heath, G.R., 1970. Basal Jurassic-Cretaceous rocks of western Great Artesian Basin, South Australia. Stratigraphy and Environment. Bull. Am. Assoc. Petrol. Geol., 54(3):383-416.

Wopfner, H., Callen, R.A. and Harris, W.K., 1974. The Lower Tertiary Eyre Formation of the southwestern Great Artesian Basin. J. Geol. Soc., Aust., 21(1):17-51.

APPENDIX A

Geological logs of Backhoe Trenches

ELEVATION AT TOP OF BACKHOE TRENCH

Trench Number	R.L. (m)	Trench Number	R.L. (m)
4	87.642	45	74.194
4A	92.886	46	72.805
4B	90.192	47	86.666
4C	84.639	53	
5	90.807	53A	
6	78.035	55	92.358
10A1	80.769	57	
10A2	81.569	58A	97.023
10B	79.794	58B	96.143
11	77.910	59	
12		60	
12A		62	
13	78.405	62A	
14	87.003	63	
15	87.954	64A	87.735
16	83.313	64B	91.338
17	83.530	65A	89.252
17A	80.720	65B	91.676
17B	77.354	66	81.839
18	87.300	67	94.865
19	75.780	68	97.397
20	91.321	69	93.310
21	91.289	80	83.765
22A	99.118	82	86.192
22B	96.968	83	87.244 (top of cut)
22C	96.006	84	84.287 (top of cut)
22D	94.096	85	116.272
23	102.443	86	76.756
24	92.120	87	79.770
25	94.640		
26	107.078		
26A	103.928		
27	98.277		
28	66.124		
29	60.782		
29A	65.088		
30	84.017		
32	73.122		
33	69.567		
34	74.877		
34A	80.059		
34B	87.559		
35	76.273		
36	74.781		
37	89.886		
37A	87.518		
38	75.939		
39	89.192		
39A	88.072		
39B	96.623		
40	68.398		
41	68.495		
42A	74.555		
42A1			
42A2			
42B	77.695		
42C	78.745		

Notes: (1) Elevations relative to Australian Height Datum.

(2) Samples of trenches are prefixed by BHT number and depth (Samples held by Dept. of Mines and Energy).

BHT 4 E.L. 87.642 m Depth 1.5 m ?Marree Formation

The trench is located below outcropping silicified sand on the edge of an escarpment. It passes through 0.5 m of red colluvium with silcrete gibber, into 1.0 m of white powdery gypsum and kaolin, and crystalline gypsum with some sand size quartz grains. The kaolinised and gypsified ?mud is probably Marree Formation (Sample). The silicified sand capping (Mount Sarah Sandstone) is less than 2 m thick.

BHT 4A E.L. 92.886 m Depth 1.4 m Marree Formation

Bleached, stained and gypsified claystone with a sandy bed between 0.6 m and 1.2 m.

0.2 m of red colluvium overlie 0.4 m of indurated, porous, micaceous, mauve claystone. (The mauve colour, under a 20X lens is made up of white background with red/brown patches). Between 0.6 m and 1.2 m, a grey (with minor yellow and pink) claystone has a high proportion of coarse, pink to clear, sub-angular quartz grains. It is underlain to 1.4 m by a grey claystone. Much gypsum is present below 0.6 m, and the grey colour is also due to a combination of two colours - white with red/brown patches (probably hematite). (Samples: 0.4 m, 1.1 m, 1.3 m).

BHT 4B E.L. 90.192 m Depth 1.0 m Marree Formation

Too hard! gypsum in red colluvium.

Float on the surface is a very porous, indurated, sandy, micaceous, white claystone. It is probably derived from a ripped rabbit warren. The float indicates probable Marree Formation at shallow depth. (Sample).

BHT 4C E.L. 84.639 m Depth 2.2 m ?Marree Formation

1.9 m of red colluvium with angular and rounded cobbles overlie gypsum impregnated, soft, pale grey mud. The mud is probably Marree Formation. (Sample).

BHT 5 E.L. 90.807 m Depth 2.7 m ?Quaternary

2.0 m of red colluvium overlie 0.7 m of white siltstone, which is patchily silicified and contains small (less than 0.5 mm) patches of brown clay. (Sample). The siltstone is probably Quaternary in age (similar to that of BHT 17).

BHT 6 E.L. 78.035 m Depth 2.0 m Marree Formation

0.5 m of red colluvium overlie crystalline gypsum impregnated, pale grey, soft, micaceous silty mud, with occasional sub-rounded quartzite pebbles distributed randomly throughout, and small (1.0 mm) iron stained black patches (sample). The silty mud is very similar to those exposed in the bulldozer cut on the north side of Charlie Swamp (BHT 84).

BHT 10A1 E.L. 80.769 m Depth 0.4 m

Too hard! Red and green gypsum.

BHT 10A2 E.L. 81.569 m Depth 1.6 m

1.3 m of red alluvium overlie medium to coarse quartz sand with a high proportion of red and green banded clay matrix. The banding is roughly horizontal. The quartz grains are sub-rounded to well rounded. The clay is impregnated with gypsum crystals. Powdery white calcium carbonate is present patchily throughout the rock. (Sample).

It may be Adelaidean (ABC Range Quartzite or Bunyeroo Formation) or Marree Formation.

BHT 10B E.L. 79.794 m Depth 1.7 m

1 m of red alluvium overlies rocks as for BHT 10A2.

BHT 11 E.L. 77.910 m Depth 1.5 m Marree Formation

0.2 m of red colluvium overlie brown/grey, soft, micaceous silty mud with some sand grains. Patches of brown clay in white silt gives a mottled effect approaching the "biomottling" of typical Marree Formation mud. Yellow alunite veining is present. Pebbles form a thin line at 0.5 m and a line of pebbles and cobbles is present at 1.0 m, within the silty mud. The clasts are mostly laminated, micaceous siltstone, but some quartzite is present and all clasts are rounded. (Sample).

BHT 12 Depth 0.7 m Recent dune sands

Too hard! Coarse, sub-angular quartz sand with a red clay matrix; slightly gypsified. (Sample).

BHT 12A Depth 1.4 m Recent dune sands

Too hard: strongly gypsified, coarse, sub-angular quartz sand. (Sample).

BHT 13 E.L. 78.405 m Depth 1.0 m Brachina Formation

Green and purple, finely laminated siltstone (Sample).

BHT 14 E.L. 87.003 m Depth 1.0 m Adelaidean

0.4 m of red colluvium overlie 0.6 m of yellow, micaceous, laminated siltstone (Sample). Bedding is roughly horizontal. This is Adelaidean sediment - probably Amberoona Formation.

BHT 15 E.L. 87.954 m Depth 1.5 m Adelaidean

1.0 m of red soil and white gypsum powder have developed on white to yellow, micaceous siltstone (sample). No bedding is visible. Thin (approximately 2 mm) brown bands within the siltstone vary from horizontal to vertical and are probably a weathering effect. Ironstone fragments litter the ground surface. This is Adelaidean sediment - probably Amberoona Formation.

BHT 16 E.L. 83.313 m Depth 1.0 m Adelaidean

0.4 m of red colluvium overlie 0.6 m of green to yellow, laminated, micaceous, argillaceous sandstone, containing a thin (approximately 5 mm) band of sandy, black ironstone (Sample). Bedding dips approximately 20^{o} to the east. This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 17</u> E.L. 83.530 m Depth 1.3 m <u>Quaternary</u>

0.5 m of white gypsum powder has developed on 0.2 m of white silt to very fine sand with no matrix except for patchily developed gypsum (sample at 0.6 m).

Between 0.7 m and 1.3 m is a pale green clay with some red staining (sample at 1.0 m). Very small white crystals (possibly halite) occupy tubules (probably recent root tubules). Angular and rough pebbles to cobbles of grey silicified fine sand, (with some medium to coarse grains), and grey/brown quartzite are present in the mud, in abundance.

Conclusion: Quaternary wind blown silts overlying a regolith. (Silts correlated with those at BHT 5, 23, 26).

<u>BHT 17A</u> E.L. 80.720 m Depth 3.2 m <u>Marree Formation</u>

The trench passes through 3.2 m of moist, soft, medium brown, "biomottled" mud, with a cluster of pebbles (possibly a thin line) at 1.5 m, containing rounded quartzite and micaceous green siltstone. Yellow alunite and gypsum veins are present.

Samples from 0.6 m and 3.1 m, are identical. The "biomottling" in the medium brown mud is due to varying shades of colour in the mud and little silt is visible. Some medium sized sand grains of quartz are present along with rare white and black mica flakes. The mud shows a very weak fissility parallel to bedding.

Very fine white sandy patches, up to 2 mm in size, are present and may represent unidentifiable arenaceous foraminifera.

<u>BHT 17B</u> E.L. 77.354 m Depth 3.2 m <u>Marree Formation</u>

1.4 m of red colluvium overlie a uniform sequence of "biomottled" silty grey-brown mud with 'erratic' siltstone pebbles and cobbles. The "biomottling" is very distinct with dark brown mud lenticles in a grey silty matrix (sample). Yellow alunite and gypsum veins are present. Poorly preserved foraminifera may be present.

<u>BHT 18</u> E.L. 87.300 m Depth 1.1 m <u>Adelaidean</u>

0.4 m of red colluvium overlie crystalline gypsum developed in white to yellow/brown, micaceous siltstone (sample). At 0.6 m a 'pod' of brown ironstone with some flat laminae of fine sand grains appears to be dipping to the west. This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 19</u> E.L. 75.780 m Depth 1.4 m <u>Adelaidean</u>

0.8 m of red colluvium overlie 0.6 m of yellow/brown, laminated, micaceous siltstone and white, very fine sandstone (sample). This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 20</u> E.L. 91.321 m Depth 1.5 m <u>Adelaidean</u>

1.0 m of red colluvium and white gypsum powder overlies weakly fissile, yellow/green, silty clay and fine white argillaceous sand (sample). Bedding dips 340/20°W. Ironstones litter the ground surface. This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 21</u> E.L. 91.289 m Depth 1.5 m <u>Adelaidean</u>

1.5 m of red and brown micaceous, laminated and fissile siltstone, dips 340/20°W (sample). This is Adelaidean sediment - probably Amberoona Formation but possibly Bunyeroo Formation? (refer BHT 25A).

<u>BHT 22A</u> E.L. 99.118 m Depth 1.5 m <u>Mount Sarah Sandstone</u>

0.4 m of massive black ferruginised and silicified, poorly sorted, fine to very coarse sandstone overlie loosely cemented, yellow/white, argillaceous medium sandstone (sample).

<u>BHT 22B</u> E.L. 96.968 m Depth 1.1 m <u>Mount Sarah Sandstone</u>

0.5 m of white gypsum powder overlie 0.6 m of white/yellow, poorly sorted, coarse, argillaceous sandstone. The grains are all quartz (except for rare red lithic grains) and are well rounded (sample).

BHT 22C E.L. 96.006 m Depth 1.4 m Mount Sarah Sandstone

- as for BHT 22B (sample).

BHT 22D E.L. 94.096 m Depth 0.7 m Mount Sarah Sandstone

- as for BHT 22B, C (sample).

BHT 23 E.L. 102.443 m Depth 1.7 m Quaternary

0.4 m of red colluvium overlie white siltstone to very fine sandstone (sample). This is probably Quaternary in age (similar to that of BHT 17).

BHT 24 E.L. 92.120 m Depth 3 m Adelaidean

Approximately 3 m of section was examined (and sampled) on the edge of an escarpment that was scraped clean with the backhoe. The E.L. of 92.120 m was recorded about 0.3 m above the base of the section.

White gypsum powder has developed over about 2 m of silt and sand (very fine to medium grain size) beds. The colour of the silt and sand varies from top to bottom: white, yellow, pale mauve, pink/white. The silt and sand is penetrated by numerous thin, clear gypsum veins. The lowest part of the section comprises moist, brown/grey, argillaceous siltstone. A thin (approx. 3 mm) band of ironstone is present on top of the argillaceous siltstone. Bedding is horizontal.

This section may be Tertiary or Cretaceous, but is probably Adelaidean (?Amberoona Formation). The lithology is similar to that in BHT55 and near horizontal bedding is present in nearby Adelaidean sediments in BHT58A, BHT58B, and BHT55. It is unlikely to be Tertiary or Cretaceous, since nearby Tertiary sediments are coarse grained (BHT 22), and none of the typical features of the Marree Formation are present.

<u>BHT 25</u> E.L. 94.640 m Depth 1.2 m <u>Adelaidean</u>

1.2 m of yellow and grey, laminated and fissile, micaceous siltstone with thin (4 mm) laminae of strongly cemented, ferruginised brown, coarse quartz sand dips 315/25^{o}SW (sample). This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 25A</u> E.L. 94.075 m Depth 1.5 m <u>Adelaidean</u>

1.5 m of well laminated, fissile, pink (some white) very micaceous siltstone (sample). This is Adelaidean sediment; possibly Bunyeroo Formation, but more probably Amberoona Formation (Refer BHT 21).

<u>BHT 26</u> E.L. 107.078 m Depth 0.5 m <u>?Quaternary</u>

Too hard: gypsum has developed in a green/white siltstone. (sample). The siltstone is probably Quaternary in age (similar to that in BHT 17).

<u>BHT 26A</u> E.L. 103.928 m Depth 1.8 m <u>Mount Sarah Sandstone</u>

0.5 m of red colluvium overlie 0.5 m of white gypsum powder developed on 0.8 m of grey, fine to medium argillaceous quartz sandstone (sample).

<u>BHT 27</u> E.L. 98.277 Depth 2.5 m <u>Mount Sarah Sandstone /Marree Formation</u>

Refer Fig. A1 and Fig. 7.

BHT 27 is located in a claypan, part of the surface of which is strewn with rounded quartzite cobbles and boulders.

0.4 m of red-brown alluvium overlie 0.38 m of friable yellow and red, very coarse, poorly sorted quartz sand. The quartz grain population is bimodal, including both angular and rounded grains.

Between 0.78 m and 1.00 m is a yellow-brown sand. At the base, it is micaceous, very coarse, poorly sorted and pebbly. The very coarse sand fines gradationally upward to very fine sand. Coarse angular quartz grains are scattered through the very fine sand. All grains consist of quartz and are again

BHT 27 E.L. 98·277m Depth 2·5m.

MT. SARAH SANDSTONE OVER MARREE FORMATION.

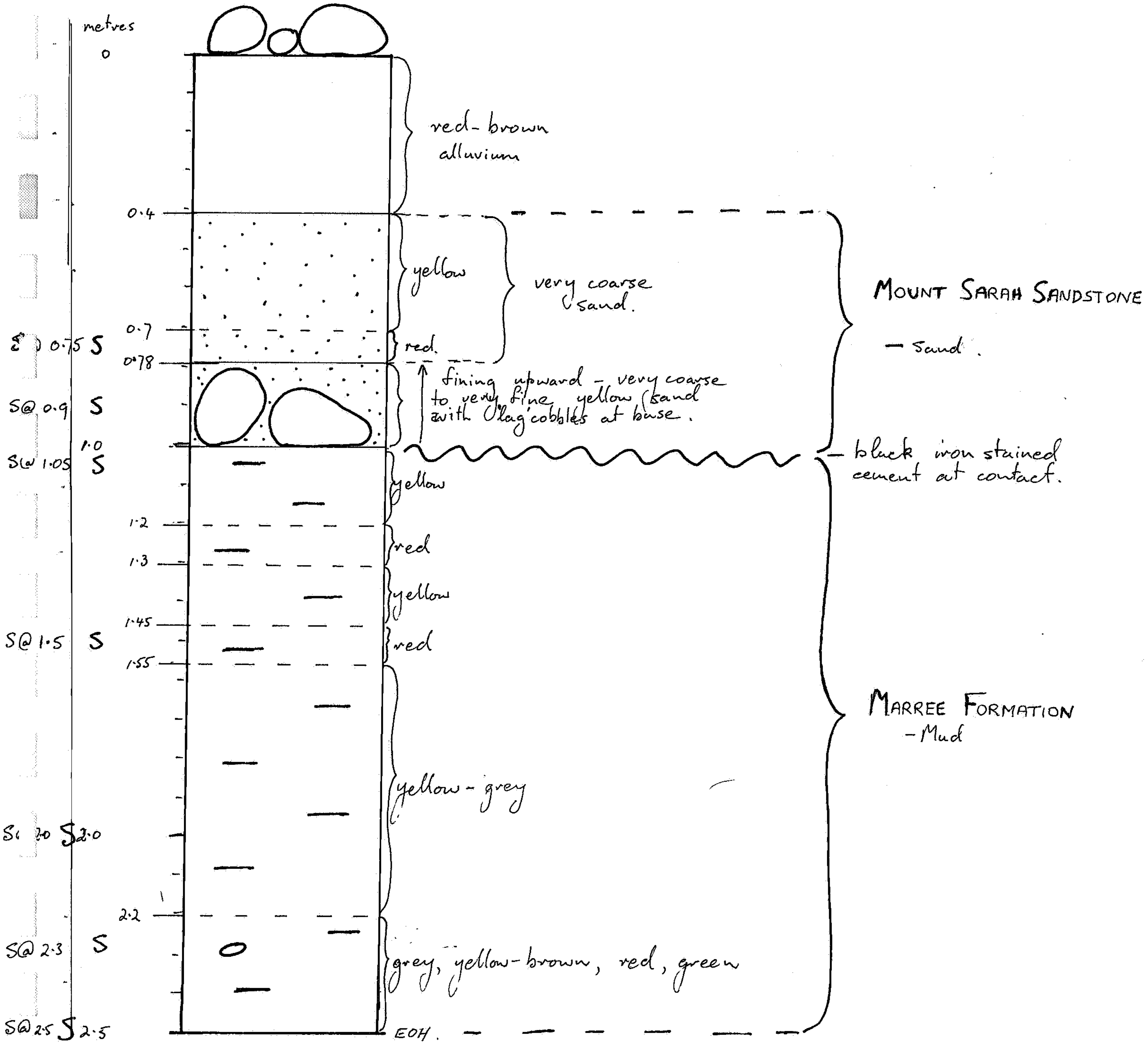


Fig. A1 S = sample.

bimodal, containing both angular and rounded grains. There is very little matrix or cement. Large rounded quartzite cobbles, representing a lag deposit, are present at the base of the sand bed. The sand between 0.4 m and 1.0 m is part of the Tertiary Mount Sarah Sandstone.

The contact between the Tertiary and underlying rock is virtually flat and horizontal, and is marked by a thin (approximately 2 mm) black ferruginous band.

Between 1.0 m and 2.5 m, mud of various colouration occurs, containing much gypsum between 1.0 m and 1.55 m as crystalline roses. The mud is sandy and micaceous, and displays distinct "biomottling". The "biomottling" is a result of a colour difference only, in the mud; dark brown lenticles occurring roughly parallel to bedding in a paler brown background. Viewed perpendicular to bedding, the "biomottling" appears as rounded and irregular patches in a pale background. White to yellow silty, sandy (up to very coarse sand size) patches occur, generally lying flat in the plane of bedding. Red and black staining occurs on some fracture surfaces and red 'spots' (iron staining) occur throughout the mud. Yellow powder (alunite?) is present in small (5 mm) patches. Very fine, white crystalline calcium carbonate is present in the sandy patches near the top of the mud. Small (1 mm) white patches in the mud may be formainifera. A rounded pebble (3 cm long) of white, micaceous siltstone is present as an 'erratic' in the mud at 2.3 m. The muds between 1.0 m and 2.5 m represent the Marree Formation. The colour banding is due to a late stage staining effect (possibly related to the gypsification?).

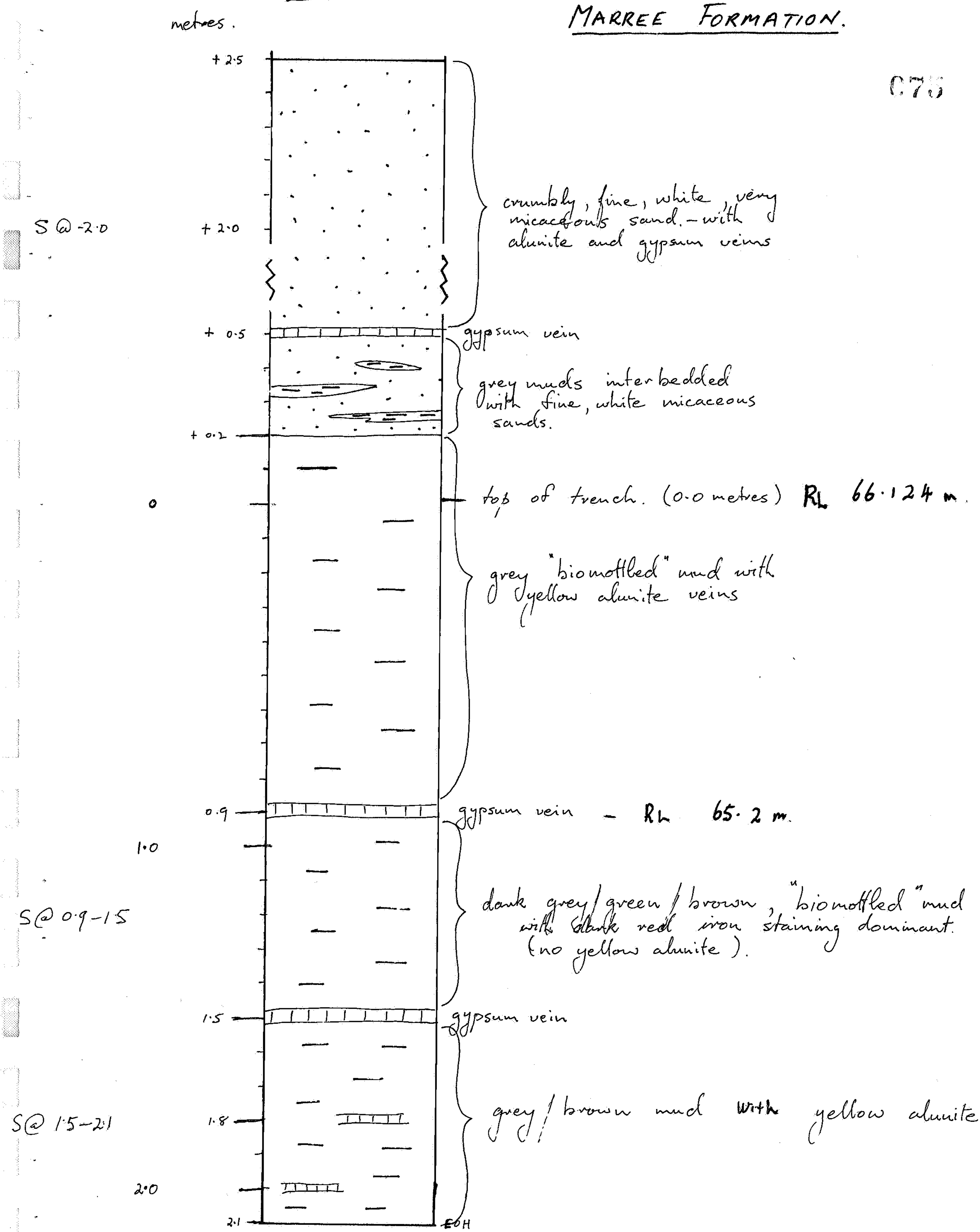
<u>BHT 28</u> E.L. 66.124 m Depth 2.1 m <u>Marree Formation</u>

Refer Fig. A2.

BHT 28.

E.L. 66·124m Depth 2·1m

MARREE FORMATION.



The mud is micaceous, with rare coarse sand grains.

Fig. A2

BHT 29 E.L. 60.782 m Depth 0.5 m "Stuart Creek Beds"

Fine, micaceous, yellow to brown sandstone (sample).

The adjacent escarpment (to about 4 m above the level of BHT 29), comprises fine white to yellow sandstone, (Fig. 5), with some yellow alunite matrix. The sandstone contains many small cavities, from which wood fragments may have been weathered.

BHT 29A E.L. 65.088 m Depth 2.0 m Marree Formation

2.0 m of soft, moist, grey to brown mud, with yellow alunite veins and gypsum veins. The mud contains foraminifera, (Haplophragmoides audax), and some black carbonaceous fragments (Sample).

BHT 30 E.L. 84.017 m Depth 1.4 m Marree Formation

0.4 m of gypsum powder overlie pale brown to grey, argillaceous fine to medium sand and silt with dark brown mud lenticles. Burrow structures, infilled with sand, and yellow alunite veins are present.

BHT 32 E.L. 73.122 m Depth 1.5 m Marree Formation

0.8 m of gypsum powder overlie a thin pebble to boulder bed. The clasts are mostly rounded quartzite. Beneath the conglomerate bed is crumbly dark brown to black mud with silt lenticles. Gypsum and alunite veins are present.

BHT 33 E.L. 69.567 m Depth 2.6 m Marree Formation/ "Stuart Creek Beds"

Refer Fig. A3.

0.2 m of red colluvium overlie 2.3 m of mud and conglomerate beds of the Marree Formation. The basal conglomerate bed of the Marree Formation rests on fine sand of the "Stuart Creek Beds" at 2.5 m.

The "Stuart Creek Beds" consist of white, micaceous, fine angular quartz sand. Some green grains (probably glauconite), and some black grains (possibly 'heavy minerals') are present.

BHT 33. 2·6m RL. 69.567

MARREE FORMATION OVER "STUART CREEK BEDS." C77

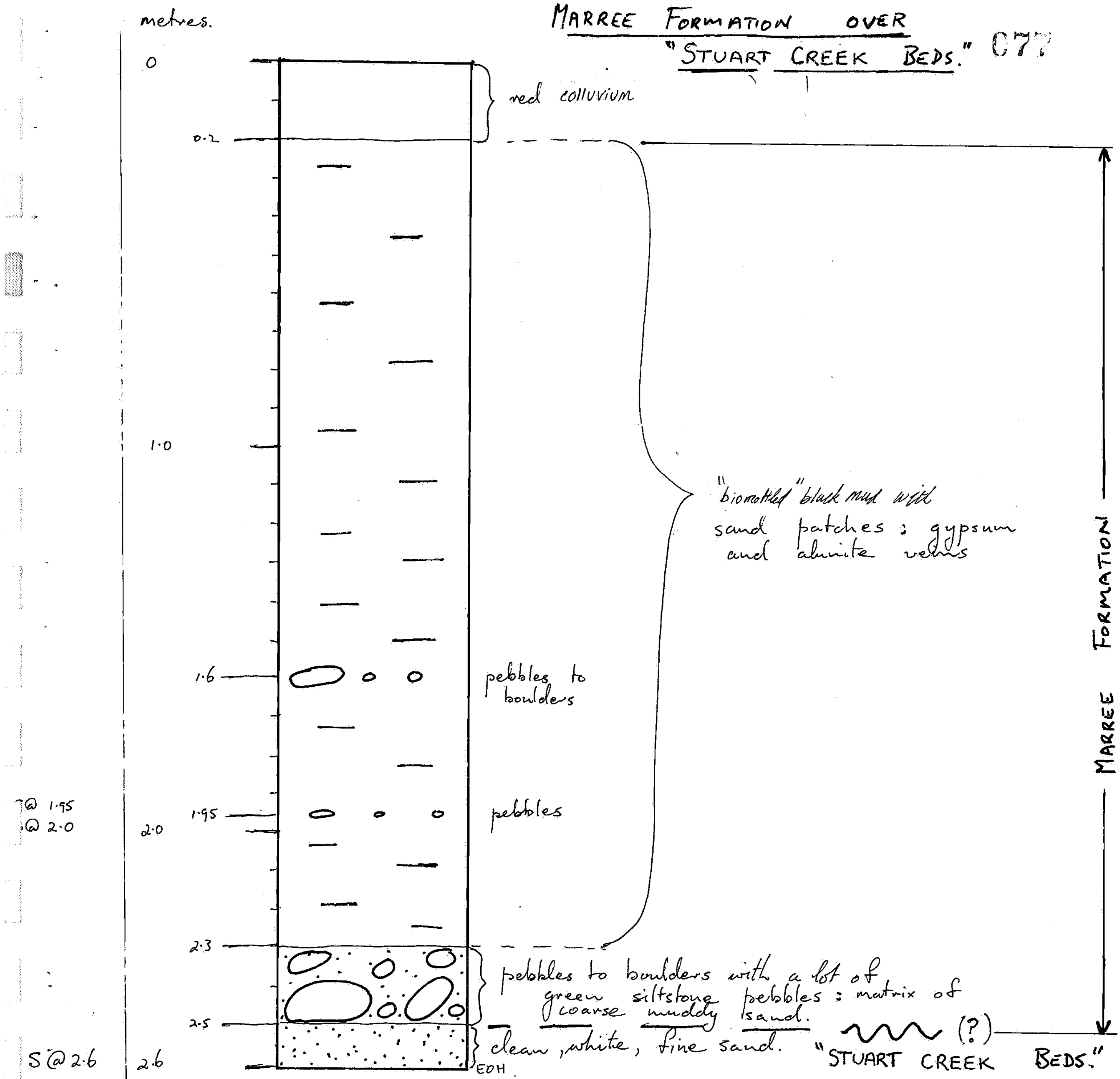


Fig. A3

Matrix is generally absent; however, yellow alunite is present as a patchy matrix and gypsum also, forming 'lustre mottling'.

Some small patches of brown clay are present. They occur as either single, rounded, elongate brown clay pellets (about 0.7 mm x 0.4 mm), or as groups of pellets infilling burrows. These are faecal pellets of sediment sifting organisms.

Tubular structures (greater than 50 mm long and 2 mm wide), are present. These are organic burrows, now infilled with sandy mud.

Cavities in the sand, probably result from organic debris (woody fragments), being removed by solution.

The contact of the "Stuart Creek Beds" and the basal conglomerate of the Marree Formation is abrupt, but no distinct break can be seen. There is an increase in overall sand grain size, an increase in muddy matrix content, and of course the occurrence of granule to boulder sized clasts.

The Marree Formation comprises micaceous, "biomottled", soft, moist black mud, with small lenses, irregular patches and layers parallel to bedding, of fine sand. Minor yellow alunite is present, and very fine, discrete green grains are probably glauconite.

Carbonaceous fragments and foraminifera are present. Haplophragmoides audax abounds but only one specimen of Textularia was identified: both forms are arenaceous (and white in colour).

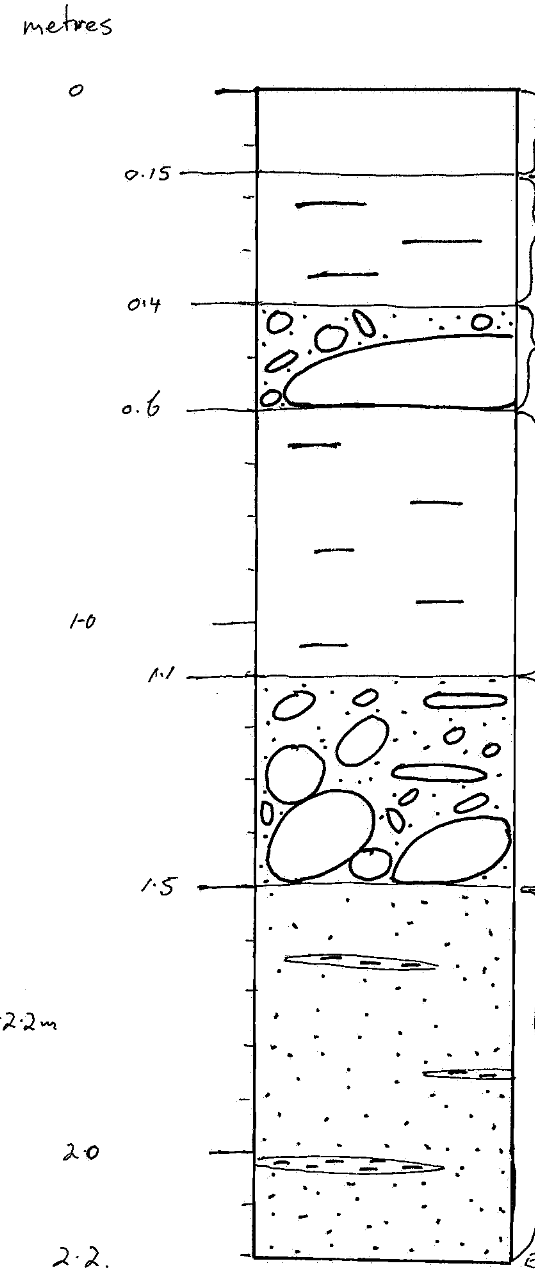
Conglomerate beds are present at 1.6 m and 1.95 m, with a basal conglomerate bed between 2.3 m and 2.5 m. Clasts range in size up to boulders and vary from angular to rounded in shape. Most are quartzites, but many sandstones, siltstones and shales are present.

<u>BHT 34</u> E.L. 74.877 m Depth 2.2 m <u>Marree Formation/ "Stuart Creek Beds"</u>

Refer Fig. A4.

BHT 34. 2·2m. EL. 74·877m Depth 2·2m

MARREE FORMATION OVER "STUART CREEK BEDS"



0 – 0.15: white gypsum powder.

0.15 – 0.4: grey mud with alunite

0.4 – 0.6: Sandy Conglomerate bed (largest clast was a rounded quartzite boulder – 1.2×0.8×0.2 m – lying horizontally)

0.6 – 1.1: grey mud with alunite.

1.1 – 1.5: coarse sand with close packed pebbles to boulders.

1.5: (?)

1.5 – 2.2: pale, brown, clean, fine, micaceous quartz sand, containing scattered coarse rounded quartz grains and thin lenses and patches of dark brown sandy mud full of cavities after woody fragments (?)

0.15 – 1.5: MARREE FORMATION

1.5 – 2.2: "STUART CREEK BEDS"

Conglomerate beds contained many cobbles and boulders of mainly quartzite, but with some laminated, micaceous siltstone.

Fig. A4

BHT 34A E.L. 80.059 m Depth 1.0 m Wonoka Formation

The trench is sited among patches of ironstone fragments. It passes through 1.0 m of laminated green mud, containing black gypsum cemented iron rich pods.

BHT 34B E.L. 87.559 m Depth 1.5 m Marree Formation

The trench is sited on a low rise, and passes through 1.5 m of "biomottled" grey mud.

BHT 35 E.L. 76.273 m Depth 2.0 m Wonoka Formation

Green, brown and mauve, non-calcareous laminated siltstones, dipping approximately 315/15-20°NE.

BHT 36 E.L. 74.781 m Depth 2.0 m Marree Formation

Nearly 2 m of alluvium overlie dry, grey "biomottled" mud.

BHT 37 E.L. 89.886 m Depth 1.2 m Marree Formation

1.2 m of dark brown mud with yellow alunite veins contains rounded cobbles and pebbles of quartzite, micaceous shale, and mud 'erratics'.

BHT 37A E.L. 87.518 m Depth 2.7 m Marree Formation

- Similar to BHT 37.

BHT 38 E.L. 75.939 m Depth 1.0 m Bunyeroo Formation

The trench is sited among patches of ironstone fragments littering the ground surface and penetrates 1.0 m of red-brown and green banded, finely laminated clay with gypsum veins and minor patches of powdery white calcium carbonate. The clay is non-calcareous.

BHT 39 E.L. 89.192 m Depth 1.2 m Bunyeroo Formation

Refer Fig. 4.

The trench starts in indurated, white mudstone and after 20 cm, passes into soft, moist, finely laminated, pink mud, dipping 315°/10°NE. The contact between the bleached, indurated white mudstone and the soft, moist pink muds represents the 'kopi'-mud contact most often seen in the Marree Formation.

BHT 39A E.L. 88.072 m Depth 1.6 m Bunyeroo Formation

1.6 m of soft, moist, finely flat laminated, pink, micaceous silty mud dips approximately $315/10^{\circ}$NE. At about 1 m, amber coloured common opal occurs in vertical and horizontal veins up to 7 mm thick (Fig. 20) (sample). The common opal is opal-CT (M. Vnuk using XRD, 1978), very badly cracked and opaque.

BHT 39B E.L. 96.623 m Depth 2.7 m Marree Formation

2.7 m of indurated, mauve, distinctly "biomottled" sandy mudstone containing 'erratic' pebbles of laminated siltstone.

BHT 40 E.L. 68.398 m Depth 1.0 m Wonoka Formation

0.4 m of red alluvium overlie 0.6 m of brown and green, calcareous, micaceous, laminated siltstone dipping $350/20^{\circ}$NE.

BHT 41 E.L. 68.495 m Depth 1.5 m Recent alluvium

The trench penetrates red alluvium and bottoms on gypsum cemented sand, containing angular pebbles and cobbles of varying lithology, including silcrete.

BHT 42A E.L. 74.555 m Depth 2.1 m "Stuart Creek Beds"

0.5 m of red alluvium overlie clean, fine, white and yellow sand. The sand is slightly micaceous, and the quartz grains are angular. A patchy matrix of yellow alunite gives the yellow colour to the sand and gypsum is present as a patchy cement. The sand is partly free flowing. The cementation occurs in layers, having a dip of approximately $000/25^{\circ}$W.

BHT 42A1 Depth 2.4 m Marree Formation/ "Stuart Creek Beds"

Refer Fig. A5.

BHT 42A2 Depth 2.4 m Marree Formation/ "Stuart Creek Beds"

Refer Fig. A6.

BHT 42B E.L. 77.695 m Depth 2.4 m Marree Formation

Refer Fig. A7.

BHT 42 A1 E.L. (approx. 75·6m) Depth 2·4m

MARREE FORMATION OVER "STUART CREEK BEDS."

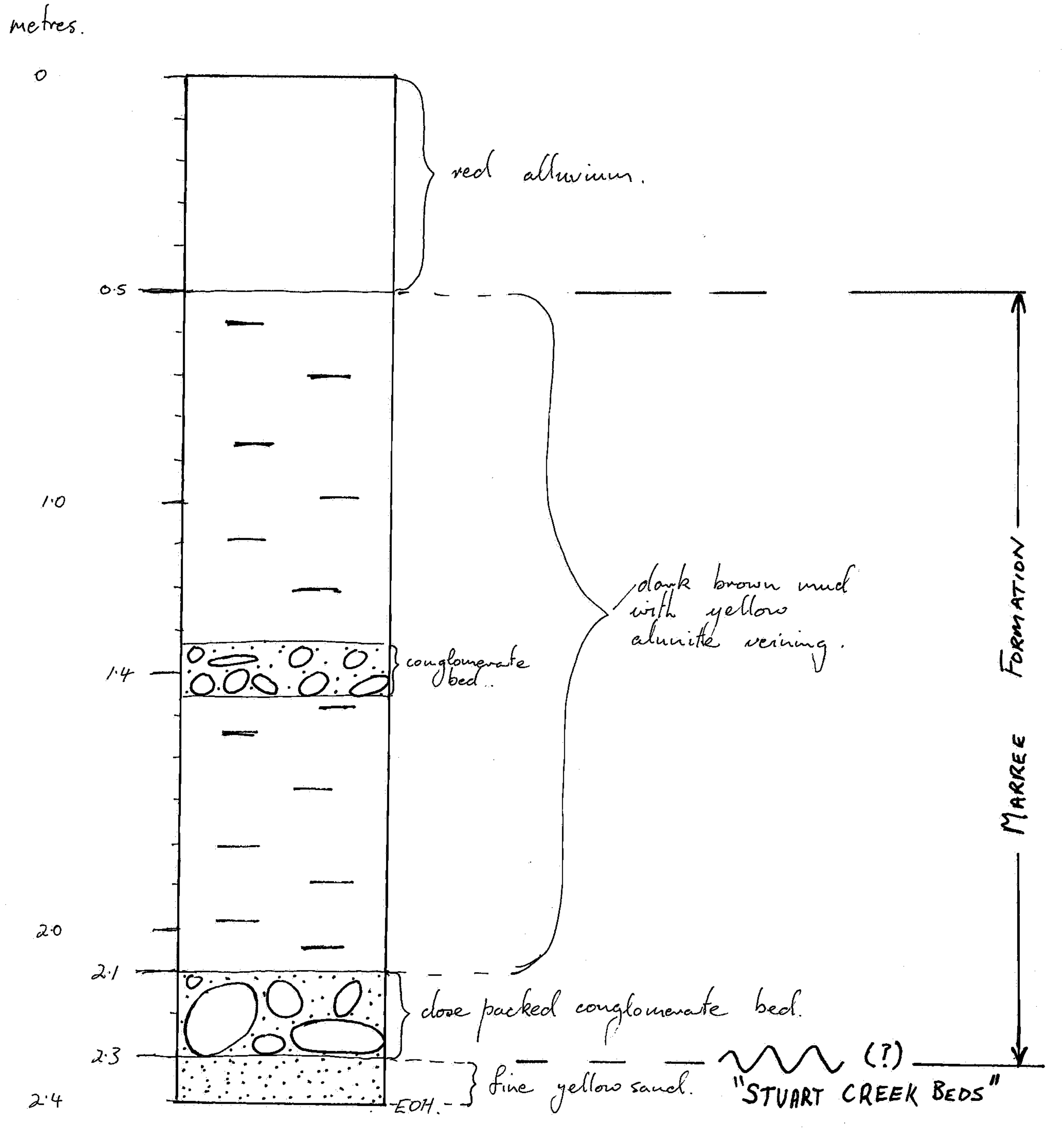


Fig A5.

BHT 42 A_2 EL (approx 75·1m) Depth 2·4m.

MARREE FORMATION OVER "STUART CREEK BEDS."

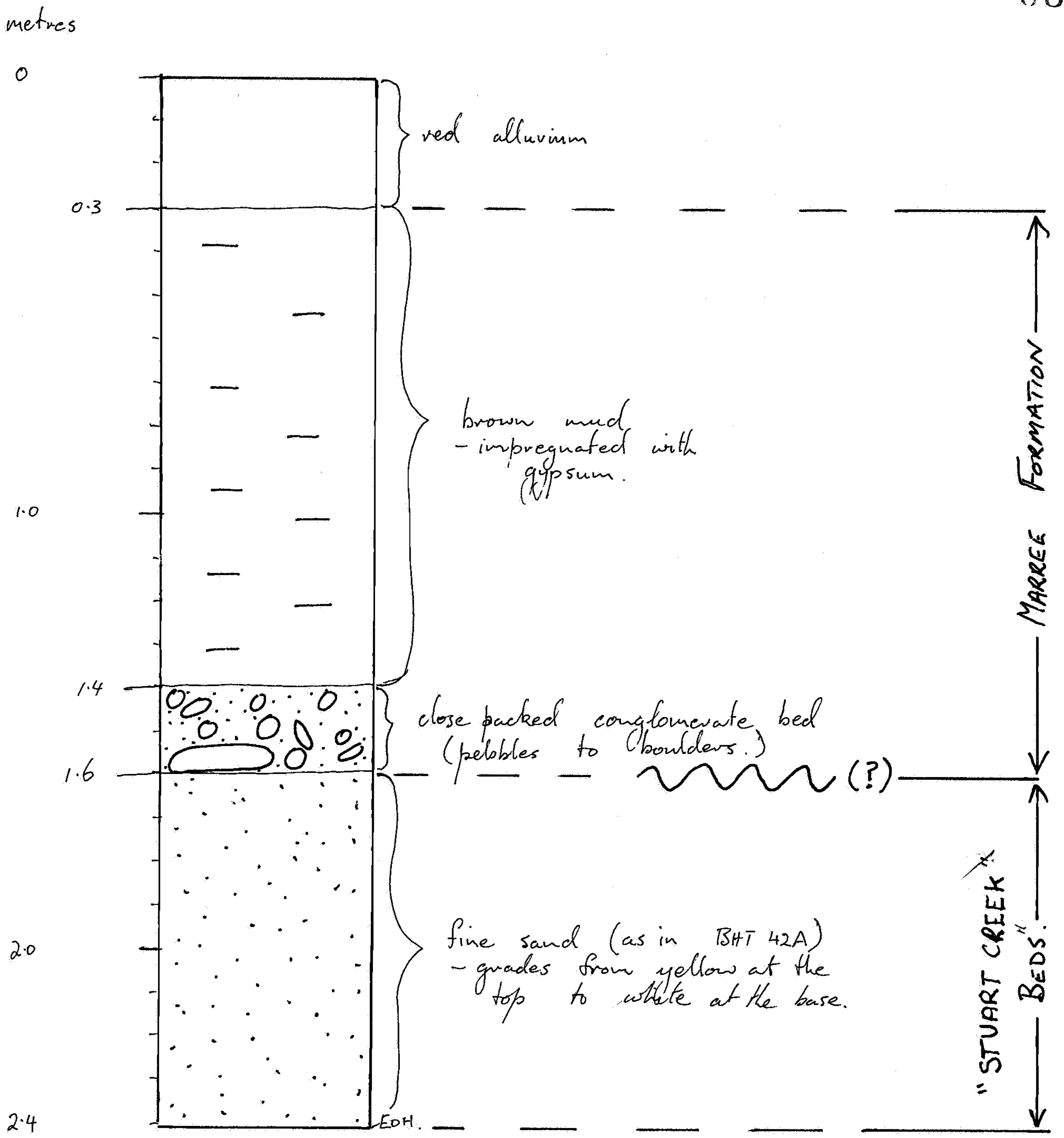


Fig A6

BHT 42 B. EL 77·695m. Depth 2·4m.

MARREE FORMATION.

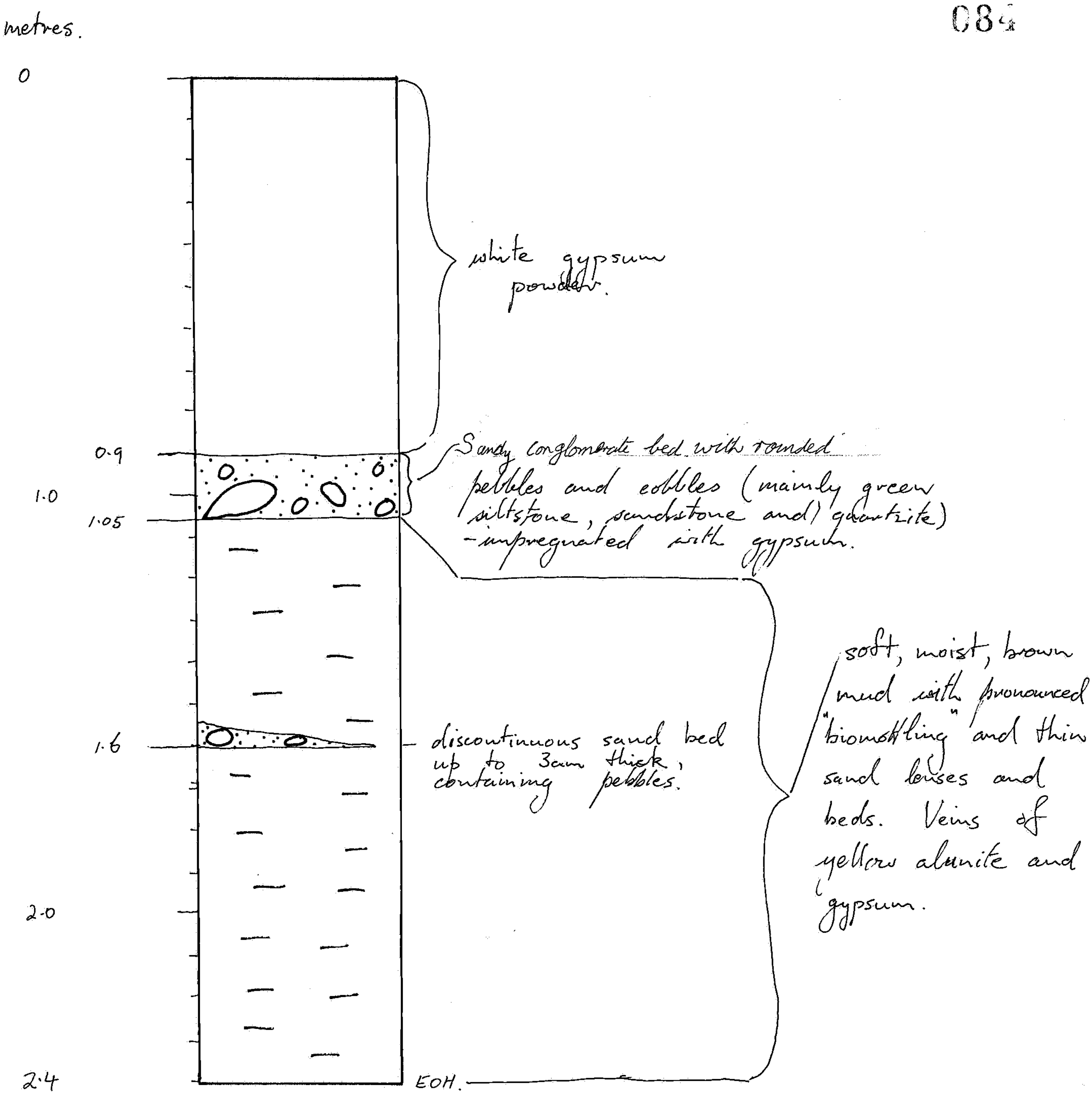


Fig. A7

BHT 42C E.L. 78.745 m Depth 2.8 m Marree Formation

Refer Fig. A8.

0.5 m of red alluvium and white gypsum powder overlie muddy silt and mud of the Marree Formation. "Biomottling" is very pronounced, with both silt lenticles in mud and mud lenticles in silt. Yellow alunite and gypsum veining is common.

'Erratic' cobbles and pebbles, and thin pebble 'lines', occur within the silt and mud. The sandy bed between 1.8 m and 2.0 m is packed with pebbles, mainly of siltstone with some of quartzite, and contains a quartzite boulder measuring 70 cm x 25 cm x 7 cm.

BHT 45 E.L. 74.194 m Depth 1.2 m Bunyeroo Formation

1.2 m of red and green colour banded, laminated and fissile clay dips slightly toward the northeast.

BHT 46 E.L. 72.805 m Depth 1.4 m Bunyeroo Formation

0.6 m of red colluvium overlie soft, moist, dark brown-red, laminated and fissile mud. It is strongly weathered, and contains gypsum veins and patches of powdery white calcium carbonate.

BHT 47 E.L. 86.666 Depth 2.3 m Marree Formation

2.0 m of white gypsum powder developed in grey to brown "biomottled" mud. An 'erratic' pebble of micaceous, laminated, and cross-bedded, fine sandstone is present along with alunite and gypsum veins.

BHT 53 Depth 1.4 m Adelaidean

0.4 m of red colluvium overlie 1.0 m of green, laminated micaceous, siltstone and very fine sandstone with some patches of angular, medium sized sand grains (sample). This is Adelaidean sediment - probably Amberoona Formation.

BHT 53A Depth 1.8 m Adelaidean

0.4 m of red soil overlie 1.4 m of laminated, green, micaceous, siltstone and very fine sandstone (as for BHT 53).

BHT 42C. E.L. 78·745m Depth 2·8m

MARREE FORMATION.

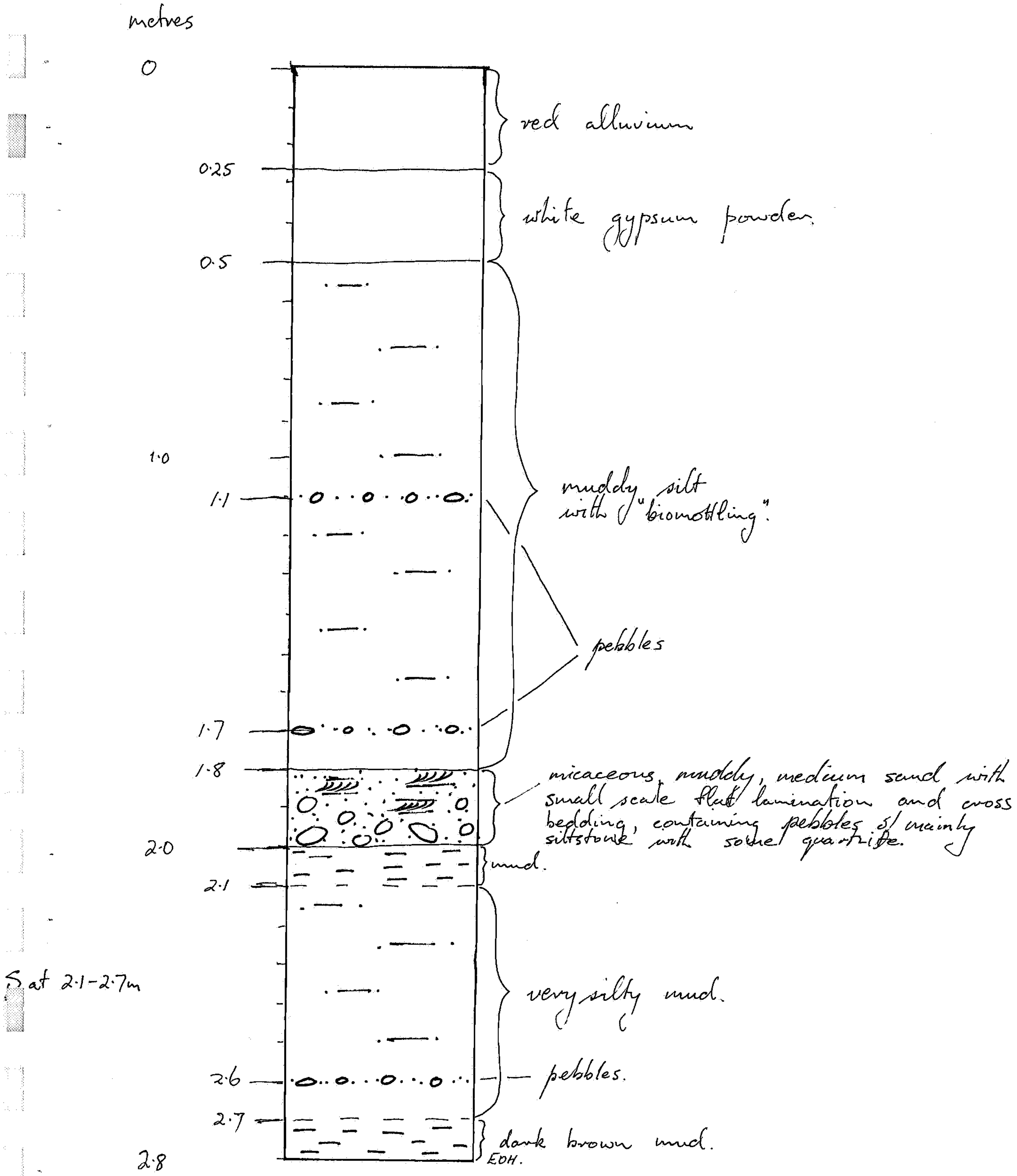


Fig. A8.

Bands of brown ironstone within the siltstone and sandstone dip $300/30^{o}$NE (sample). This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 55</u> E.L. 92.358 m Depth 1.3 m <u>Adelaidean</u>

1.3 m of yellow and grey banded, soft, moist slightly micaceous muddy siltstone dips about $000/2^{o}$W (Sample). This is Adelaidean sediment - probably Amberoona Formation.

<u>BHT 57</u> Depth 0.7 m <u>Quaternary</u>

Too hard: grey patchily but strongly silicified, poorly sorted, very fine sand. Where it is not silicified, it is gypsified (sample). This may be a Tertiary sand, but is probably of Quaternary age (Similar to siltstone in BHT 17).

<u>BHT 58A</u> E.L. 97.023 m Depth 1.7 m <u>Adelaidean</u>

0.4 m of red colluvium overlie powdery white gypsum, impregnated pale green mud (sample).

At 1.5 m, there is a 2 cm thick continuous quartzite band (sample) around the hole lying virtually horizontally (perhaps $000/2^{o}$W). Below the quartzite band is a laminated, weakly fissile green clay (sample). This is Adelaidean sediment (possibly Brachina Formation or ABC Range Quartzite).

<u>BHT 58B</u> E.L. 96.143 m Depth 1.2 m <u>Adelaidean</u>

1.0 m of red colluvium and white gypsum (powder and crystal) overlies 0.2 m of green-grey, micaceous laminated siltstone. (Sample). This is Adelaidean sediment, (possibly Brachina Formation or ABC Range Quartzite).

<u>BHT 59</u> Depth 1.8 m <u>Adelaidean</u>

0.4 m of red alluvium overlie laminated and fissile, very micaceous, green (with some grey) siltstone, dipping approximately $300/5^{o}$SW. (Sample). This is Adelaidean sediment - probably Amberoona Formation.

BHT 60 Depth 1.7 m Adelaidean

1.0 m of red alluvium overlies 0.7 m of laminated, yellow-green, micaceous siltstone (sample). It contains a thin (5 mm) band of ironstone and dips 330/20°SW. This is Adelaidean sediment - probably Amberoona Formation.

BHT 62 Depth 1.2 m Quaternary alluvium

Red mud overlies muddy, medium grain size sand, cemented with gypsum.

BHT 62A Depth 1.4 m Quaternary alluvium

- As for BHT 62 (sample).

BHT 63 Depth 1.6 m Adelaidean

0.4 m of red alluvium overlie laminated and weakly fissile, very micaceous, mauve siltstone, dipping 320/10°SW. (sample). This is Adelaidean sediment - probably Amberoona Formation.

BHT 64A E.L. 87.735 m Depth 2.4 m Mount Sarah Sandstone

1.2 m of red colluvium overlie 1.2 m of free flowing, yellow, poorly rounded, medium grain size quartz sand (sample).

BHT 64B E.L. 91.338 m Depth 1.4 m Mount Sarah Sandstone

0.8 m of red colluvium overlie 0.6 m of indurated, grey, poorly rounded, medium grain size, quartz sand. The matrix is white and calcareous (sample).

BHT 65A E.L. 89.252 m Depth 2.7 m Mount Sarah Sandstone

1 m of red soil overlies 1.7 m of free flowing yellow to white, poorly rounded, medium grain size quartz sand (sample).

BHT 65B E.L. 91.676 m Depth 1.4 m Mount Sarah Sandstone

0.4 m of soil overlie 1.0 m of friable, pale yellow/brown, poorly rounded, medium grain size quartz sand. The sand has a white calcareous matrix, except for patches about 2 cm in size which are dark brown, have no matrix and are cemented by iron oxide (sample).

BHT 66 E.L. 81.839 m Depth 1.8 m ?Adelaidean

0.1 m of red alluvium overlie 1.7 m of soft, moist, mud and clay, horizontally colour banded in zones 15-50 cm thick. Colours include dark to light grey, white, pink, mauve, red and green; they are sometimes separated by a yellow stained band.

The clay is weakly fissile in a horizontal plane, and is tough and strongly slickensided (samples). This is probably Adelaidean sediment (?Amberoona Formation).

BHT 67 E.L. 94.865 m Depth 1.8 m Mount Sarah Sandstone/ Adelaidean

Refer Fig. A9.

1.3 m of yellow sand, with red soil developing at the top, and a pebble layer at the base, overlie fine sand to silty mud. The contact is sharp and irregular.

The sediment below 1.3 m is probably Adelaidean (?Amberoona Formation); above 1.3 m is Tertiary Mount Sarah Sandstone.

BHT 68 E.L. 97.397 m Depth 2.0 m Recent Alluvium

2.0 m of red sand and silt.

BHT 69 E.L. 93.310 m Depth 2.0 m Recent Alluvium

2.0 m of red sand and mud.

BHT 80 E.L. 83.765 m Depth 2.0 m Marree Formation

Red alluvium overlies gypsum developed in brown to grey silty mud.

BHT 82 E.L. 86.192 m Depth 2.5 m ?Marree Formation

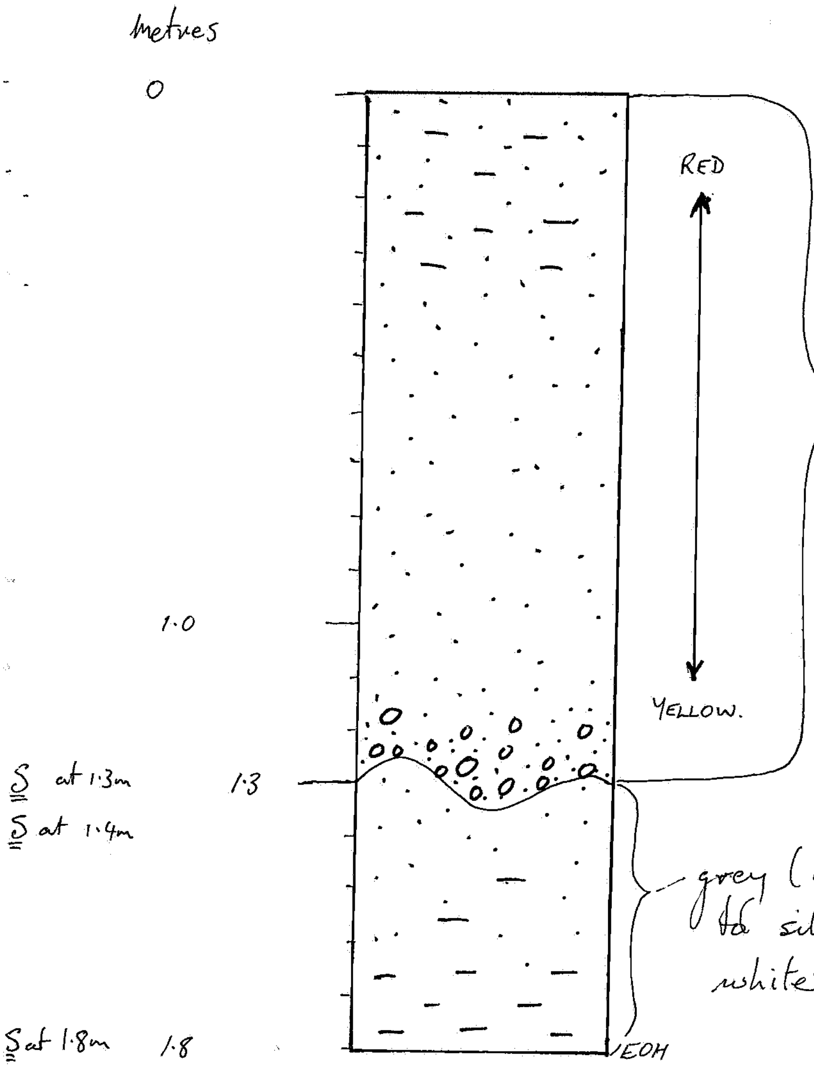
Red colluvium overlies pale grey mud and muddy sand heavily impregnated with gypsum (sample).

BHT 83 E.L. 87.244 m Depth 6 m Marree Formation

BHT 83 is located in the base of a 3 m deep bulldozer cut. There are approximately 6 m of uniform, moist, soft, brown mud, (sample) with yellow alunite and gypsum veins. "Biomottling" is distinct with dark brown mud lenticles in a paler brown mud

BHT 67.

EL. 94·865m Depth 1·8m



friable, rounded, medium sand with rounded pebbles of milky quartz and quartzite at the base, grading upward to muddy sand. The basal sand is calcareous in some patches.

grey (minor red and yellow) fine sand to silty mud. The sand has a white calcareous matrix.

Fig A9.

background. One fossil shell imprint of a bivalve was found. Small, (approx. 1 mm) patches of white silty material, (non-calcareous), may be the remains of foraminifera, but are unidentifiable. Coarse quartz sand grains are distributed randomly throughout the mud, and sparse 'erratic' rounded pebbles of green mudstone are present. No common opal was observed, although fragments are present on the bulldozer dumps.

BHT 84 E.L. 84.287 m Depth 6 m Marree Formation

BHT 84 is located in the base of a 3 m deep bulldozer cut, made in a low rise on the northern edge of Charlie Swamp. The cut and trench expose 6 m of micaceous, light brown, silty mud, sometimes sandy, grading into muddy sand. Black common opal is present in veins, in no particular orientation, in the top 1 metre (Vnuk, 1978, Fig. 8).

A thin sandy conglomerate bed, containing clasts up to cobble size, is present at about 5.5 m. Scattered throughout the mud as 'erratics', are rounded pebbles (mainly of green micaceous shale), and rounded coarse quartz grains (sample).

BHT 85 E.L. 116.272 m Depth 1.6 m Marree Formation

The trench is sited on the top of a mesa where no Tertiary sediments are present. It penetrates 1.6 m of brittle, silicified white mudstone.

BHT 86 E.L. 76.756 m Depth 2.7 m Marree Formation/ Wonoka Formation

Refer Fig. A10.

BHT 87 E.L. 79.770 m Depth 2.2 m Marree Formation

0.6 m of red alluvium overlie gypsum developed in brown to grey silty mud.

BHT 86. E.L. 76·756.m Depth 2·4m

MARREE FORMATION OVER WONOKA FORMATION.

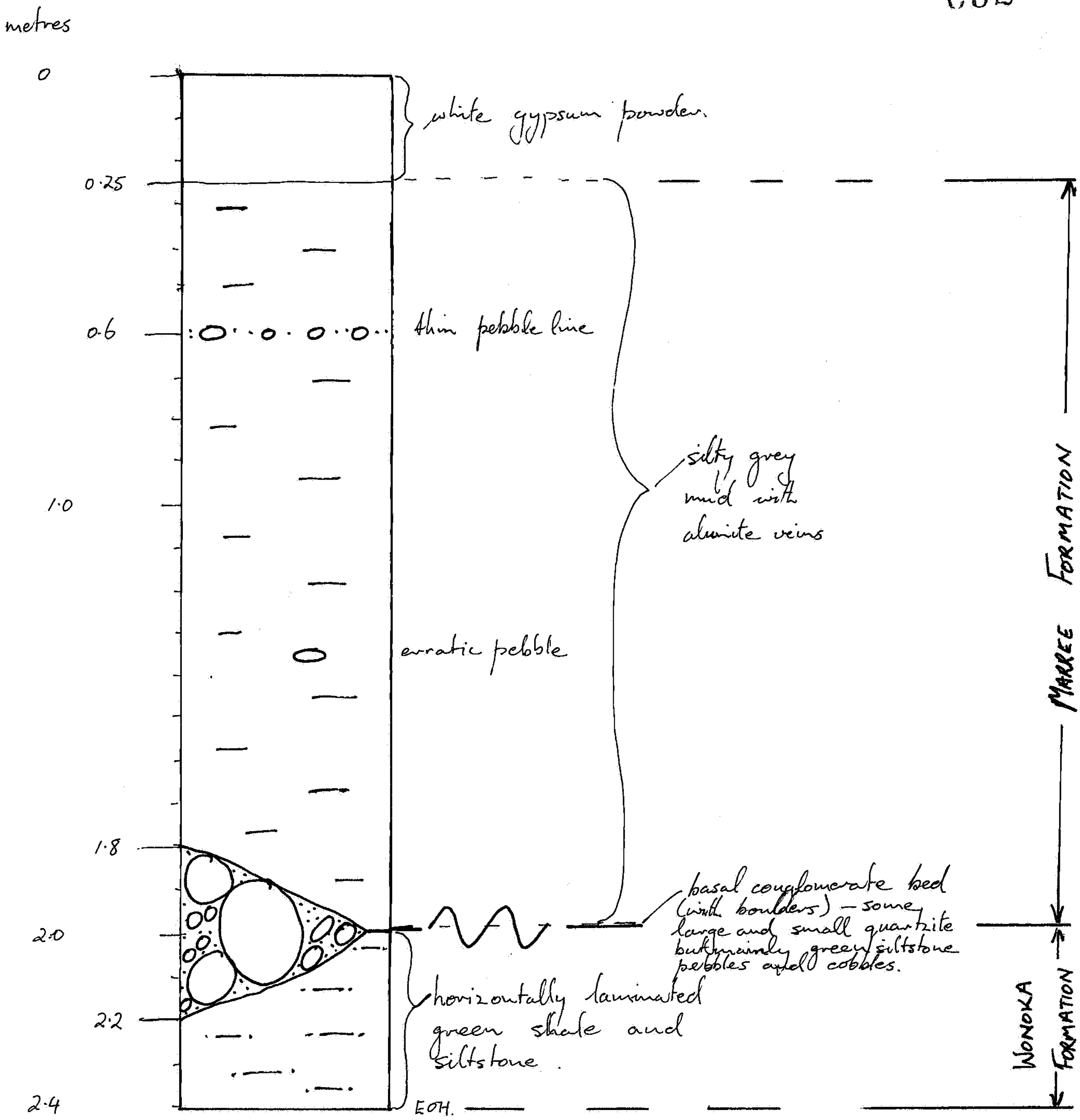


Fig. A10

APPENDIX B

Petrographic descriptions of two rocks from the Charlie Swamp area.

Extracted from Amdel Report GS2433/79

By Sylvia Whitehead

DESCRIPTION OF CALCITIC AND PARTLY SILICIFIED SEDIMENTS

Sample: 6338 RS1; Applicant's number 550/55B; TSC20344

Descriptive information: Surface sample

Hand Specimen:

The sample consists of an elongate mass about 20 cm long and about 5 cm thick of fine grained, silicified sediment in contact with carbonate-rich sediment. Where differential erosion has exposed the contact between the siliceous material and the carbonate rock, part of it appears irregular and part of the surface of the silicified material appears concretionary. There is also evidence of fine banding in the silicified material. Although the silicified zone is roughly parallel to the bedding there are places where the boundary between silicified and unsilicified rock cuts across the fine layering.

Thin Section:

This was cut to include portion of the contact between silicified rock and carbonate-rich rock.

In both the silicified zone and the carbonate-bearing zone the rock contains at least 50% of detrital quartz which is not very well sorted and varies in grain size from about 0.05 to 0.4 mm with a few scattered larger grains to about 0.6 mm. Grain boundaries have been considerably modified by the cementing minerals but relict textures suggest that many of the larger grains were rounded and the smaller grains were angular or subangular. Both the calcareous and the silicified sediment also contain about 1 to 2% of scattered heavy mineral grains mainly opaque oxides, zircon, tourmaline and rutile and these are not concentrated in any particular layer or zone. There are a few grains of feldspar and of microcrystalline quartz.
In the calcareous zone the detrital mineral grains are surrounded and separated by fine to medium grained calcite with some optically continuous patches up to 0.3 mm in size but these patches enclose or partly enclose a number of detrital grains. No overgrowths of secondary quartz were found on the detrital grains and some of them show small embayments suggesting that the quartz has been corroded by the cementing calcite. In this zone the detrital grains are not touching and they are not welded.

In the silicified zone many of the quartz grains are surrounded by optically continuous overgrowths which, in a few places, have intergrown to fill some interstices but in general there are only thin overgrowths of this secondary quartz. In some zones optically continuous overgrowths on the detrital grains were not found. Most of the remaining interstices have now been filled by very fine grained, fibrous chalcedonic quartz.

The boundary between the calcareous zone and siliceous zone is irregular and gradational in that over a distance of about 2 to 3 mm there are some scattered patches of calcite cement surrounded by sediment which is now cemented by chalcedonic quartz. This transitional zone was carefully searched for evidence to show the age relationship between calcite and chalcedonic quartz and, although absolutely conclusive evidence was not found there are some features which suggest that it is more likely that the chalcedonic quartz replaced calcite than that calcite replaced the chalcedonic quartz. There are a few places where very small, isolated patches of calcite less than 0.05 mm in size are new well separated from larger patches of calcite and there are a few places where patches of calcite which are in optical continuity are apparently separated by silicified zones up to about 0.1 mm wide but, because these could be connected in a plane other than that in which the section was cut, this evidence is not considered absolutely conclusive. In general, isolated patches of cementing chalcedony were not found in the calcite-cemented zone adjacent to the boundary or transition zone (Note: there are a few detrital grains of microcrystalline quartz which are similar in general appearance to the cementing chalcedonic quartz and these should not be confused with the cementing chalcedony). In general, interstices contain either calcite or quartz and contacts between these two minerals are generally along grain boundaries. No interstices were found in which a definite relationship could be established of one mineral overlying another.

Conclusions:

This is a calcite-cemented, fine grained sandstone with a zone of silicified, fine grained sandstone. Absolutely conclusive evidence proving the age relationship between these two cementing minerals was not found but, in the transition zone there are some features which suggest that an earlier calcite cement may have been replaced by the chalcedonic quartz.

Sample: 6338 RS2; Applicant's number 550/49B; TSC20342

Thin Section:

This is a sandstone which, in places has been cemented by chalcedonic to microcrystalline quartz and in some zones is cemented by very fine grained calcite.

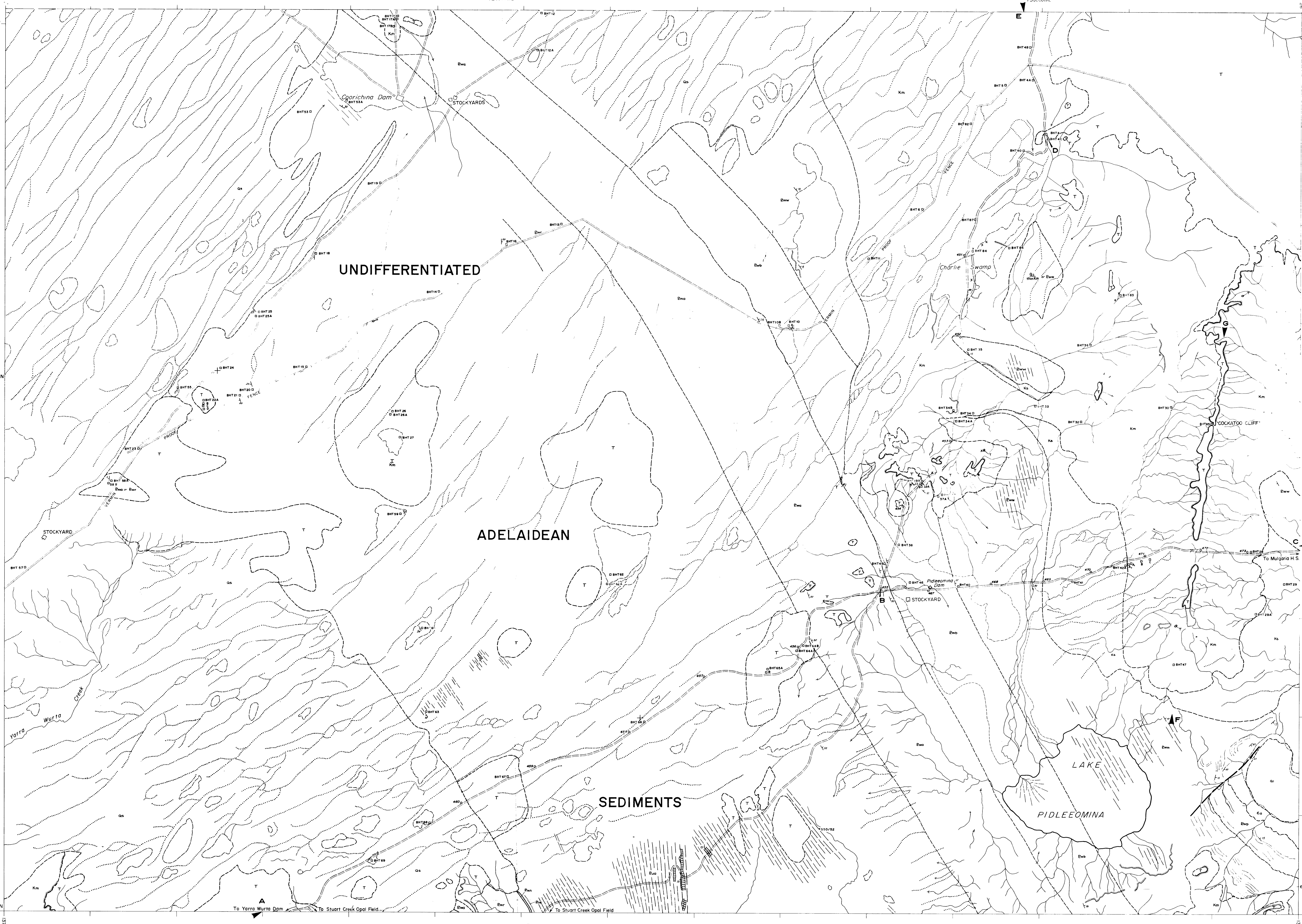
The detrital quartz is moderately well sorted with a common grain size of about 0.1 to 0.3 mm and a few larger grains to about 0.6 mm. There are a few grains of microcrystalline or cryptocrystalline quartz and very few heavy mineral grains. A large proportion of the detrital grains are surrounded by a film of dark brown material which may be, or may have been iron oxide-stained clay.

The chalcedonic quartz is generally similar to that in Sample 550/55B but the calcite is very much finer grained and merges with thin, turbid layers of calcite which encrust parts of the surface. This surface calcite is very similar to calcrete in general appearance.

Where cementing silica and calcite are in contact there is conflicting evidence of age relationship. There are some interstices which are lined with a colloform layer of chalcedonic quartz about 0.02 mm thick and the interior of the interstice contains calcite which almost certainly crystallised after the colloform layer of quartz.
There are however, other interstices in which some very fine grained carbonate is associated with the iron oxide-stained material necrusting the detrital grains and this is overlain by chalcedonic quartz. A few interstices were found which are lined with a very thin layer of calcite and the remaining interstice filled by microcline quartz and there are some interstices in which there is a layer of calcite associated with the iron oxide-stained material in direct contact with the detrital quartz grains followed by a thin layer of very small quartz crystals projecting into the interior of the interstice which was then filled or partly filled by calcite. It is therefore clear that there has been some alternation in crystallisation of calcite and quartz in this rock and probably there is no great age difference between them.

Conclusion:

This sandstone consists of quartz grains with a surface staining of iron oxide or iron oxide and clay cemented partly by microcrystalline quartz and partly by calcite which is similar and probably related to calcrete. Evidence shows that some calcite crystallised before interstitial microcrystalline quartz and some crystallised after the interstitial quartz.



LEGEND

CAINOZOIC	QUATERNARY	Ql	Lake deposits ; gypseous clay , silt and sand .
		Qs	Sand ridges and sand spread with claypans.
	TERTIARY	T	Probable MOUNT SARAH SANDSTONE of ? Miocene Age but may include other units. Sand and silt , sometimes calcareous, with minor clay . Common pebble layers of polished milky quartz and also reworked silcrete clasts. Variably silicified and ferruginised.
MESOZOIC	LOWER CRETACEOUS	Km* / Km	Lower part of MARREE FORMATION (Aptian). Brown to grey mud with sandy or conglomeratic beds. Characterised by the presence of 'erratics', distinctive bioturbation and yellow alunite veins. May be intensely weathered to light , porous , white rock in upper portion (Km*).
		Ks	"STUART CREEK BEDS" Fine , micaceous sand ; white , yellow or pale brown. Sometimes ferruginised. Poorly outcropping ; hence boundaries somewhat speculative.
PALAEOZOIC	LOWER CAMBRIAN	Єa	ANDAMOOKA LIMESTONE. Massive yellow to brown limestone with chalcedonic nodules. Oolitic , with intraformational conglomerate. The top is capped by massive white quartz.
UPPER PROTEROZOIC	ADELAIDEAN — Wilpena Group	Ꝑwp	POUND QUARTITE. White , red and purple thin bedded quartzite and sandstone with ripple marks and shale casts.
		Ꝑww	WONOKA FORMATION. Laminated , green and brown , micaceous and calcareous siltstone . Purple and green limestone near the top.
		Ꝑwb	BUNYEROO FORMATION. Red and green micaceous shale and siltstone .
		Ꝑwa	A.B.C. RANGE QUARTZITE. White to grey , flaggy quartzite interbedded with sandstone , siltstone and shale .
		Ꝑwr	BRACHINA FORMATION. Green and purple micaceous shale and siltstone .
		Ꝑwn	NUCCALEENA FORMATION. Yellow weathering dolomite , purple shales.
	ADELAIDEAN — Umberatana Group	Ꝑue	ELATINA FORMATION. Brown , calcareous , coarse feldspathic sandstone.
		Ꝑua	AMBEROONA FORMATION. Green and yellow laminated and micaceous siltstone Some coarse calcareous sandstone. Yellow weathering dolomite , sometimes sandy.

Geological boundary – observed.
Geological boundary – inferred.
Fault – inferred.
Bedding trend.
Strike and dip of bedding.
Horizontal bedding.
Backhoe trench (BHT).
Temporary bench mark (TBM).
Digging(s).
Vermin proof fence with adjacent track.
Sand ridge.
Claypan
Creek.
Gate.
Ridge (man made)
Scarp.
Locality referred to in report
Track

LEVEL INFORMATION

TEMPORARY BENCH MARKS		BACKHOE TRENCHES		BACKHOE TRENCHES	
NUMBER	E.L.(m.)	NUMBER	E.L.(m.)	NUMBER	E.L.(m.)
451	85·247	4	87·642	36	74·781
452	76·423	4A	92·886	37	89·886
453	81·279	4B	90·192	37A	87·518
454	85·244	4C	84·639	38	75·939
455	78·075	5	90·807	39	89·192
456	89·795	6	78·035	39A	88·072
457	79·328	10A1	80·769	39B	96·623
458	84·319	10A2	81·569	40	68·398
459	93·470	10B	79·794	41	68·495
460	97·196	11	77·910	42A	74·555
461	95·387	12	–	42A1	–
467	70·335	12A	–	42A2	–
468	68·598	13	78·405	42B	77·695
469	66·119	14	87·003	42C	78·745
470	70·695	15	87·954	45	74·194
471	78·692	16	83·313	46	72·805
472	83·111	17	83·530	47	86·666
473	71·147	17A	80·720	53	–
		17B	77·354	53A	–
		18	87·300	55	92·358
		19	75·780	57	–
		2C	91·321	58A	97·023
		21	91·289	58B	96·143
		22A	99·118	59	–
		22B	96·968	60	–
		22C	96·006	62	–
		22D	94 096	62A	–
		23	102·443	63	–
		24	92·120	64A	87·735
		25	94·640	64B	91·338
		25A	94·075	65A	89·252
		26	107·078	65B	91·676
		26A	103·928	66	81·839
		27	98·277	67	94·865
		28	66·124	68	97·397
		29	60·782	69	93·310
		29A	65·088	80	83·765
		30	84·017	82	86·192
		32	73·122	83	87·244
		33	69·567	84	84·287
		34	74·877	85	116·272
		34A	80·059	86	76·756
		34B	87·559	87	79·770
		35	76·273		

LEVEL INFORMATION RELATIVE TO AUSTRALIAN HEIGHT DATUM

METRES 1000 0 1 2 KILOMETRES

Fig. 22

DEPARTMENT OF MINES AND ENERGY – SOUTH AUSTRALIA

CHARLIE SWAMP OPAL DIGGINGS
GEOLOGICAL PLAN

	COMPILED. G. J N	DRN N. S.	SCALE 1 : 25 000	PLAN NUMBER 79-133
DIRECTOR GENERAL		CKD	DATE 26-1-79	

3463
3463-1

FIG. 23

NOTES (1) Elevations relative to Australian Height Datum

(2) See Geological Plan for Cross Section locations and legend.

(3) Measured elevation levels of locations within 200 m. of section line have generally been projected to the section line.

Measured elevation level of outcropping conglomerate beds — presumed continuous.

HORIZONTAL SCALE

METRES 1000 0 1 2 KILOMETRES

$\frac{V}{H} = 25$

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA		SCALE Hor. 1:25000 Vert. 1:1000
COMPILED G. J. NICOL	CHARLIE SWAMP OPAL DIGGINGS	DATE 26-1-79
DRN N. S. CKD	GEOLOGICAL CROSS SECTIONS	PLAN NUMBER 79-141

3463-2