THE GEOLOGY OF THE DEPOT CREEK AREA
FLINDERS RANGES, SOUTH AUSTRALIA

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ABSTRACT

A sequence of Late Precambrian sedimentary rocks, reaching a total thickness of 7,000 ft., was mapped at Depot Creek, on the western scarp of the Southern Flinders Ranges, South Australia.

A review of studies on or near the area by previous authors is presented.

Ten formations were recognized and mapped. Formations (4) to (10) have been placed in the Adelaide Supergroup, formations (7) to (9) belonging to the Sturt Group, and formation (10) belonging to the Marino Group. From the oldest to the youngest, these are:-

(1) Pre-Adelaide Supergroup Redbed Sequence

A shallow water deposit with minor dolomite sedimentation.

(2) Dolerite

Intrudes (1), but upper age limit is uncertain. Extensively altered, possibly by reactions during cooling.

(3) Depot Creek Volcanics

Subaerial trachytic lavas, which have undergone extensive post-depositional alteration. The origin of amygdales and tuffaceous rocks is discussed.

(4) Emeroo Quartzite

A transgressive shallow marine sand body unconformably overlying the volcanics.

(5) Dolomite-Magnesite Sequence

Continuous dolomite sedimentation with minor magnesite conglomerates and clastics, probably deposited in a lagoonal environment.

(6) Dolomitic Sandstone

Possibly also lagoonal, but with a more constant influx of arkosic sand.

(7) Tillitic Sequence

Overlies (6) with possible disconformity, and comprises thin tillite overlain by fluvio-glacial sandstones and conglomerates.

(8) "Tapley Hill" Formation

A relatively uniform body of laminated siltstones deposited in quiet water.

(9) "Brighton Limestone"

A dolomitic limestone with numerous beds composed largely of stromatolites. Gradational contacts with underlying and overlying formations.

(10) Willochra Formation

Shallow water redbeds - siltstones, gritty sandstones and shales.

The area is structurally simple, the fold style being concentric. The region contains a culmination of fold axes. Fold axes and cleavages in the Adelaide Supergroup differ in orientation from those below it, and this may be due to folding prior to deposition of the Adelaide Supergroup. The present day western margin of the ranges is considered to be a fault scarp, perhaps on the site of a reactivated Palaeozoic fault.

Comparison with the Adelaide region shows that marked similarities exist in the sequences above the tillites of the respective areas, and this justifies the terms Sturt and Marino Groups.

No economic mineral deposits are known, although creek gravel has been used for railway ballast.

GEOLOGY OF THE DEPOT CREEK AREA

I INTRODUCTION

(A) HISTORY AND GEOGRAPHY

The area mapped is shown by the locality maps (Fig.1) It is accessible by road from both east and west, the latter route being impassable after heavy rain. Approximately 22 square miles of country was mapped, extending from the western scarp of the Flinders Ranges, for 4 miles eastwards through rugged country with relief up to 2,000 feet.

The region is generally described as semi-arid, the annual rainfall ranging from about 9" on the plains to the west (Pirie-Torrens Sunklands) up to about 13" in the east at Depot Flat. The main drainage channel is Depot Creek, which runs from east to west across the centre of the area and floods across the Pirie-Torrens Sunklands about half-way between Pt. Augusta and Lake Torrens. Two springs emerge from tributaries and drain into Depot Creek, resulting in a number of permanent water holes along the creek.

Vegetation is dependent to a large degree on the underlying rock types. Native pines are confined largely to quartzite ridges in the north of the area, and on a limited area of the Tillite sequence near Depot Creek. Low stunted mallee trees (a eucalypt) predominate on the lime and magnesia rich soils of the dolomite-magnesite sequence, and to a lesser extent on the Emeroo Quartzite. The "Tapley Hill Formation", "Brighton Limestone" and Willochra Formation are characteristically devoid of large trees, and support only porcupine and annual grasses. Porcupine grass is practically ubiquitous throughout the area, reaching its maximum development on the "Tapley Hill Formation". Perennial shrubs are well developed on the Tillite sequence. Redgums are confined to major water courses, while along the foot of the western scarp are black oaks, and further west saltbush and blue bush of the plains.

In 1802 Captain Matthew Flinders became the first white man to sight this region - from the head of Spencer Gulf. He named Mount Arden, a prominent topographic feature some 2,940 feet above sea level,

LOCALITY MAPS
DEPOT CREEK AREA

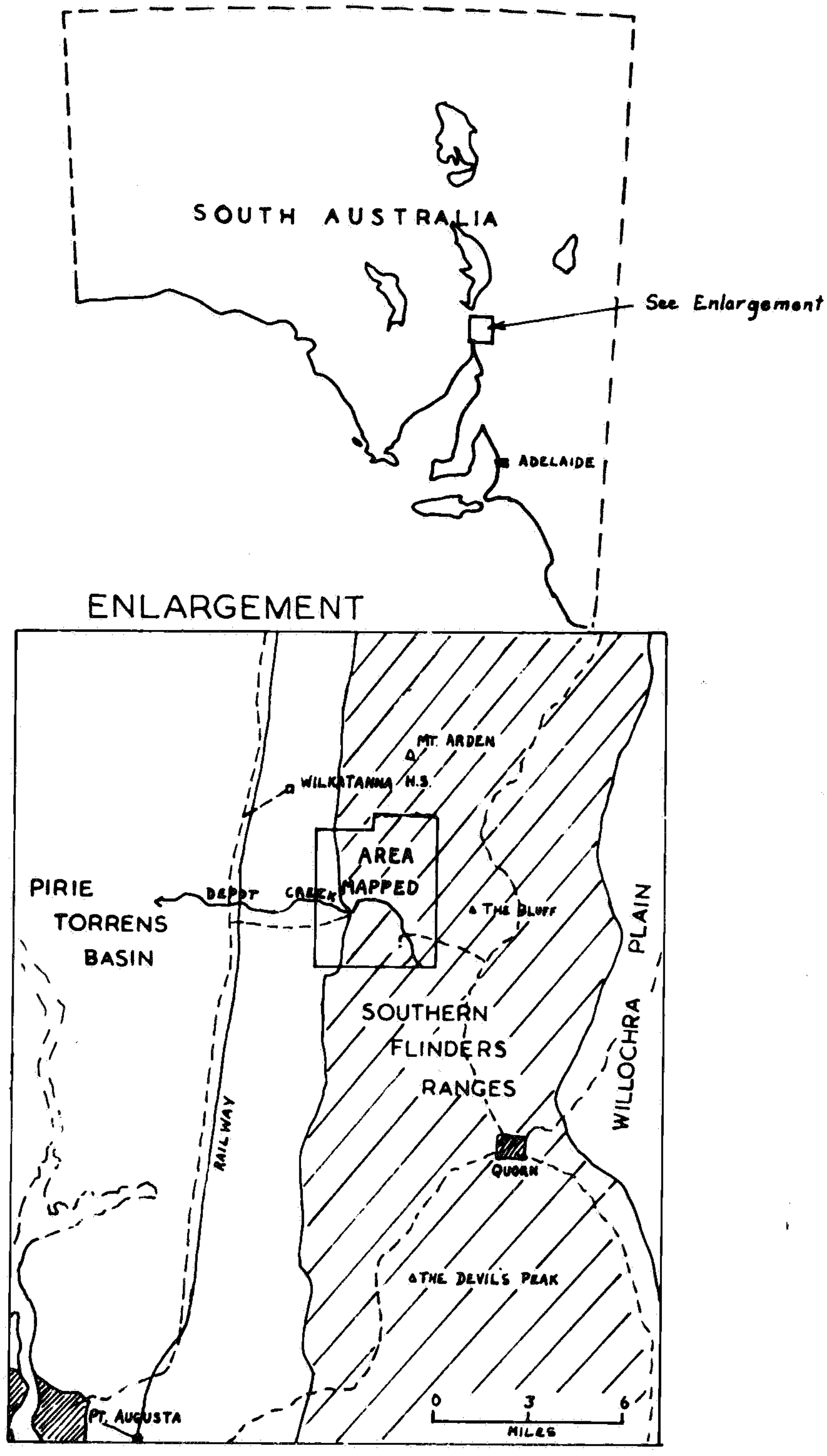


Figure 1

and about two miles to the north of the limits of the area mapped. Depot Creek was named by the explorer, Edward John Eyre, who established a camp and depot on the southern bank of the creek adjacent to the western foot-hills on 18th May, 1839. He discovered the water holes 1½ miles upstream. These were used by Eyre and later explorers, and the country was eventually taken up as pastoral leases during the 1850's. Brown (1908) records minor copper showingsnear Eyre's depot which were prospected during or before 1860.

In 1915 a large area along the western side of the ranges, including the Depot Creek area, was acquired asa water reserve by the Commonwealth Railways. Two weirs were built, and a number of bores sunk both in Depot Creek and on a tributary to the east. Water was piped to Port Augusta for use in locomotives and for domestic purposes. When the Morgan-Whyalla Pipeline was completed in 1944, and River Murray water became available, the project was abandoned and most of the equipment and facilities removed.

Today the area is used for sheep grazing with some wheat farming being carried out on Depot Flat.

Plate 1 shows the view looking north from Depot Creek, and illustrates the topography and nature of the vegetation in the area.

(B) PREVIOUS WORK

The first published work on the Depot Creek region was by Howchin, 1928, who examined sections at Pichi Richi Pass, Devil's Peak, the Dutchman's Stern, along the upper reaches of Depot Creek, and at Mundallio Creek. In the Depot Creek area, he recognized the following sequence:-

TOP: Purple Slate Series
"Brighton Limestone" Horizon
"Tapley's Hill" Horizon
BOTTOM: Sturtian Tillite.

Mawson, 1947, discussed the geosynclinal sediments of the Western Flinders Ranges, in the Copley, Emeroo, Mt. Remarkable and Port Germein areas. In the Emeroo locality, he measured a section near Mundallio Creek:-

Plate 1. View looking north from Depot Creek, illustrating topography and types of vegetation. Mount Arden arrowed

Plate 2. Halite casts in the pre-Adelaide Supergroup Redbeds.

TOP: Units		Thicknesses (ft)
23,24	Purple Series of Sandstones and Shales	2129
21,22	Slates with limited arenaceous intercalations	1590
20	Calcareous slates and argillaceous limestones (Brighton Limestone Horizon)	264
19	Laminated Slates (Tapley Hill Type)	658
17,18	Glacial and Glacigene Sediments	1006
16	Laminated shales	362
12-15	Sandstone and Shales, much of it dolomitic and Marly.	1392
10,11	Marly series with dolomite and magnesite	719
8, 9	Sandy to marly transitional beds	692
BASE: 1-7	Emeroo Range Basal rudaceous and arenaceous sediments	4288

Thus the upper units of Mawson's section may be related to those of Howchin:-

Howchin	Mawson
Purple Slate Series	Units 21-24
"Brighton Limestone" Horizon	Unit 20
"Tapley's Hill" Horizon	Unit 19
Sturtian Tillite	Units 17-18

Subsequent studies on a regional scale were carried out by private companies in the search for oil, and by the Geological Survey of South Australia. Resulting publications are those of Brunnschweiler, 1956, and of Webb and Von der Borch, 1962. Brunnschweiler, working for Geosurveys, Australia, Limited, noted the occurrence at Depot Creek of "Willourian" strata below the units 1-7 described by Mawson. Near Wilkatana, about four miles to the north, he recorded the outcrop of possible Archaean substratum beneath these "Willourian" strata, which he considered to be thinner than at Depot Creek. The rocks which he regarded as substratum are "quartzites and sandy states", in which "the degree of metamorphism .....is surprisingly low, considering its probable Archaean age". He further considered there to be no evidence of faulting along this unconformable contact, nor along the western scarp of the ranges. The present authors feel, however, that the "Archaean Substratum" of Brunnschweiler is actually the top part of the Emeroo Quartzite, down-thrown by a strike fault, (see figure 3) and that his "Willourian phyllitic wavy dolomitic shales" are really the dolomites above the Emeroo Quartzite. Moreover, Brunnschweiler recognized unconformities between the "Willourian" sediments and the overlying volcanics, and also at the top of the Emeroo Quartzite, for which no evidence was seen. He did not recognize the unconformity between the "Willourian" volcanics and the Emeroo Quartzite, whose basal conglomerate contains pebbles of the former.

Webb and von der Borch, 1962, mapping the Willochra one-mile sheet, recognized a sequence about 15 miles north of Depot Creek, which is essentially similar to that found at Depot Creek.

II METHODS OF STUDY

A) FIELD WORK

During October 1965, a reconnaissance section along Depot Creek, from the West to the east, revealed the presence of several mappable units. In subsequent field trips during 1966, these boundaries were extended along strike in order to delineate the structures. This work was combined with the running of more detailed sections through the individual units, and an examination of the contacts and sedimentary structures.

In the volcanics which had been recognized by Brunnschweiler, the attitudes of flow structures were measured, and these in addition to bedding, cleavages, and small scale fold axes of the sedimentary rocks, were plotted on the accompanying map.

A representative set of samples of some 130 handspecimens was collected (Geology Department Number A290-)

B) LABORATORY WORK

Approximately 100 thin sections were prepared and examined. Several refractive index determinations and x-ray determinations (using both diffractometer and powder photographs) were carried out to aid the identification of minerals in the volcanics, and the carbonates present in the magnesite-dolomite sequence.

Poles to bedding, small fold axes and cleavages were plotted on an equal area stereographic net.

III GEOLOGY

A) INTRODUCTION

Early attempts at stratigraphic classification of late Precambrian rocks in the Mt. Lofty-Flinders Ranges-Olary Arc have been made by David. (1922, 1927, 1932), Howchin (1923), Hossfeld (1935) and later Mawson (1940), Mawson and Sprigg, (1950), Daily (1963) and Thomson et al. (1964). One of the most significant papers was that in which Mawson and Sprigg named the known stratigraphic sequence the "Adelaide System". This was subdivided into three series, the Torrensian, Sturtian and Marinoan, which were recognized over a wide area, although individual formations were not always recognized. Later a fourth series, the Willouran Series, was recognized, south-west of Marree, and included in the Adelaide System.

The above time-stratigraphic classification was considered unacceptable by Daily, (1963) due to the absence of index fossils, and the possible diachronous nature of the rock units. Instead he proposed the use of the corresponding rock-stratigraphic units, viz, Torrens Group, Sturt Group, and Marino Group, together constituting the Adelaide Supergroup, up to the base of the Cambrian.

However, regional mapping by the South Australian Geological Survey has shown that these groups are not always easily recognizable in parts of the Flinders Ranges. Instead, a new classification, Thomson et. al., 1964), based on the recognition of the "Upper Tillite", originally described by Mawson (1949), was proposed. The new groups, whose type sections are well exposed and structurally relatively simple, are the Burra, Umberatana and Wilpena Groups, the Burra Group corresponding roughly to the Torrensian, Umberatana Group to the Sturtian plus part of the Marinoan, and the Wilpena Group to the upper part of the Marinoan. The Callanna Beds, corresponding to the Willouran, below the Burra Group, are as yet incompletely mapped and, unlike the other groups, have not been formally subdivided into formations.

The present authors agree with Daily (1963) that the time-rock units - system and series - are incapplicable outside the type areas of those systems and series, and therefore accept the term "Adelaide Supergroup" to replace "Adelaide System". As the base of the Adelaide system wasoriginally defined as the base of the Aldgate Sandstone, and the Emeroo Quartzite is considered to be the rock-equivalent of the Aldgate Sandstone, (but not necessarily contemporaneous), the base of the "Adelaide Supergroup" in the Depot Creek area will be defined as the base of the Emeroo Quartzite. The precise relation of the isolated outcrop of underlying redbeds and volcanics is not known, and, therefore, it is considered that correlation with the Callanna Beds of the Willouran Ranges is perhaps not warranted.

The authors have not introduced any new formational names; they have used previously applied formational names where direct continuity with the type sections of those formations is visible, e.g. Emeroo Quartzite, Willochra Formation.

In the case of the "Tapley Hill Formation" and the "Brighton Limestone", the same names have been used as in the type area near Adelaide because

(1) of the very similar lithologies,
(2) of the rather unique nature of the Tapley Hill formation in both sections.
and (3) very similar rock types outcrop immediately above and below them.

It must be stressed, however, that no time-correlation is implied.

Daily's (op.cit.) classification of the upper part of the sequence into Sturt and Marino Groups has been found useful in the Depot Creek area, due to a change from the "Brighton Limestone" up into redbeds, exactly as in the type section near Hallett Cove. In other areas of the Flinders Ranges, however, where the Sturt-Marino boundary is not so evident, the use of the Umberatana-Wilpena grouping is preferable. A twofold grouping is thus considered useful, to reflect facies changes in moving eastwards across the geosyncline.

For the beds above and including the Emeroo Quartzite and below the Tillite Sequence, neither the term "Burra Group" nor Torrens Group" were found acceptable, because of the different sequences represented in them. This group has therefore been left unnamed.

B) STRATIGRAPHY

A sequence of generally easterly dipping strata was recognized in the area, from the pre-Adelaide Supergroup Redbeds to the lower part of the Marino Group.

1. The Pre-Adelaide Supergroup Redbed Sequence

The oldest unit exposed in the area is a flaggy, purplish-grey sandstone with heavy mineral laminations, frequently cross bedded. In the three isolated exposures seen north of Depot Creek, it is brecciated or contorted. Aththe base, the sandstone is dolomitic, and passes up into more dolomitic sandstones and siltstones at the top.

Overlying this is a sequence of purplish-brown dolomitic siltstones and fine sandstones with minor pink dolomite lenses and interbedded purple shales. Sedimentary structures include ripple marks, mud-cracks, mud-flakes, and one example of possible halite casts. (See plate 2). Purple shaly partings are common, and often contain flakes of detrital mica. These features are all suggestive of a mudflat environment, possibly partly lagoonal, with periods of exposure to the oxidizing conditions of the atmosphere.

The total exposed thickness of these sediments is 300 ft. To the north and south of Depot Creek, the area of outcrop is limited by faulting, and to the west by a cover of recent sediments.

2. The Dolerite

The purple shale and silstone sequence has been intruded by an apparently conformable sill-like body of dolerite. South of Depot Creek, this is a massive green rock, with epidote, a dark green amphibole, and feldspar laths. Thin epidote veins are common. At the upper contact the rock is very fine grained, but to the west away from the contact, the grain size increases up to 5 mm. Outcrop is limited to the west by recent piedmont deposits. Adjacent to the upper contact, Brunnschweiler, (Op. cit.) noticed numerous injection filons brecciating the country rock immediately south of Depot Creek. Several thinner sills, up to 10" thick, with irregular outlines, occur within the purple siltstones above the main brecciated contact. Boudinaged lenses of fine grained sandstone are oriented sub-parallel to an easterly dipping foliation. Veins of very pale green sericite and a pink carbonate also oocur in these brecciated shales.

To the north of Depot Creek, there are several small sills, up to 50 ft. thick, also intruding the purple dolomitic sandstones and shales. Further north, a number of isolated dolerite bodies outcrop, and these are extensively sheared.

The age of the dolerite is uncertain as it is nowhere seen definitely to intrude rocks younger than pre-Adelaide Supergroup Redbeds. Small dolerite bodies do, however, occur within zones of diapiric breccia higher in the sequence, but these may be rafted blocks.

3. The Depot Creek Volcanics

The volcanics show a sharp contact with the underlying sediments. Where this contact is exposed, in the bed of Depot Creek, the base of the volcanics is marked by a 6" bed of tuffaceous rock with some coarse quartz grains.

No evidence of baking was observed at the contact.

The overlying volcanics vary is thickness from about 300 ft. to the north of Depot Creek - to 750 ft. in the south. Outcrop is limited to the north and south by faulting. The volcanics are fine to medium grained, predominantly dark purple in colour, but frequently containing green chloritic aggregates.

The greater part of the volcanic sequence is made up of very vesicular and amygdaloidal rocks. The amygdales, which are up to 2 cm. long, are usually filled with quartz, and may be rimmed with pink feldspar. Flows are recognized by a concentration of vesicles and amygdales in their upper portions, and by prominent partings between successive flows. See plates 3 and 4. The best example seen was in the bed of Depot Creek, where a continuous succession of three flows, each about 3 ft. thick is exposed. See plate 5.

Where the attitudes of these flows are measurable, they are concordant with the overlying and underlying sediments. The upper surfaces of the flows are typically wavy and irregular.

Tension gashes are common. Some are filled with talc, while the majority contain quartz with minor specularite. In several areas through the volcanic sequence, there are networks of veins of fine grained reddish brown material, which were interpreted in the field as late stage intrusions. Immediately south of Depot Creek, however, there are veins containing heterogeneous rook fragments, which resemble the tuffaceous bed at the base of the volcanics.

The volcanics are bounded at the top by an apparent erosion surface, with lighter coloured weathered zones penetrating down into the lava flows.

A specimen of a hard, brick-red chert was collected, not in situ, from the northern area of the volcanic outcrop. It is believed to have been associated with the erosion surface on the volcanics, and similar fragments occur in the basal conglomerate of the Emeroo Quartzite above it. X-ray diffraction showed the material to be quartz, but the grain size is too small to be resolved under the microscope. The nature of the bright red, very finely dispersed opaque pigment is not known.

Plate 3. Illustrates several lava flows, densely amygdaloidal near their surfaces.

Plate 4. Illustrates one thicker lava flow with concentration of amygdales at top.

Plate 5. A continuous succession of three easterly dipping lava flows, each 3 ft. thick

Plate 6. Concentric domed stromtolites on a bedding plane in the Dolomite Magnesite sequence, with partial replacement by black chert.

4. The Emeroo Quartzite

The Emeroo Quartzite is a thick body of sandstone and quartzite, with minor conglomerate lenses near the base. The lowest member of the Emeroo Quartzite is a dark purple qu rtzite, up to 20 ft. thick, with abundant iron oxide cement. This is overlain by very well sorted medium grained quartzite with prominent dark coloured heavy mineral laminations, 1-2 mm. thick, developed within tabular and lenticular festoon cross-bedding. Conglomerate lenses occur within this cross-bedded quartzite in Depot Creek and in the first tributary immediately to the south. The dominant rock types represented in the boulders of the conglomerate are purple volcanics, identical to the Depot Creek Volcanics, purple felspathic quartzites, and dark red cherts. Two successive conglomerate lenses each about 3 ft. thick, occur in Depot Creek, inter-bedded with cross-bedded quartzites.

Heavy mineral laminations decrease in the quartzite upwards and softer bands of felspathic sandstone and impure flaggy sandstone become common, with minor reddish siltstones developed in the south. The greater portion of the Emeroo Quartzite is a medium to thick-bedded, medium grained felspathic quartzite, vaguely laminated. Large scale cross-bedding is developed locally. In the middle and upper parts there are thin interbeds of impure greenish sandstone and quartzite. At about 200 ft. below the top, there is a 20 ft. band of very micaceous red sandstone and siltstone, with mudcracks. This is overlain by a flaggy felspathic quartzite with a number of lenses of grey thick-bedded dolomite, interbedded with siltstone and sandstone. Several dark grey lenticular chert bodies also occur near the top of the quartzite, and contain irregular jasper-like bands.

The thickness of the Emeroo Quartzite varies from 1400 ft. in the south, 1,200 ft. at Depot Creek to 2,300 ft. in the northern part of the area mapped. In both the south and north the lower contact is not exposed.

Isolated outcrops of breccia in the north may indicate faulting which could increase the apparent thickness. About 14 miles to the north, Webb and von der Borch (op. cit.) mapped over 3,000 ft. of Emeroo Quartzite on the western edge of the Willochra 1-mile sheet. At a comparable distance to the south, Mawson (op.cit., 1947) had recorded 4288 ft. of Emeroo Quartzite near Mundallio Creek.

5. The Dolomite-Magnesite Sequence

The Emeroo Quartzite is everywhere overlain, apparently conformably, by a sequence of alternating carbonates, siltstones and minor quartzites. The base of this sequence, is marked by a thick-bedded grey dolomite. Above, thinly bedded dolomites become more prominent as interbeds. Locally, magnesite conglomerates are developed in this sequence of alternating flaggy and thick-bedded grey dolomites, whose thickness varies from 100 to 200 ft.

The overlying beds consist of blue-grey thinly bedded siltstones and shales, partly dolomitic, also of varying thickness, from 50 ft. in Depot Creek to about 200 ft. in the south, and contain interbeds of dolomite and pink quartzite. They are overlain by a 10 ft. marker bed of cross-bedded pink quartzite and gritty felspathic sandstone, dolomitic at its base. Two such beds, each 10 ft. thick, occur north of Depot Creek.

The upper part of the Dolomite-Magnesite sequence is about 1,000 ft. thick, and consists of a monotonous alternation of dark blue-grey flaggy dolomites, thick-bedded dolomites and magnesite conglomerates, with odd thin interbeds of sandy dolomite . The flaggy dolomites show many concentric mounds on bedding planes, from 2" to 8" in diameter, believed to be stromatolites. These domes are typically solitary. Dalgarno, 1966, has described the structures, from the lower parts of the sequence, as "small domes with concentric wavy laminations". Plates 6 and 7 illustrate the structures of the stromatolites on bedding planes and also show their partial replacement by chert. Local small slump structures were observed in the more silty flaggy dolomite interbeds.

The more massive dolomites, also dark grey in colour, occur in beds usually 6" thick, some up to 2 ft. thick. Thin dolomitic greenish siltstone showing fine bedding laminations occur in the sequence. Near the top of the sequence, two 2 ft. bands of black and dark grey very fine grained shale occur.

Plate 7. Another example of more irregular stromato lites, on bedding plane, partially replaced by chert.

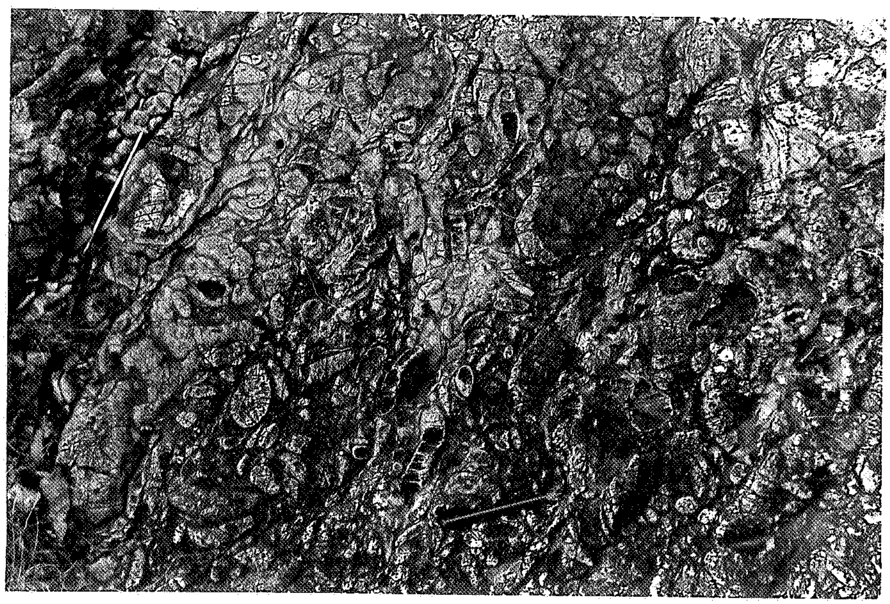


Plate 8. Illustrates the shapes of the coarser pebbles in the magnesite conglomerate. acking and curling of the flakes suggests desiccation.

The magnesite conglomerates, generally occur as massive beds, from 6" to 3 ft. thick andare characteristically interbedded with the flaggy and massive dolomites. There is considerable variation in the grain-size and textures of these conglomerates. The finest contain small pebbles, 1-2 mm in diameter, of creamish white magnesite, set in a dark grey dolomitic matrix. These pebbles are usually sub-spherical, although some are slightly elongated and aligned parallel to the bedding. The coarser pebbles, grading up to 5 cm in diameter, are ovoid, and well rounded, and show a characteristic orthogonal joint pattern on weathered surfaces. The pebbles are composed of varying amounts of dolomite and magnesite, as determined by x-ray diffraction, but magnesite appears to predominate. The matrix, which is sandy in some cases, was also identified by x-ray diffraction as mainly dolomite with minor magnesite in some samples. One sample of conglomerate from near the bottom of the sequence is coarsely recrystallized, with dolomite pebbles and matrix.

In the upper parts of the sequence, the pebbles in the conglomerate are very large, up to 6" in diameter, but more tabular and curved, with transverse cracks suggestive of mud-cracked carbonate which were curled by desiccation and rounded by transport. Plates 8 and 9 show these features.

A prominent feature of the entire carbonate sequence is the selective replacement of certain beds by dark grey to black chert. These chert bands, usually 2 - 6" thick, are all lenticular, but some are continuous for up to several hundred yards. Locally, they show small discordant tongues which cut across the bedding planes, indicating secondary origin. Plate 10 illustrates the nature of the chert pods, and plate 11 shows the selective replacement of magnesite conglomerate by chert.

Plate 9. Some large curled and rounded magnesite mudflakes in magnesite conglomerate

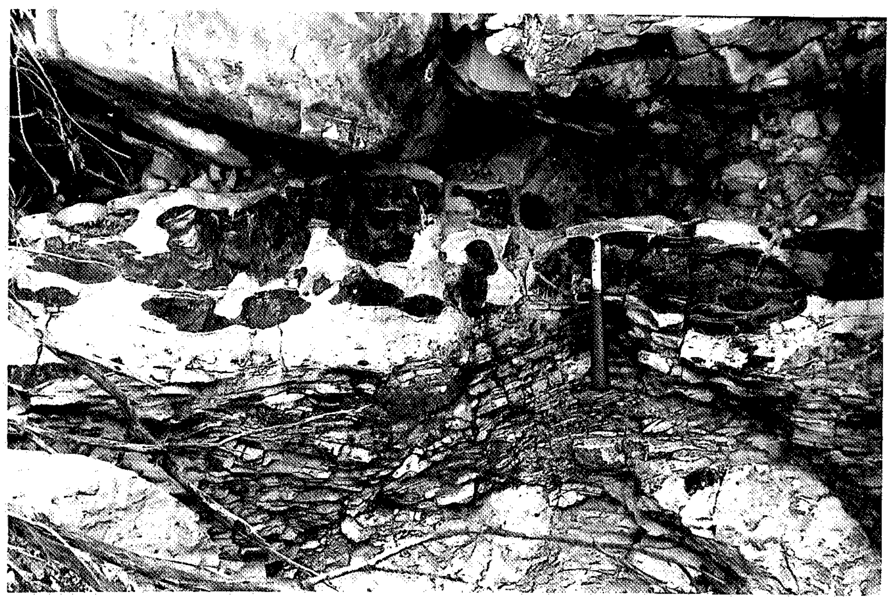
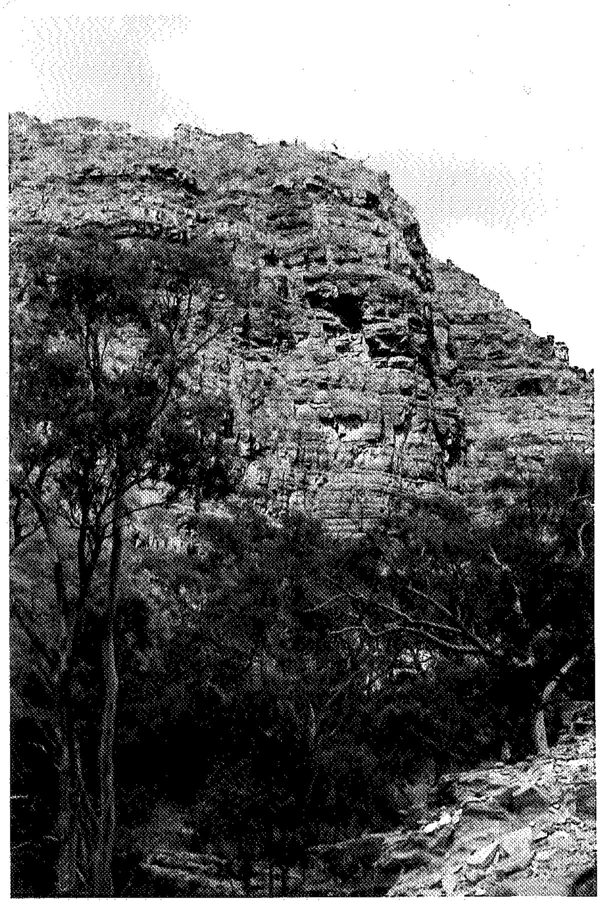


Plate 10. Irregular chert pods replacing a massive dolomite bed.

Plate 11. The selective replacement of magnesite conglomerate by chert.

Plate 12. A Cliff section in near horizontal beds, of the upper Dolomite-magnesite sequence, and the dolomitic sandstone.



6. The Unnamed Dolomitic Sandstone

This formation consists dominantly of a sequence of pale to medium grey dolomitic sandstones with thin dolomite and quartzite interbeds.

At the top of the underlying formation, there are 8 ft. of thin dolomitic siltstones, overlain by 10 ft. of clean grey quartzite, in part laminated. Above this there are two thin magnesite conglomerate interbeds, locally overlain by 10 ft. of quartzite to the south of Depot Creek. The overlying dolomitic sandstone is between 300 ft. thick in the south and 600 ft. thick in the north of the area.

The dolomite in the sandstones occurs mainly in the matrix, which forms up to 50% of the rock. The quartz grains are medium to coarse grained and well rounded. On weathered surfaces the sandstone assumes a dark reddish brown colour, with thick laminations apparently reflecting the varying amounts of sand. Mudcracks and current ripple marks are common on some bedding partings. Plate 12 shows a cliff section in horizontal beds, of the upper Dolomite Magnesite sequence and the dolomitic sandstone.

One specimen of dolomitic sandstone was collected because of an apparent trace fossil (e.g. a worm-track), on a muddy parting. Closer examination revealed it to be a peculiarly curved mudcrack, outlined by thin mudflakes, and infilled with sand. It is illustrated by plate 13. Manchuriophycus, a pseudo fossil.

Several interbeds of pink and white quartzite occur within these dolomitic sandstones, and near the top there is a 100 - 200 ft. thick band of finely laminated greenish grey shale and siltstone in a varve-like association. In places the alternating laminae are coarser, i.e. fine sand and silt. The uppermost member of the formation is a lenticular quartzite bed, which laterally changes facies into a dolomitic sandstone, and into a yellow weathering dolomite in the south. Some of these dolomites contain gritty interbeds. The upper boundary is well defined, and evidence of an unconformable contact with the tillite is discussed under the heading Petrology-Tillitic Sequence.

Plate 13. An unusual curved mudcrack.

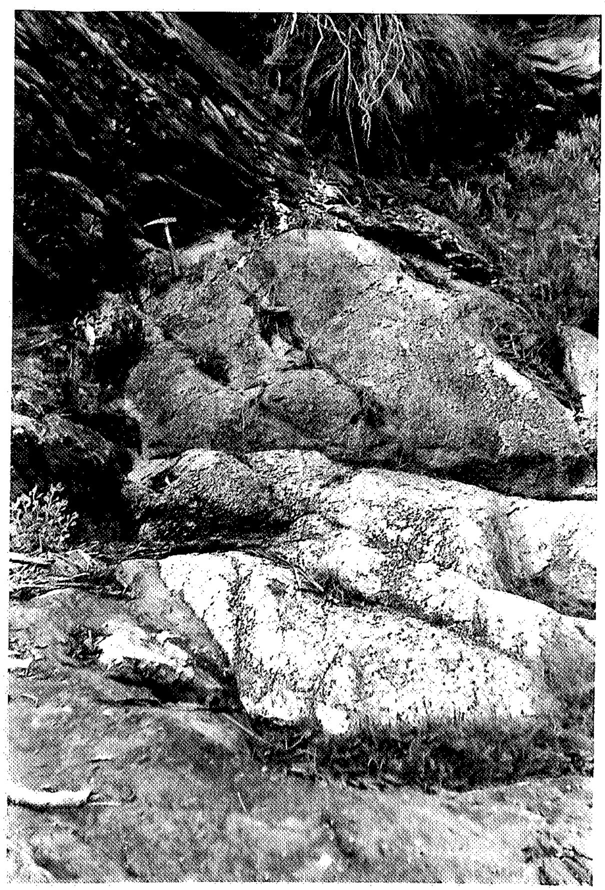


Plate 14. A 10ft. erratic boulder of granite in the tillite, showing cross-fracturing.

STURT GROUP

7. The Tillitic Sequence

In the southern part of the area, the base of this sequence is marked by the top of the lenticular bed of yellow weathering dolomite. In the northern area, the dolomite interfingers with thin quartzites, gritty dolomitic sandstones and pale greenish siltstones. To the immediate north of Depot Creek, the base is marked by a quartzite interbed. The base of the tillite sequence is defined as the base of a pebbly, highly cleaved mudstone, interpreted as tillite. The tillite overlying the dolomites and quartzites is a rock composed predominantly of a very fine greenish-grey clay matrix, in which a steeply dipping cleavage is well developed, and rather scattered pebbles, cobbles and boulders. The smaller pebbles, are generally the most angular, the commonest rock types being cherts, dolomites, quartzites and rarer igneous and metamorphic rocks. The cobbles and boulders tend to be less angular, and here gneisses, granites and pegmatites are more common. The largest boulder seen, a coarse grained granite, is 10ft. in diameter, set in the clay matrix. (Plate 14.)

The presence within the tillite of dolomitic boulders, themselves containing large rock fragments, suggests reworking of a pre-existing boulder bed. However, the dolomitic boulders have ill-defined boundaries, and this explanation is not entirely satisfactory.

The tillite, which reaches a maximum thickness of less than 100 ft. is overlain by more dolomitic pebble beds which grade laterally into dolomitic sandstones and quartzites. The sandstones are poorly sorted, grey, mainly fine grained, but with gritty bands. Locally, these are lenticular pebbly beds. In Depot Creek, the sandstones are cut by numerous quartz veins, and include a 2 ft. thick lens of conglomerate with a sandy matrix, suggestive of a stream channel fill. The pebbles which show some degree of sorting, are quite angular. Further south, the grey massive dolomitic sandstone overlies varve-like shales, with very regular laminations of silty and sandy material. Occasional small pebbles occur in this shale.

Near the top of the tillitic sequence yellow weathering pebbly dolomite lenses with stromatolites become prominent, together with numerous lenses of angular conglomerate or sedimentary breccia. These differ from the tillite in that the pebbles have undergone some sorting, the dominant size range being 2-5 cm. The pebbles are, however, still quite angular. The matrix also has a predominance of sorted sand size material.

This rock, illustrated by plate 15, is therefore not considered a true tillite.

About 1½ miles west of Depot Flat, the uppermost bed of the sequence is, however, considered to be tillitic, due to the predominance of the characteristic cleaved clay matrix and rather angular pebbles with a greater size range. The exact extent of these lenses was not mapped. The uppermost beds in the sequence are largely dolomitic sandstones, dolomites and pebbly dolomites.

8. <u>The "Tapley Hill Formation</u>".

The upper boundary of the tillitic sequence is clearly defined in the area mapped, by the top of pebbly and boulder beds, partly dolomitic, which are everywhere overlain by a well bedded dark grey dolomite, up to 50 ft. thick, which is in part flaggy due to thin shale partings. Shale interbeds 2 - 10 cm. thick appear in the upper part. These pass up into thinly laminated dark grey shale, in part fissile along bedding planes, except where a cleavage is developed. On weathered surfaces, the ½ mm thick pale greenish and purple laminations alternate. Upwards from the base, the rock becomes coarser grained and the laminations become less prominent. In the northern parts of the area, the rock has a prominent partings along the closely spaced bedding planes, but south of Depot Creek, this is not developed - the most obvious foliation being a fracture cleavage. The upper parts of the formation become a calcareous, in part massive, siltstone, with thin dolomite interbeds. The colour of these upper beds is a paler greenish grey unlike the dark grey at the base. Weathered surfaces are characteristically reddish. Several lenticular interbeds of laminated grey dolomite, whose upper boundary is ill-defined, occur near the top of the formation. The total thickness is greatest to the south of Depot Creek, where it reaches 1,000 ft.

Plate 15. Sedimentary breccia occurring in lenses within and above the tillite, considered to be of fluvioglacial origin.

Plate 16. Stromatolite bed in the "Brighton Limestone".

9. The "Brighton Limestone".

The lower part of this formation grades down into the calcareous top of the "Tapley Hill Formation." Like the dolomite interbeds in the latter, it is thinly bedded, with beds ½ - 1 cm. thick, separated by more argillaceous and ferriginous bands. Stromatolites are best developed in this part of the formation. They vary in diameter from 2 - 12", and are characteristically concentric mounds, convex upwards. Unlike the stromatolites lower in the sequence, these are rarely seen isolated, but usually form prominent beds The few isolated ones are generally hemispherical, although one elongated one was seen. Most frequently, the outcrops showed vertical sections through the stromatolites, in which successive laminae were added mainly to the uppermost surfaces of the mounds. These form columns up to 4 ft. high, as illustrated by plate 16.

The laminated dolomites pass up gradationally into more massive grey and brown partly recrystallized dolomite, and then into a pink sandy dolomite. The pink dolomite is commonly oolitic, the oolites being up to 1 mm in diameter, and contains numerous recrystallized dolomite rhombs. The upper horizons contain well rounded medium grained quartz and feldspar, and weather a buff-yellow colour, as distinct from the greenish weathering of the lower member. The upper boundary is again ill defined, as there are numerous interbeds of pink sandy dolomite in the overlying formation.

To the north of Depot Flat, there are intertonguing lenses of pink sandy and gritty dolomites of a few yards, these intertongue also with the overlying Willochra Formation. The total maximum thickness of dolomite is 650 ft.

THE MARINO GROUP

10. The Willochra Formation

The base of this formation is defined as the base of a sequence of red-beds overlying the "Brighton Limestone". The contact is gradational in the area over an interval of about 50 to 100 ft. (transition zone). The lithologies are very similar to those of the Marino Group in its type section near Hallett Cove. It is stressed that this boundary is not always clearly defined in some other areas of the Flinders Ranges, especially in the eastern zones, where the Department of Mines subdivision into Umberatana and Wilpena Groups is more realistic. The type section of the Willochra Formation (Thomson et al, 1964) is located near the NW corner of the Willochra 1 mile sheet. Within the transition zone there is an interbed of 50 ft. of partly sandy grey dolomite. Towards the north, this becomes gritty with numerous well rounded quartz and feldspar grains, with pink rock fragments. The amount of dolomite varies considerably laterally.

The Willochra Formation is characterized by thinly interbedded shales and sandy siltstones. The shale beds from 1 - 5 mm thick, are usually deep purplish red in colour, and often form prominent partings in the rock. Current ripple marked surfaces are common, with rarer oscillation ripples and occasional sand-filled mudcracks. The current ripples have a wavelength of 2 - 4 cm., and an amplitude of about 3 mm. Thinly interbedded in lenticular and wavy bands are greenish grey siltstones, locally dolomitic, or sandy, about 1 cm. thick. These show frequent irregular crossbedding structures, and minor very small scale slumps. Thin dolomite and clean sandstone interbeds still occur in the lower part of the sequence. The upper boundary of the Willochra Formation is outside the area mapped.

C. PETROLOGY AND DISCUSSION

1. The Redbed Sequence

Microscopic examination of the shales and sandstones collected showed that silt sizes predominate. Taking the upper size limit of silt to be 1/16 mm (Pettijohn, 1957, after Wentworth), only the oldest member exposed can be classified as a sandstone. This is a fine, heavy mineral laminated sandstone, consisting of subangular to angular quartz grains, not well sorted (ranging from 0.05 - 0.20 mm), with minor detrital micas and micro-cline. Carbonate and clay minerals form a fine grained interstitial matrix corroding the quartz grains. Abundant haematite in anhedral to subhedral grains accentuate the sedimentary lamination, and show micro-folding.

The uppermost beds contain sand size particles, but generally have an average grain size of 0.02 - 0.05 mm i.e. medium to coarse silt.

Quartz is the major detrital mineral present, occuring generally as equidimensional grains, with a few longer splinter-like fragments. The particles are mostly poorly rounded to angular, as is expected in the silt-size fraction. A carbonate identified by x-ray diffraction as dolomite, occurs throughout the sequence as extremely fine irregular grains or as irregular aggregates corroding quartz grains at their boundaries. Detrital muscovite flakes are common, and aid the parting of the rock on bedding planes. Some of the sandier members contain rare scattered detrital albite grains. Clay minerals are rather minor, except in mudflakes and in thin shaly interbeds.

In the whole sequence, finely divided anhedral iron oxide grains, probably haematite and limonite, impart to the rocks their red colour, and are indicative of an oxidising environment.

Thin pink dolomite lenses are common near the base of the exposed sequence.

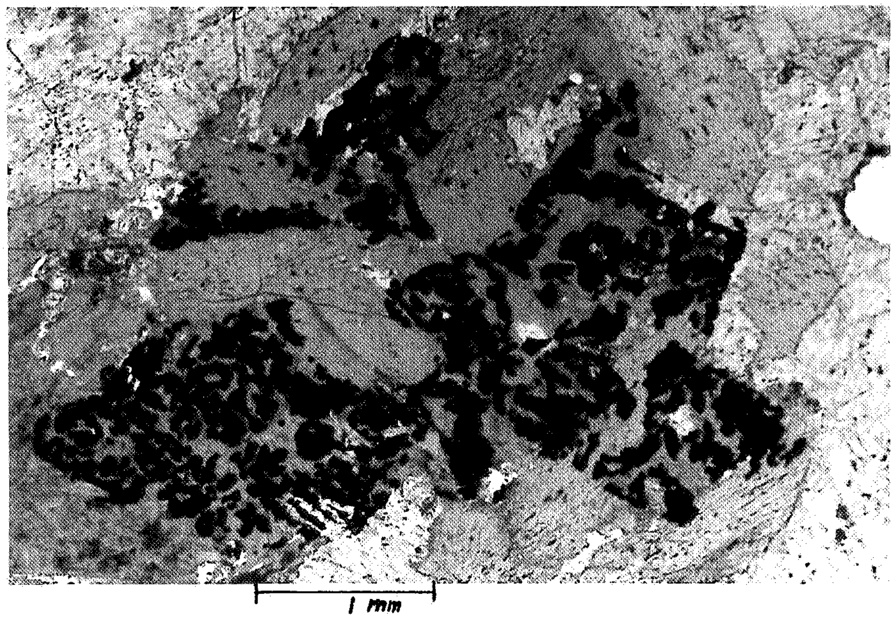
One sandy siltstone specimen showed mesoscopic folding with an amphitude of about 1 cm. This is also reflected by the microscopic kinking of detrital muscovite flakes within the siltstone. Chlorite appears to have formed by the recrystallization of a shaly layer in the siltstone, and shows partial alignment parallel to an axial plane fracture.

The occurrence of numerous desiccation features, such as mudcracks, mudflakes and halite casts, along with fairly small wavelength ripple marks, and the predominance of silt-size sediments, with abundant dolomite, suggest a lagoonal or other very shallow water restricted environment, with occasional subaerial exposure.

2. The Dolerite

Microscopic examination shows that the dolerite has undergone extensive alteration. No calcium-rich feldspars occur, albite being the only feldspar present. This is invariably partly sericitized, and twinning is obliterated in some. The texture is commonly intergranular, but in some sections it is sub-ophitic. Mafic minerals account for more than half of the rock, the most important being a green amphibole. Most of this is hornblende, although some actinolite is also present. It shows simple twining, (probably relict after a pyroxene, as in plate 18), and lath-like form in the coarser-grained varieties (up to 5 mm), while in finer-grained varieties nearer the margin, it is usually interstitial. The pleochroism of the hornblende is from pale yellow-green to deep bluish green, but actinolite shows an almost non-pleochroic pale green.

Apart from these two major minerals, there are a number of important secondary minerals. Epidote occurs as irregular masses, and gives the rocks their green colour in the hand specimen. It is closely associated with the plagioclase, sometimes appearing to replace it. Chlorite is present, usually as pseudomorphs after pyroxene or amphibole, and is recognized by its green colour and anomalous birefringence. Small amounts of iron oxides, sphene, leucoxene are present as accessories. The iron oxides have been identified under the reflected light microscope as magnetite, haematite and ilmenite. Large grains originally crystallized as magnetite, but have been partially martitized, resulting in a rim of haematite, surrounding an irregular core of magnetite. Extremely small euhedral crystals of haematite are scattered throughout the rocks, and these contain exsolved ilmenite. In some crystals, ilmenite is the host with exsolved haematite. The iron oxides commonly occur as sketetal rhombs associated with the amphibole, and this may be due to the crystallization of the oxide along the cleavage planes of the amphibole (Plate 17). The grain size of the rock varies from 0.1 mm at the chilled upper contact to 5 mm in the coarse interior of the sill.



17. Iron oxides as skeletal rhombs associated with amphiboles.

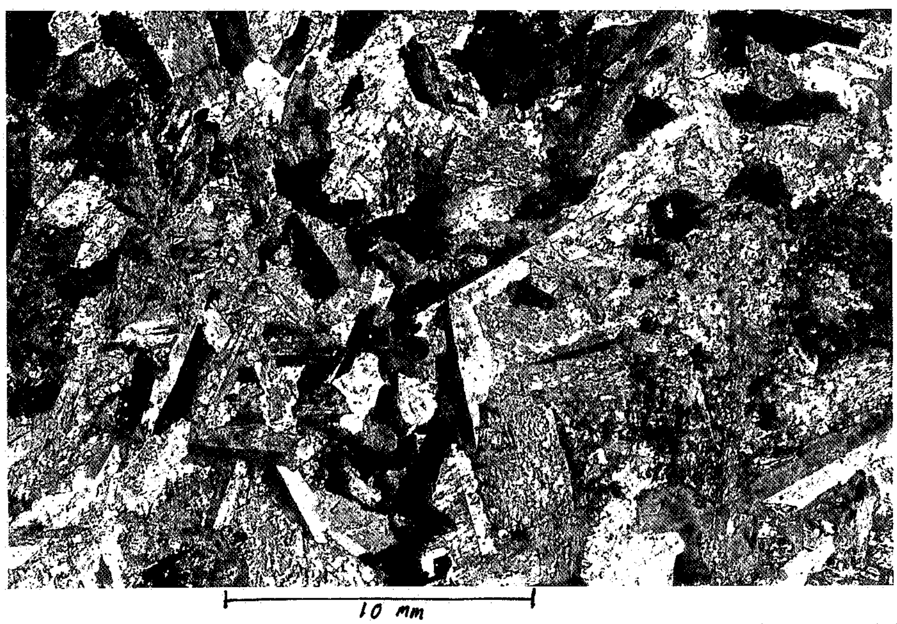


Plate 18, Relict twinning in amphiboles, probably after pyroxene. (X nicols).

The mineral assemblage albite-epidote-actinolite-chlorite is characteristic of the greenschist facies of regional metamorphism. In the process of retrogressive metamorphism originally calcic plagioclase has been saussuritized, leaving albite, and the calcium has been incorporated into the epidote-actinolite-chlorite assemblage. Hornblende is present in most of the rocks examined apparently as a metastable mineral. Wiseman, (1934), described a similar occurrence of hornblende at lower metamorphic grades than expected, in the epidiorites of the Scottish Highlands. The presence of hornblende in the chlorite and biotite zones was explained by Wiseman as being due to Ostwald's Law, that a change is not always directed to the most stable form, but may pass through intermediate metastable phases.

In view of the general lack of regional metamorphism of the surrounding rocks, the retrogressive metamorphism of the dolerite may be regarded as a readjustment to new temperature conditions during the cooling of the sill.

3. The Depot Creek Volcanics

The previously mentioned base of the Depot Creek Volcanics, a 6" tuffaceous band, is a heterogeneous rock containing quartz and fragments of volcanic material. The quartz varies from angular to rounded, and shows uniform or slightly strained extinction. A number of rock fragments are composed entirely of very small quartz grains with highly sutured boundaries. These resemble quartz from amygdaloidal lavas. Alternatively, all the quartz and feldspar may be extraneous detrital material. The former alternative is preferred because of the similarity to the amygdaloidal quartz in the overlying lavas, and it may have been derived from previous flows nearby.

The mineral assemblage of the actual lavas is very unusual The dominant minerals are a potash feldspar, and haematite. The potash feldspar is visible in hand specimen after staining with sodiumcobaltinitrite. It was identified by x-ray diffraction on the diffractometer a s orthoclase, but with a marked tendency to triclinicity although no cross-hatched microcline twinning is present. It occurs as a plexus of euhedral to subhedral laths, in part almost acicular, up to 1 mm long in the coarser varieties. It commonly has a rather low axial angle, 60° being the highest estimated. The feldspar, partly sericitized, makes up about half the bulk of the rock.

Haematite, identified from polished sections, occurs in all the rocks as abundant (up to 50%) very finely divided grains interstitial in the feldspar plexus. They impart to the rock its dark purplish colour.

Chlorite is also a common mineral in most of the specimens, comprising up to 30% of the rock. It occurs asvery fine pale green radiating aggregates in the matrix, stained with limonite, or scattered interstitially. X-ray diffraction suggested that more than one type of chlorite may be present, but these were not identified. A refractive index determination on chlorite from some of the volcanics suggested clinochlore.

One specimen of apparently deeply altered fine grained volcanic rock, of a creamish-white colour, showed a plexus of potash feldspar with interstitial muscovite, in which the feldspar laths show a slight degree of parallel orientation.

Prominent microscopic flow banding was observed in one thin section, where alternate haematite-rich and feldspar-rich layers could be distinguished. Mostly, however, the rocks showed no microscopic evidence of flow.

In some thin sections, some chlorite aggregates are rimmed by haematite, which also infills partings in these aggregates. These are the only textures suggestive of pseudomorphous replacement of ferro-magnesian minerals, possibly pyroxene or olivine, by chlorite and haematite.

A characteristic feature of all the lavas is the presence of amygdales, varying in diameter from 1 - 10 mm. The largest vesicles occur in the upper parts of each flow, where the lava has the finest grainsize. Few vesicles are left unfilled - some have been only partly infilled with haematite or chlorite rims. The amygdales are generally spherical to irregular in shape.

The mineral most commonly rimming the amygdales is an alkali feldspar, unidentified because of its fine grain size. In some specimens, however, untwinned potash feldspar occurs as coarsely crystalline pink rims, 2 mm thick. The feldspar is usually followed by quartz, of variable grain size, commonly elongate and forming radiating aggregates. Some of the larger amygdales have a central region, apparently the last filled, containing a pale green fibrous chlorite. In some specimens, the order of crystallization is partly reversed, e.g. quartz - K feldspar - chlorite or K feldspar-chlorite-quartz. Commonly the grain size, especially in quartz, increases towards the centre of the amygdale. Idiomorphic hexagonal sections of apatite were also seen in some amygdales. Muscovite is also a rare infilling mineral. Plate 19 illustrates a typical amygdale filled with potash feldspar, quartz and chlorite.

The Origin of the Amygdales

The origin of the amygdale infillings is not clear. The abundance of quartz in them, in a rock devoid of quartz, suggests that the quartz may originate from solution out of the underlying rocks. Alternatively, the quartz-potash feldspar-chlorite assemblage could represent a late stage differentiated fluid. However, the extent of alteration of the amygdale minerals is not known. In any case, the amygdales are considered to have been infilled during consolidation and cooling of the lavas, or shortly after, because apparent fragments of amygdales occur in tuffaceous bands.

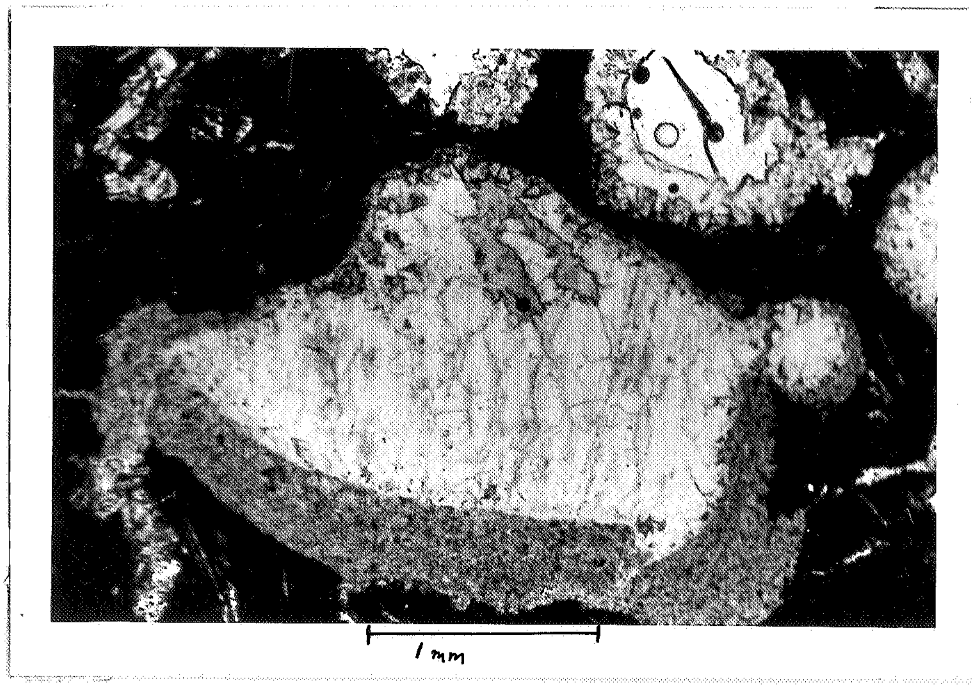


Plate 19. Amygdales in the volcanics, rimmed with potash feldspar (cloudy), and filled with quartz (clear) and chlorite (high relief).(x nicols)

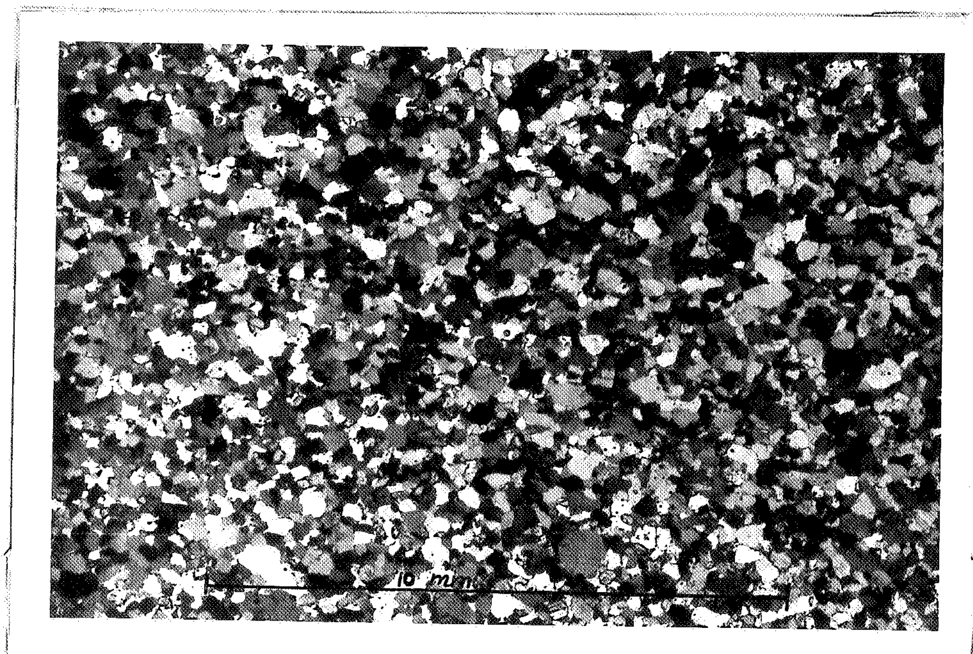


Plate 20 Thin section of Emeroo Quartzite showing good sorting and re-crystallization of rounded quartz and feldspar grains. (x nicols).

A third possibility is that the amygdale infillings originate, at least in part, from the breakdown of pyroxene in the original lavas. A calcium-deficient pyroxene, e.g. hypersthene, has the composition (Mg,Fe) $OSiO_2$. Chlorites have the approximate composition 5 MgO, (Al,Fe)O, $4(Al,Si)O_2$, having a ratio of 4 silica molecules to 6 metallic oxides. Some silica would therefore be released from the alteration of pyroxenes to chlorite + haematite. It is doubtful, however, whether all of the silica in amygdales can be accounted for in this way without some mobilization, since some specimens are free of quartz amygdales.

In addition to the quartz in the amygdales, numerous microscopic fine grained quartz veins occur. This supports the contention that the quartz is derived from hydrothermal fluids, such as a late stage differentiate.

The Intrusive Veins

The petrology of the dark reddish brown veins and tuffaceous bodies in the lavas is poorly understood. The veins consist of very fine quartz grains with abundant haematite rimming them. The haematite is concentrated near the contact of the veins with the lavas, with the tuff-like rock bearing an intrusive relationship to both. Up to one third of the rock consists of fine to medium quartz grains, of highly variable shape. Some grains are well rounded, some angular. Their possible detrital origin is supported by limonite coatings on some grains, and the presence of minor well rounded detrital minerals such as fourmaline and rutile, detrital bent muscovite flakes, and subangular cloudy feldspar. The rock has a fine grained cherty matrix, with some fine euhedral carbonate crystals, radiating chlorite aggregates, and abundant dispersed haematite. Some of the haematite, however, may be skeletal around original ferromagnesian minerals.

The general similarity of this rock to the basal tuffaceous layer suggests that it may have been tectonically injected. However, the presence of detrital sand may indicate that a sandstone below the volcanics has been brecciated and injected into them, producing a rock with both a volcanic and a sedimentary aspect.

Some dark reddish brown veins occur near the top of the volcanics as irregular networks. It is difficult to conceive of a tectonic origin for them. They may represent a late stage magmatic or hydrothermal phase of the vulcanism. More work is needed to solve the relationship of the veins to the lavas.

Discussion of the Petrology of the Lavas

The very unusual mineral composition of the lavas remains unexplained. On the basis of the absence of free quartz and the presence of potash feldspar, they might be classified as trachytic; however, the haematite content is much higher than would be expected for intermediate rocks. Crawford (1963), Fander (1963) and Compston et al., (1966), described similar lavas from Roopena, Eyre Peninsula, and from Wooltana, Northern Flinders Ranges, the gross lithology of which is essentially similar. They considered the feldspar to be primary sanidine, and the haematite to be primary. The present authors feel that this interpretation is not valid for the Depot Creek Volcanics because:

(1) the feldspar was identified as orthoclase, with a tendency to triclincity, and therefore not sanidine.

(2) in some thin sections, haematite occurs in skeletal form around chlorite aggregates suggesting pseudomorphous replacement of ferromagnesian minerals.

(3) it is most unlikely that up to one half of an intermediate rock be composed of primary haematite with no ferro-magnesian minerals.

(4) the textures of the rocks indicate extensive alteration.

Thus it is suggested that the original lavas were possibly of intermediate composition, and that subsequent alteration, has crystallized minute scattered haematite and chlorite aggregates from original pyroxenes. The presence of orthoclase rather than true low temperature microcline remains enigmatic.

The presence of amygdales in flows, the absence of pillow lavas, and the deposition of the lavas on very shallow water sediments suggest that the flows were subaerial.

4. The Emeroo Quartzite

The petrology of the Emeroo Quartzite indicates its probable origin as a thick, transgressive, fairly mature, littoral sand body.

The lowest member, generally a medium grained dark purple felspathic quartzite, contains up to 10% microcline as fine subrounded grains, and rounded medium to subrounded fine quartz grains, coated with up to 5% iron oxides, probably haematite and some translucent limonite. The margins of the quartz grains are finely sutured by the iron oxide cement. In some grains, iron oxide inclusions mark overgrowths of quartz. Traces of rounded tourmaline occur. If the iron oxide cement is derived directly from the weathering of the underlying volcanics, then this would imply that the volcanics had attained their present iron oxide content before the deposition of the Emeroo Quartzite.

The overlying pink cross-bedded quartzite has a similar lithology, except for the opaque minerals. The original quartz grains were very well rounded, but they have been completely cemented together by authigenic quartz overgrowths in optical continuity with the grains. The overgrowths have irregularly sutured margins. The original outlines of grains are marked in some by inclusions of iron oxides, as illustrated by Pl. 20. Clear authigenic microcline is also present around the margins of cloudy, poorly twinned detrital microcline. Very small amounts of detrital mica and tourmaline are also present.

The opaque minerals are concentrated in irregular but distinct laminae, up to 1 mm thick. Examination of a polished section revealed that the opaque minerals were predominantly fine aggregates of haematite with elongated parallel exsolution bodies of ilmenite aligned along the cleavages of the haematite. Rounded rutile grains and angular wedges of sphene are also present.

The heavy mineral laminations become far less prominent in the overlying quartzites and arkoses. The arkosic rocks contain 25% feldspar, as fine to medium grains of cloudy microcline, with rare albite. Many grains are moderately rounded, though some have a more tabular habit. Some overgrowth of microcline was again observed. Small amounts of opaque iron oxides occur in thin laminae and small concretions. Rock fragments are rare; some traces of fine grained granoblastic quartz-feldspar rocks and other metamorphic rocks were seen. Other specimens contain only about 5 - 15% microcline, with traces of detrital chlorite and muscovite flakes, and rounded tourmaline grains. Plate 20 shows typical well sorted Emeroo Quartzite.

The less indurated sandstone beds are poorly cemented with chert and clay material, leaving many voids. Carbonate cements are either absent, or have been leached out.

Near the top of the formation, well cemented slightly felspathic quartzites occur. The grain-size is smaller here, and all the quartz grains are well rounded and recrystallized with sutured margins. Many show undulose extinction, which is continuous into the quartz overgrowths, indicating post-diagenetic deformation presumably during the main period of folding. In these rocks, microcline is partly sericitized and iron-stained. Some very fine chlorite appears to be authigenic as it cuts across quartz grains.

The purple sandstone and siltstone near the top of the Emeroo Quartzite is composed mainly of silt and fine sand-sized subrounded quartz grains, with minor subrounded microcline. The purple colour is imparted to the rock by the presence of scattered very fine iron. Traces of tourmaline are present, together with flakes of muscovite and biotite on some bedding planes.

A fine grained pink dolomite interbed also occurs within the upper beds of the Emeroo Quartzite. The cause of the bright pink coloration was not observed in thin section due to the very fine grain size. Very minor irregular quartz and feldspar grains are scattered in the dolomite. Numerous lenticular vughs, up to 1 cm. in diameter, contain clear, coarsely recrystallized carbonate and a final filling of medium grained idiomorphic quartz crystals.

Discussion

The Emeroo Quartzite is a remarkably uniform thick unit with few shale or carbonate interbeds. The sorting is generally quite good, and the original detrital quartz grains appear all to have been well rounded. Coarse sand sizes are generally absent. Texturally, therefore, the sand is rather mature. Mineralogically, however, it appears to be less mature, due to the almost ubiquitous relatively fresh feldspar, usually microcline, making up between 5% and 25% of the rocks.

Textural maturity could be produced in beach sands by being constantly reworked and spread out over a shallow shelf by a transgressive sea. The abnndance of low angle festoon crossbeds and both current and oscillation ripple marks indicate a generally very shallow water environment of deposition.

Except for the basal conglomerate lenses, which are largely of local origin, the provenance of the sands is not known. Abundant microcline, with traces of micas, tourmaline, rutile and sphene, suggest moderately rapid erosion from granitic and metamorphic terrains. Part of the quartz, however, may be reworked from earlier sandstones, to explain the high degree of rounding. It is not known whether the sediments were derived from the older Precambrian shield to the west, or from highlands to the east of the geosyncline, since both these areas contain granitic and metamorphic rocks. Further study of the provenance of heavy minerals, coupled with palaeocurrent analysis is necessary to determine the possible sources of the sands. It seems, however, that the great thickness and constant shallow water facies can be explained only by itsbeing a transgressive sand body.

5. The Dolomite-Magnesite Sequence

X-ray diffraction work was carried out on numerous samples of these rocks, and diffractometer traces showed a total absence of calcite in this sequence. Magnesite was generally found to be present only in the "magnesite conglomerates", both in the matrix and in the pebbles.

The lowermost beds are not magnesite-rich.

Black discordant chert bodies are commonly associated with the carbonates. In thin section, the cherts generally mimic the texture of the rock they are replacing, especially oolitic dolomites and magnesite conglomerates. There are many examples of microscopic replacement textures of chert after dolomite. Many of the chert bands are concordant and may extend for several hundred feet. Only one specimen showed thin laminations in thin section. Examination by Mr M Walter revealed the presence of microscopic rod-shaped algae. The grain size of the chert varies from about 0.002 mm to 0.020 mm.

Possible oolites occur in some of the massive dolomite beds. They are almost always recrystallized to 0.05 - 0.2 mm grain size, but show a relic oolitic texture. Some fine grained quartz is present in almost all the carbonate rocks examined, even where there are no macroscopic chert bodies. Selective recrystallization of grains is common in the carbonate rocks.

The magnesite conglomerates show a great variation in the size of the pebbles. The smallest are 1 - 2 mm in diameter, and are of ovoid shape. They are often partly recrystallized along their margins. White magnesite is the dominant mineral, but dolomite occurs in some of the coarsely recrystallized pebbles. The matrix of the conglomerates, which usually forms about half the bulk of the rock, also contains magnesite, but is generally richer in dolomite. Fine detrital quartz and some partly sericitized microcline are almost always present in the matrix, and may form up to one third of the matrix. The detrital grains are generally strongly corroded by the carbonate matrix, and some of the coarser grains show strained extinction. Some limonite staining is present. Where not recrystallized, the carbonates are very fine grained, 0.001 mm to 0.002 mm. Some are patchily recrystallized to about 0.5 mm. grain size, but still without idiomorphic form. One specimen collected is a completely recrystallized coarse marble. Chert replacing the carbonates of the conglomerates occurs in well defined ovoid shapes representing the magnesite pebbles. However, the replacement is not complete microscopically, and some secondary carbonate veins and idiomorphic crystals are seen to cut across the chert.

Interbeds of arkose and shale occur within the sequence. The arkose is poorly sorted, the range of size of quartz grains being 0.2 - 1.5 mm, and of microcline 0.2 - 1.0 mm. The shape of the quartz grains depends on grain size - the finer grains tend to be more spherical but angular, while the coarser grains are generally better rounded. There seems to be a slight tendency to grading in the bedding. The cross-hatched twinned microcline, partly sericitized, is less well rounded. Some rounded lamellar twinned albite also occurs. Traces of irregular detrital muscovite flakes and rounded detrital grey-blue pleochroic tourmaline are present. A very fine coating of limonite and clay cements some quartz and feldspar grains loosely together. A few scattered rock fragments of chert and granitic material were seen.

The shale interbeds are thinly laminated, some laminae being silty. Detrital muscovite occurs on some bedding partings. The bulk of the rock is composed of very fine grained clay minerals, with minor clay-size quartz grains. Silt-size angular quartz grains are common in some laminae. One specimen also contained irregular carbonate grains in the silty layers, with cubic limonite pseudomorphs after pyrite. The laminae show some evidence of grading, with compaction features at the top.

Environments of Deposition for the Dolomite-Magnesite Sequence

Alderman and Skinner, (1957), discussed the present day deposition of primary dolomite in the Coorong lagoons, South Australia. Although previous authors had considered primary dolomite to be geologically unimportant, and that most ancient dolomites have formed by diagenetic replacement of limestones, occurrences of broadly similar lagoonal dolomite have been subsequently discovered in other areas of the world.

Forbes, 1960, described the occurrence of a dolomite-magnesite sequence "at scattered points northward of Adelaide at a constant stratigraphic level within the Adelaide System". Using current bedding structures in the arkoses of the Depot Creek area, he deduced the easterly direction of current. He also recorded an easterly downwards tilt of the depositional surface, causing slumping.

In a subsequent paper, (Forbes 1961), he discussed the origin of the magnesite formations. He inferred the bedded magnesite "to have formed in areas of shallow water, marginal to the sea, chiefly because magnesite occurs frequently as a conglomerate, and is closely associated with mudcracked beds". Paralic conditions were envisaged, magnesite being precipitated "by alkaline waters of continental origin reacting with sea water". He considered that marginal uplifts supplied too much sediment to the basin to allow the precipitation of magnesite in the southern areas of the Adelaide Geosyncline.

Von der Borch, 1965, described the precipitation of magnesite, dolomite, hydro-magnesite, magnesian calcite and aragonite in the Coorong lagoons, and the relationship between these associations and environment of deposition. He concluded that dolomite formed best in lake waters with high seasonal pH, and that two alternatives exist for the formation of the magnesite-dolomite association. They could be either coprecipitated or mixed with local dolomite eroded from the older dolomite beds, or the association may result from post-depositional alteration of the hydromagnesite-aragonite assemblage.

Peterson and von der Borch, 1965, described the precipitation of inorganic chert in the Coorong Lagoon, as gelatinous opal-cristobalite. Drying of the lakes and a lowering of pH from 7.0 to 6.5 causes the precipitation. This intimate association of early diagenetic chert with carbonate sediments is very similar to that seen at Depot Creek, and supports a similar environment for the dolomite-magnesite sequence.

The environment envisaged, therefore, is one of restricted lagoons with periods of marked, possibly seasonal, desiccation. The influx of alkaline continental waters could cause the precipitation of magnesite as well as dolomite in the lagoons. The magnesite conglomerates were probably formed by the desiccation and cracking of magnesite sediments, and the reworking of the curled magnesite mud-flakes and pebbles after transportation.

6. The Dolomitic Sandstone

All specimens examined are sub-arkoses with a dolomitic matrix. Quartz grains form about 50% of the rocks, and occur in alternating fine and coarser layers. The coarser quartz grains, 1 - 2 mm, are well arounded, and only slightly corroded by the carbonate cement. They contain numerous unidentified inclusions. The fine and medium grains are more angular, and of subspherical to elongate shape. The quartz predominantly shows strained extinction. The amount of feldspar present varies from 5% to 15%, perthitic microcline being the most important. It occurs as rounded fine to medium grains with well developed cross-hatched twinning. Some albite and cloudy orthoclase are also present. The minor detrital constituents (forming less than 5% of the rock) include rare rounded chert fragments, dolomite, biotite flakes and metamorphic quartzites.

The matrix of the rock, forming up to one third, consists of fine grained dolomite, frequently patchily recrystallized to anhedral crystals. Fine grained detrital quartz also occurs in the matrix. The quartz thus has a bimodal distribution of grain size.

The formation includes several interbeds of clean pink quartzite. The quartz grains are well sorted, well rounded, and subspherical in shape. They commonly show strained extinction, which again passes in continuity into authigenic overgrowths, indicating post diagenetic deformation.

The intergrown margins of the quartz grains are highly sutured. Many authigenic overgrowths contain minute carbonate rhombs as inclusions. Partly cloudy potash feldspar forms less than 20% of the rock, occurring as subrounded medium to coarse grains. Minor detrital tourmaline and fragments of chert and fine quartzite are present. Some sericite occurs in weathered feldspar grains. Some quartz grains are cemented by a small amount of chloritic matrix.

The dark grey siltstone at the top of the formation consists of about 50% fine (0.01 to 0.03 mm) subangular quartz grains, with minor feldspar, and very fine grained clay minerals of low birefringence. Flakes of detrital muscovite, biotite, chlorite and possibly phlogopite form up to 15% of the rock.

The presence of varying amounts of dolomite and sand in beds of this formation indicates its probable origin by the varying influx of detritus into an environment similar to that of the dolomite-magnesite sequence. Interbeds in the formation vary from almost pure grey dolomite to clean felspathic quartzites. On a much smaller scale, interbeds about 1 cm thick occur in the dolomitic sandstone, which show varying amounts of sand, the sandy layers weathering out in relief over the dolomitic layers. Abundant shallow water features occur - current and oscillation ripple marks; mudcracks indicate frequent exposure. There is no doubt that the sequence is of shallow water facies, and it is suggested that it represents lagoonal conditions essentially similar to those of the underlying formation. This is also attested to by the several thin magnesite conglomerate beds at the top of the underlying formation, where similar dolomitic sandstones are interbedded.

The characteristic red-brown colour of the sandstone on weathered surfaces is suggestive of the presence of siderite in the matrix, weathering to limonite. No siderite was, however, identified in the fresh sample x-rayed, and the origin of the staining is not known.

7. The Tillitic Sequence

The actual tillite is the lowest member of this sequence, and consists of highly cleaved pebbly mudstones, with boulders and cobbles of all sizes up to 10 ft. The matrix is greenish grey in colour, and partly limonite stained. The cleavage is somewhat wavy and irregular, but a phyllitic sheen is developed on some cleavage planes. The matrix is composed dominantly of clays and chlorite, which under the microscope, show a slight preferred orientation parallel to the cleavage. The coarsest grains, only 0.010 mm long, are probably pale green chlorite. Limonite is present as very fine brown particles infilling some cleavages.

Other specimens of tillite show a large amount of fine carbonate and quartz as well as clay minerals in the matrix. Quartz is also present in detrital grains, from silt to coarse sand size. It is generally subangular to subrounded. Subrounded potash feldspars and rock fragments are also present, quartzite and fine grained dolomite being dominant, up to 5 mm in diameter. The petrology of the boulders was not examined.

Overlying the tillite is a fine grey sandstone with gritty bands. This differs from the tillite mainly in showing an appreciable degree of sorting, with a removal of any fine grained matrix. Rock fragments, however, are still common. Fine to medium grained quartz makes up 80% of the rock, the larger grains being subrounded. A small amount of albite and perthitic microcline are present. Chert is the dominant lithology of rock fragments, together with irregularly recrystallized carbonate grains. The matrix, making up only 10% of the rock, consists of clay minerals and finely dispersed limonite. Limonite coatings are common on some quartz grains, and also infills some interstices. Plate 21 illustrates the poorly sorted nature of the grits in thin section.

Dark grey pebbly dolomites occur above the sandstone. The dolomite matrix is very fine grained and forms about 70% of the rock. Fine to medium quartz and albite grains are quite angular. Fragments of dolomitic sandstone, chert, and fine grained volcanic rock with abundant opaque minerals, up to 3 mm. are common. Authigenic chlorite is developed around some quartz grains, parallel to a slight foliation.

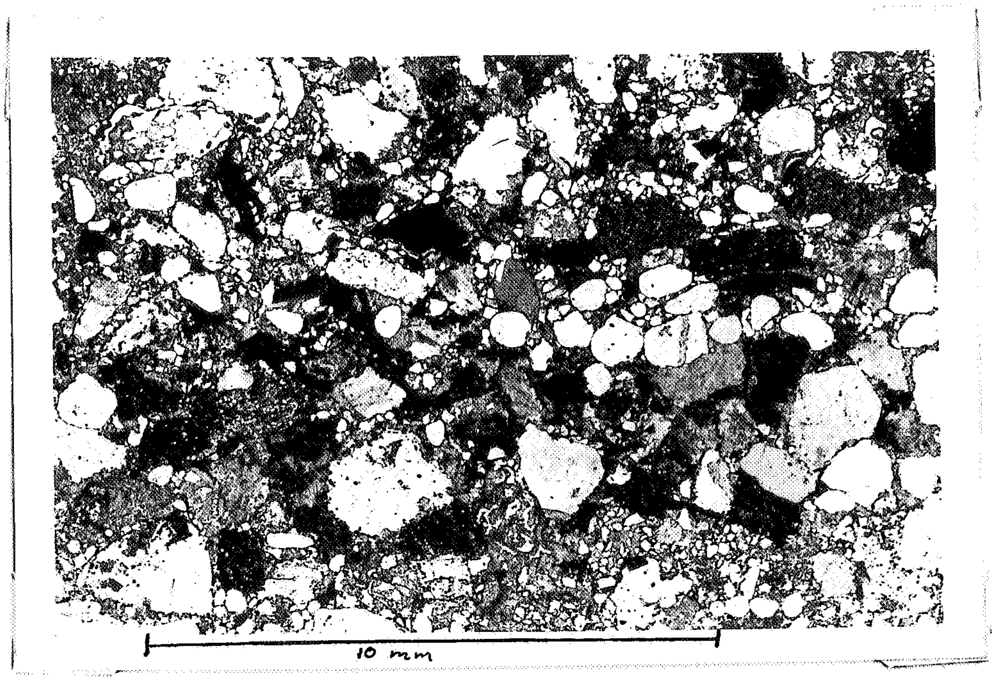


Plate 21. Shows the poorly sorted nature of the gritty sandstones above the tillite. (x nicols).

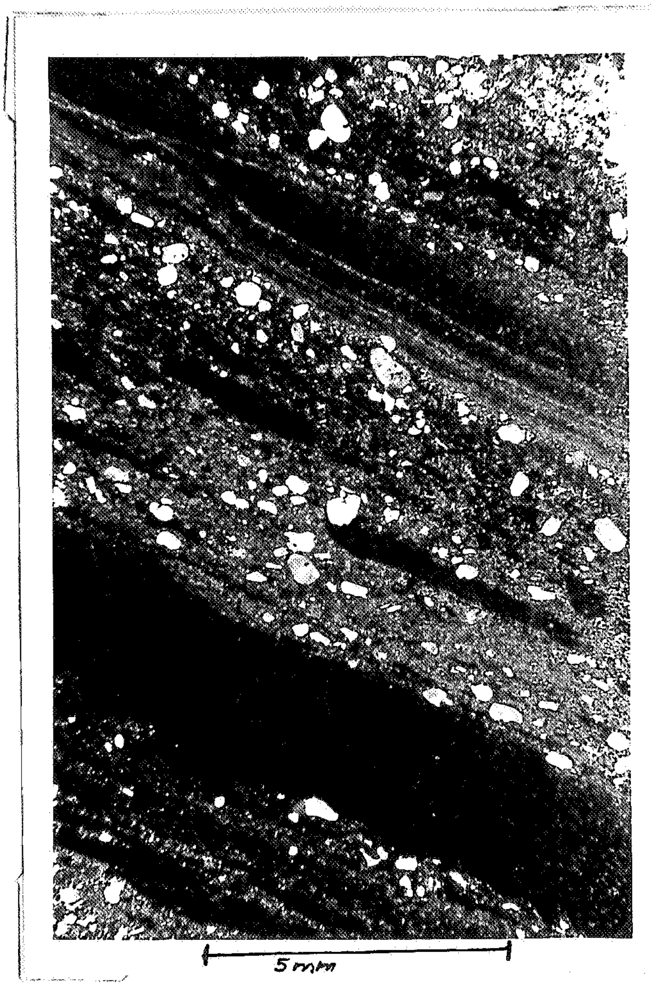


Plate 22. Illustrates the alternating silty and shaly beds in the Willochra Formation.

Discussion

Crowell (1957), Dott (1961), Schermerhorn and Stanton (1963) and Chumakov (1965) have all reexamined the evidence for the glacial origin of certain pebbly mudstones in Africa, North America and Siberia.

They have all decided that the evidence precludes a glacial origin for the so-called "tilloids" or "symmictites", and have postulated instead deposition from mud-flows in turbidite sequences. The present authors examined the criteria used, and applied them to the tillitic rocks at Depot Creek. It is concluded that these rocks are of glacial origin. The following chief differences exist between the South Australian and the West Congo late Precambrian sequences: -

(1) Sedimentation in the West Congo Geosyncline occurred in four cycles, at the beginning of the last three of which there was a period of rapid subsidence following local emergence. Tilloid rocks were deposited at the beginning of these cycles. The rocks in South Australia, however, are part of a shallow water succession - the dolomitic sandstone below and the grits and dolomites immediately above the tillite all show features of shallow water deposition. There is no evidence for rapid subsidence.

(2) The West Congo Tilloids are intimately associated with graded greywackes and quartzites - a turbidite environment. There is no evidence of turbidites under the miogeosynclinal conditions of deposition in the Western Flinders Ranges.

(3) Individual tilloid beds are sometimes graded in the West Congo Sequence. There is no grading in the South Australian tillite, either macroscopically or microscopically. In fact, bedding is rarely observed at all in the tillite.

(4) At Depot Creek, presumably rafted pebbles have been found in varve-like thinly bedded siltstones and shales.

In addition, the South Australian rocks show a wide variety of igeeous and metamorphic rock types in their boulders. Striated boulders have been observed by Howchin (1929), and Wilson (1952), in the Peterborough and Clare regions respectively. No striated boulders were observed at Depot Creek, although some show faceting.

The maximum size of boulders is significantly larger than those of the West Congo Tilloids, and it is unlikely that these should be carried by a medium other than ice. Moreover, the local occurrence of pebbles in a varve-like laminated siltstone strongly support the glacial origin of the rocks at Depot Creek.

The tillite is approximately 50 - 100 ft. thick, and is overlain by sandstones, laminated varve-like siltstones, dolomites, gritty sandstones and angular conglomerates or sedimentary breccias. Unlike the tillite, these all show the effects of sorting. Stromatolites in the dolomite interbeds indicate shallow water conditions. The sedimentary breccias, which occur as lenses, intertongue laterally in part with the tillite, and in part with the sandstones above it, since a glacial origin is accepted for the pebbly mudstones, the overlying sedimentary breccias and grits are considered to be of fluvioglacial origin, showing some degree of sorting. They oocur typically in shallow cut-and-fill channels within and above the tillite.

The contact with the underlying formation is sharp, and the lithology of the beds below the contact is somewhat variable. This and the occurrence of chert and dolomite fragments in the tillitic sequence suggests that there may be an unconformity at the base of the tillite. However, no evidence of an erosional surface or angular unconformity was seen. 20 miles to the south, Segnit (1939) recognised an unconformity in this stratigraphic position, his evidence being:-

(1) variable rock types below the contact in different localities, and

(2) lack of indentation by boulders into dolomite beds below the contact. This indicates that the beds were consolidated when the boulders were deposited, and hence the possibility of a disconformity.

An unconformity has been mapped in areas of the Northern Flinders Ranges. (Campana, et. al 1961 and Thomson et al, 1964).

8. <u>The "Tapley Hill Formation"</u>.

The base of this formation is marked by a thinly bedded dark grey granular dolomite. In thin section, the matrix is seen to be composed of subhedral dolomite crystals, 0.01 to 0.02 mm in diameter. In patches, the dolomite is recrystallized and also fills microscopic veins. Irregular iron oxide grains are scattered throughout the matrix. The granules are of dark colour, and are partly recrystallized at their margins, obliterating any concentric structure. They vary from 0.2 mm to 0.5 mm in diameter, and are of very fine grain size. The granules, which are generally ovoid in shape, are roughly oriented parallel to the bedding.

Partly thinly interbedded in the basal dolomite, and also overlying it, there are very thinly laminated shales and siltstones. Half of the rock is composed of dark brownish-green very slightly pleochroic flakes of clay minerals, which are oriented parallel to the bedding. The fine grained dark shaly laminae contain abundant very fine brown limonite pigment.

They show crossbedding on a microscopic scale, invisible in the hand specimen. The coarser silty layers contain abundant subangular to angular detrital quartz grains, from 0.005 mm to 0.02 mm. in diameter. Very minor angular potash feldspar grains are also present.

Specimens from higher up in the formation show up to 60% detrital silt-size quartz, as well as increasing amounts of very fine grained carbonates. Detrital mica flakes are rare, and show signs of compaction. In general, the quartz is concentrated in the light coloured laminae, and brown clay minerals in the darker ones.

Discussion of Origin

The thin grey basal dolomite is quite continuous over the area mapped, but further mapping in other areas is needed to ascertain its extent. If the granules are of oolitic origin, then a shallow water environment would be indicated, as wave action is necessary for their formation. (Pettijohn, 1957, p. 402) However, as no concentric or radical structures are preserved, their origin remains unsolved.

The overlying shales and siltstones are the only rocks in the area which show no signs of shallow water deposition. Oscillation ripple marks and mudcracks are totally absent; crossbedding occurs only on a microscopic scale, and the evenness of the laminations indicates deposition in quiet water, below the wave base. Rapid subsidence is not envisaged, however, because of the absence of turbidite sequences. A lacustrine environment is a possible alternative, but the wide extent of similar rocks throughout the geosyncline render this less plausible

The suggestion that the fine laminations are due to varve formation has been discounted by Howchin (1929) and Sprigg (1942) for the following reasons:

(1) laminations are irregular in thickness and differ in composition rather than grain size,

(2) lack of erratics, and great lateral extent.

The present authors find that these objections are valid for the Tapley Hill Formation of the Depot Creek Area.

9. The "Brighton Limestone"

The lower member of this formation, which passes gradationally down into the Tapley Hill Formation, is the only carbonate rock examined in the area with any calcite content. X-ray diffraction revealed calcite and dolomite to be present in almost equal amounts.

Stromatolites reach their maximum development here. They are typically low domes, consisting of alternating layers 2 - 3 mm thick, of dark brown and clear carbonate material. The dark brown layers show a microscopic lamination, by the presence of finely disseminated iron oxide or possibly organic matter. The macroscopic layers are fairly continuous, often passing from one column into adjacent columns. There is, however, some minor truncation of layers, with a new growth added on over the truncated layer. There is some branching of columns. Also, in the upper parts of the columns, the domesbecome rather sharp while the joins between columns are broad and saucer-shaped.

The carbonates in the rock are generally very fine grained, with rare recrystallized patches. A dolomitic limestone of similar lithology also occurs above and below the stromatolite beds, with frequent thinly interbedded shaly laminae.

The presence of both dolomite and calcite suggeststhe possible replacement of original limestone by dolomite.

The upper member of the "Brighton Limestone" is generally brownish pink in colour, and contains numerous ovoid to spherical oolites, 0.2 to 0.5 mm in diameter. A few are coarser, and or irregular shape, suggesting some reworking. Dolomite is the only carbonate present here. Patches of the oolitic dolomite are recrystallized to coarse, euhedral, clear, partly lamellar twinned dolomite. The outer rims of oolites are stained with reddish-brown very fine grained iron oxide pigment, which is also present in the dolomite aggregates forming the nuclei of the oolites. The oolites are composed of thin concentric laminae showing variations in the grain size and amount of iron oxide pigment present.

Since algae require sunlight for photosynthesis, the presence of stromatolite horizons in the lower member, and oolites in the upper membe of the "Brighton Limestone" indicate shallow water conditions. By the time of the deposition of the top of the Tapley Hill siltstone therefore, conditions of shallow water must have again prevailed, allowing algal beds to grow.

10. The Willochra Formation

The bottom of this formation marks a gradational but definite change to redbed deposition. Interbeds of pink dolomitic sandstones, arkoses, and dolomites occur near and just above the contact, with some thin gritty bands. The detrital fraction of the dolomitic sandstones consists dominantly of quartz, with minor fine albite and microcline grains, odd muscovite flakes, and fragments of pale brown siltstone and very fine grained quartzite and pink chert. A small percentage of the sand grains are spherical oolitic carbonate concretions. The matrix forms about 15% to 25% of the rock, and consists of very finely crystalline dolomite, with odd coarser twinned crystals. In other dolomitic interbeds, there are variations in the relative amounts of detrital quartz and matrix.

Coarse rounded quartz sand grains are common in thin gritty bands. Fine grained silt-size quartz is commonly present together with dolomite in the carbonate matrix.

The major lithology of the Willochra Formation is a greenish grey calcareous siltstone with thin purple shale interbeds. The greenish grey bands are strongly bimodal, 60% being composed of angular to subangular quartz grains, of silt size. Minor chlorite, muscovite and albite are also present. Irregular clay patches may be mudflakes. Some of the chlorite may be authigenic, as it rims and corrodes quartz grains. In other thin sections, fine grained dolomite is the dominant cement, with minor clays.

The purple shaly layers are very fine grained, and composed mainly of clay minerals, with a little quartz. The colour is due to very finely dispersed iron oxides, probably haematite. Fine muscovite flakes occur on some bedding planes, and may be partly aligned parallel to the bedding, indicating some compaction.

Plate 22 illustrates the interbedded shaly and silty layers. Shallow water deposition is indicated in this formation by abundant ripple marks on shale bedding planes, irregular cross-bedding in silty and sandy layers, and the presence of oolites in the dolomitic beds. The numerous thin purple shale interbeds contain oxidized iron pigments, which suggest frequent exposure to the atmosphere. Locally, exposure is also indicated by the presence of mudcracks on shale partings.

D. STRUCTURE

1. Introduction

The trends of fold axes in the Northern Mount Lofty Ranges is generally north-south. Further north, towards the Olary Arc and Southern Flinders Ranges the trends swing to NNE, NE, and even to ENE. The Depot Creek area shows predominantly N-S trends, but these swing to NNE and NE further north and east.

The area mapped lies on the western limb of a large regional syncline, the core of which contains rocks of Cambrian age, first reported by Daily (1956), and mapped by Webb and von der Borch (1962). This mapping and that by the present authors shows the culmination of the main synclinal axis in the area. The most obvious effect of this has been to produce two prominent topographic features - the Dutchman's Stern and The Bluff, which represent outcrops of the ABC Quartzite in the regional syncline. The Dutchman's Stern represents the plunge of the syncline to the south while The Bluff is the nose of the northerly plunging structure.

The Emeroo Quartzite outcrops over a distance of 35 miles, and forms the western scarp of the Flinders Ranges. Over this distance, Depot Creek is the only place where rocks stratigraphically below the Emeroo Quartzite outcrop. This too may be the effect of axial culmination, the oldest rocks being brought closer to the surface.

2. Folding

The style of folding, best shown by Plate 27 is concentric. The photograph shows the radial jointing usually associated with concentric folding. This example was observed on the northern side of Depot Creek, in the dolomitic sandstone formation, just west of the major fault. The manner in which bedding attitudes change across the structures also indicates that the folds are approximately concentric. The accompanying vertical cross sections were constructed by the method of Busk (1929)

The limb of the syncline is complicated by folds on a number of scales. On the macro scale are the mappable anticlines and synclines shown on the map. On a somewhat smaller scale are the numerous parasitic folds having their westerly dipping limbs from a few feet to a few tens of yards long. Folds of this nature are particularly prominent in the dolomite-magnesite sequence, in the less competent silty dolomite interbed. These are markedly asymmetrical, with a shallow westerly dipping limb, and a steep, easterly dipping limb. Examples of folds on even smaller scale are shown in Plates 23 and 24. The first is an example of the disharmonic minor folds commonly encountered in the dolomite-magnesite sequence, while the latter shows complex folds in a shaly matrix of the lower redbeds.

Cleavage was observed in only a few places. Valuesfrom the Adelaide Supergroup show westward inclination. The matrix of the true tillite is very highly cleaved, probably as a result of its very fine grain size. However, because there is little recrystallization or orientation of micas, this is interpreted asa fracture cleavage. The very small disharmonic folds (Plate 25) have very attenuated limbs, and the plane through these is analogous to a crenulationcleavage, but on a larger scale.

A summary of field data is presented in figure 2. The two great circles enclose the central part of the plot, and represent the limits of the field of poles to bedding. The corresponding fields of the resulting statistical fold axes are shown by the small circles. This reflects the change in axial plunge from south to north. Measured minor foldaxes of the Adelaide Supergroup fall within the fields of the statistical fold axes.

It is significant that both small fold axes and cleavages in the underlying rocks have markedly different orientations to those of the Adelaide Supergroup. Possible explanations for this are:-

1. The rocks beneath the unconformity at the base of the Emeroo Quartzite were folded prior to deposition of the Adelaide Supergroup. There is, however, no observed angular discordance. However, measurements in the volcanics show similar orientation to bedding in the overlying Emeroo Quartzite.

2. The rocks have simply reacted to the folding forces in a different manner.

Plate 23. Disharmonic minor folds in the Dolomite-Magnesite Sequence.

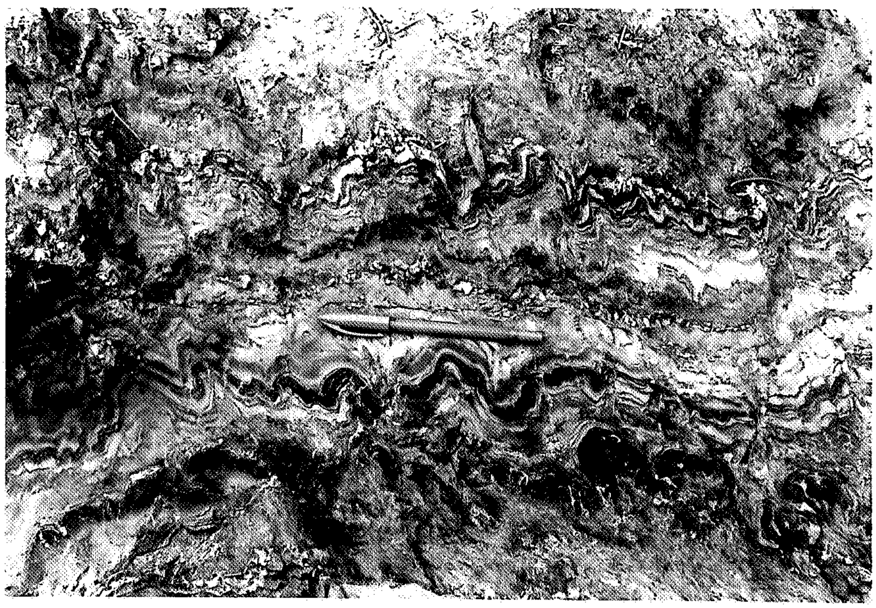


Plate 24. Complex folding in a shaly member of the lower redbeds.

Plate 25. Very small disharmonic folds with attenuated limbs, and a plane analogous to a crenulation cleavage, but on a larger scale, in the Dolomite-Magnesite Sequence.

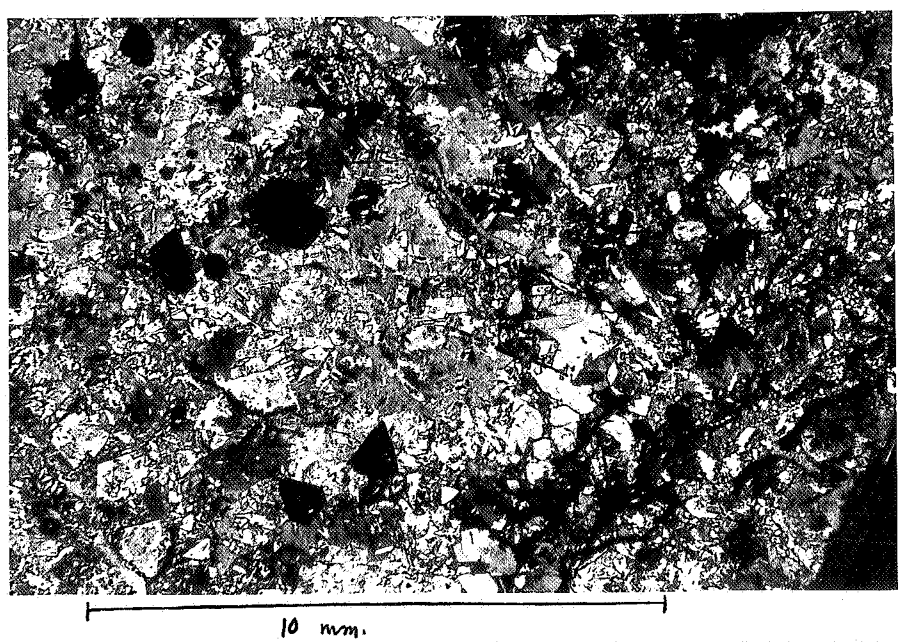


Plate 26. Thin section of diapiric breccia showing limorite pseudomorphs after pyrite, and recrystallized carbonate rhombs.

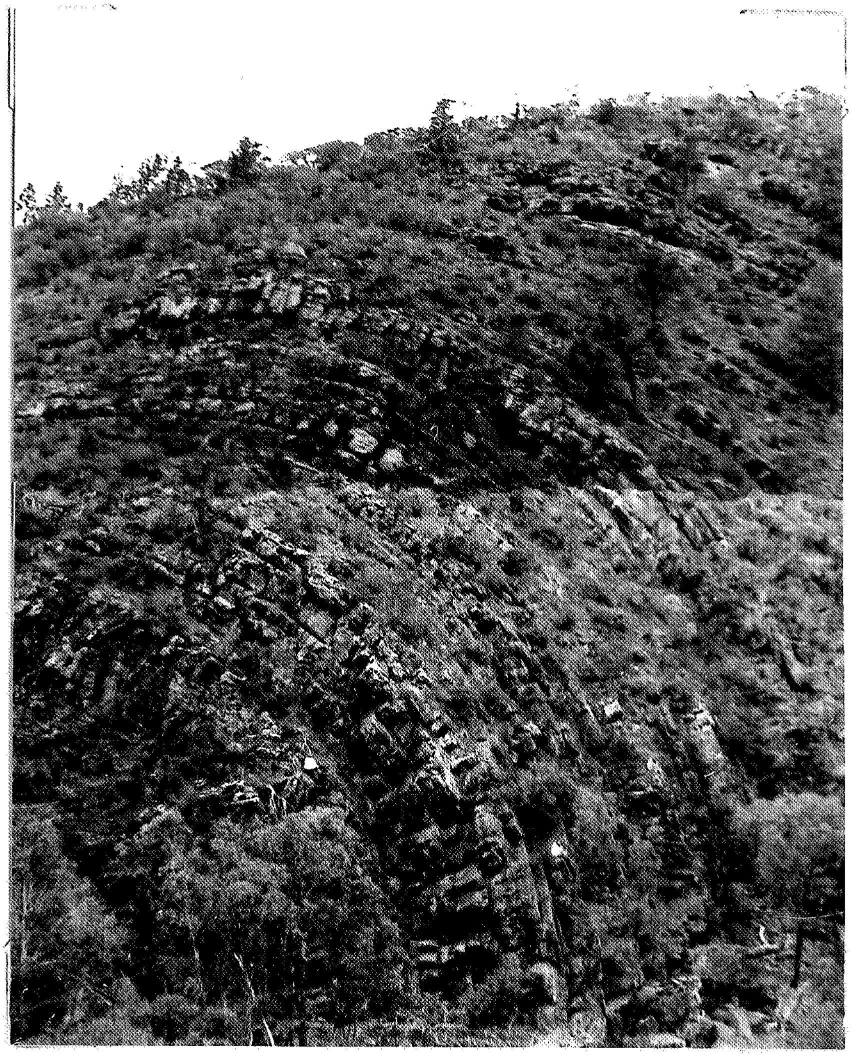


Plate 27. Illustrates concentric folding and radial jointing in the dolomitic sandstone formation.

π-DIAGRAM SHOWING CLEAVAGES AND ADDITIONAL MEASURED FOLD AXES

Cleavages.

× Adelaide Supergroup

⊗ Others.

Additional Measured Fold Axes.

• Adelaide Supergroup.

◉ Others.

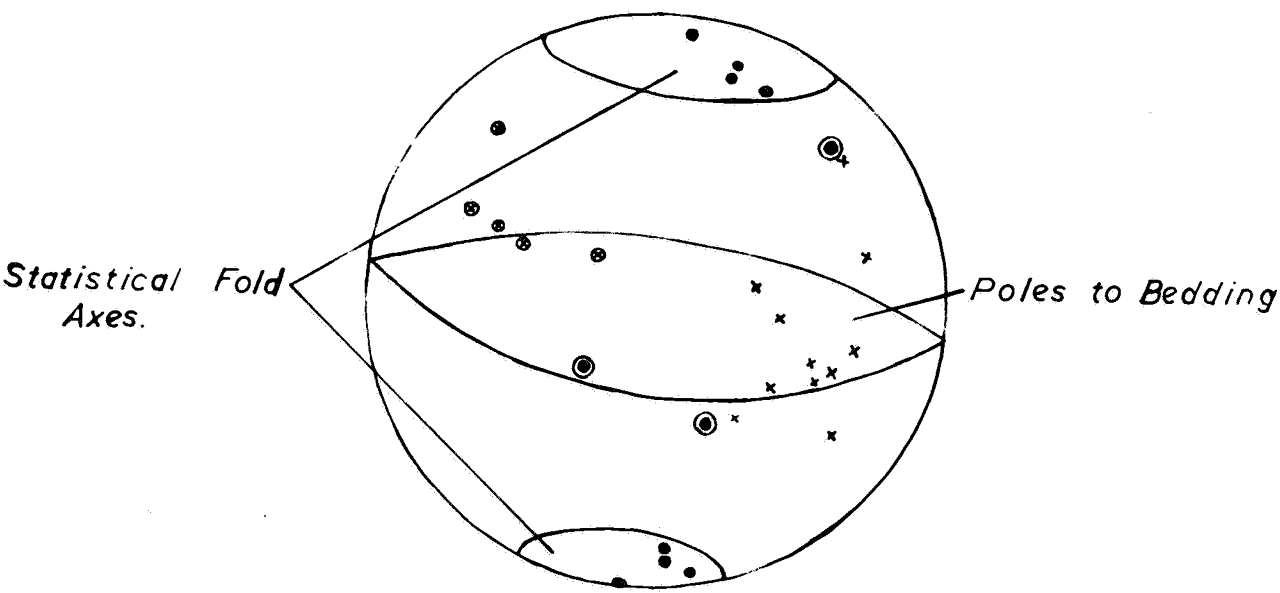


FIG. 2.

3. FAULTING

The two largest faults in the area both hinge at their southern extremities, and the folding in the vicinity of these hinges suggest that they began as fractures in developing folds. The major north-south fault has a vertical displacement of approximately 500 feet in the north, and dips wevtwards at 80° to 85°. The western block has moved upwards relative to the eastern one, so that the fault is a high angle reverse or thrust fault.

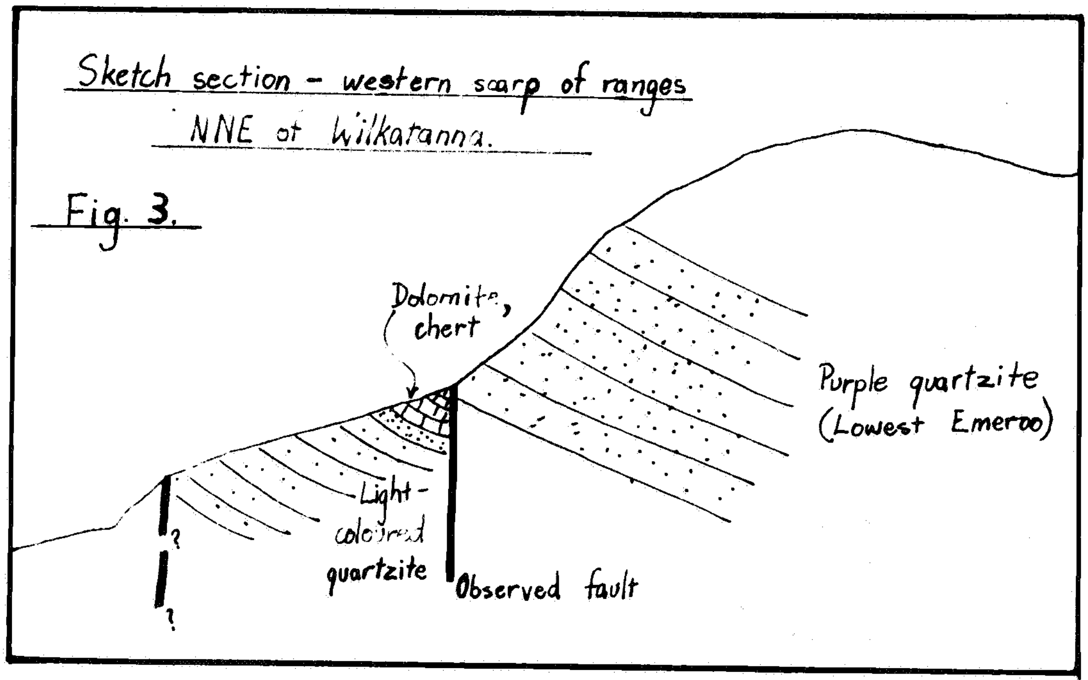
The western scarp of the ranges has , in the past, been considered to be a fault scarp resulting from block movements during Late Tertiary time (Mawson, 1947). However, Brunnschweiler (1956), denies that there is any evidence for this. The authors believe that there is the following evidence for a fault in this position: -

1. Two miles from Wilkatana and outside the area here mapped, a vertical , north-south trending fault has been observed in the Emeroo Quartzite along the western scarp. This shows on aerial photographs as a prominent lineament. A second lineament just to the west may be another fault. To the east of the observed fault is purple lower Emeroo Quartzite, while on the western side dolomite with chert overlies light coloured quartzite identical to the uppermost Emeroo. The sketch cross section, figure 3, shows that the eastern block must have a vertical displacement of 2 - 3,000 feet.

2. The volcanics, dolerite and sandstone have undergone strong shearing in the westermost exposures, and a number of poor outcrops of breccia were noted north of Depot Creek.

3. Cambrian dolomites and limestones containing Archaeocyatha were found in the Wilkatana oil bores, some three miles west of the scarp. (Unpublished SANTOS information - Mines Department Records) These are almost flat lying or gently dipping. It thus appears likely that a fault of large displacement exists between these rocks and the outcropping Emeroo Quartzite, which is of the order of 15,000 feet lower stratigraphically.

The above is evidence for faulting associated with folding. Since the present ranges result from very recent events, the scarp may be a reactivated older fault.



Sketch section - western scarp of ranges
NNE of Wilkatanna.

Fig. 3.

4. THE DIAPIR

Thompson Gap is a relatively straight gully cutting across the strike of the mapped sequence. This resultsfrom the outcrop of a band of breccia, some $1\frac{1}{2}$ miles long, and up to 200 yards wide. The rock contains angular fragments of sandstone and siltstone set in a light grey matrix of fine to medium grained carbonate. Microscopic examination (plate 26) reveals an irregular scattering of fine grained dolomite which is recrystallised in patches to euhedral crystals 0.5 to 3.0 mm. across Other large fragments are of quartz, feldspar biotite and sandstone (all angular). Limonite occurs as pseudomorphs after pyrite, and in irregular veinlets. Large blocks of dark green epidote and amphibole rich dolerite identical in hand specimen and thin section to that outcropping further north, were also seen within the breccia. By comparison of the breccia with that reported by Coats (1964, 1965), this structure is considered to be diapiric. However, the contact with the country rock is quite sharp and no upturning of adjacent beds was observed. This, and the linear nature of the structure suggests that diapiric material has been intruded along an observed fault. If the dolerite in the diapir is the same one as that out-cropping, it means that it must have been intruded before the diapirism took place.

A small mass of diapiric breccia containing dolerite and specularite outcrops on the south bank of Depot Creek.

GEOLOGIC HISTORY

The earliest record of sedimentation in the area was of a shallow water environment receiving fine sand and silt. Presence of dolomite and halite casts suggest possible evaporitic conditions, with occasional subaerial exposure. These sediments were covered by volcanics which are considered to be subaerial.

An unknown period of time elapsed before sedimentation recommenced A widespread marine transgression resulted in deposition of a thick blanket of sand. As conditions stabilized the first lagoons formed, and dolomites were deposited. Occassional influxes of sand and mud occured, but lagoonal sedimentation continued over a wide area for a considerable time. During this time conditions suitable for the formation of magnesite arose in a number of localities. These show shallow water and desiccation features. During the time represented by the overlying formation dolomite sedimentation continued, but with a constant supply of quartz and feldspar sand, perhaps because of renewed uplift in an adjacent land mass. Throughout this period shallow water conditions predominated, with frequent subaerial exposure. Boulder tillite appears quite suddenly, and may lie unconformably over the underlying sediments. Whether this is the record of a land moraine or the result of ice dumping into an aqueous environment cannot be determined on present evidence. Reworking of ice laid material occured, and the numerous lenticular bodies of poorly sorted sandstones, grits and conglomerates suggest largely fluvial environments. The region of melting ice was probably quite close, as suggested by the extreme heterogeneity and angularity of the clastic material. Possible marine conditions are suggested by growth of stromatolites.

The record of glacial activity ceases abruptly. The basin of deposition apparently deepened, and fine material was deposited in quiet water with no, or only weak, bottom currents. The basin gradually shallowed, and more massive bedded siltstones are superseded by algal limestones, indicating very shallow water conditions.

The environment of deposition of the Willochra Formation is also a shallow water one, again with periods of exposure.

The overlying formations were not mapped, but studies in other areas show that sedimentation continued into the Cambrian, and was probably terminated by tectonic movements during this period. These movements, which folded and faulted the sequence, may have recurred spasmodically over a long period of time, since the Triassic rocks of the Springfield Basin are folded (Webb and von der Borch, 1962). Much of the present day relief of the Flinders Ranges has been attributed by some authors to broad arching and doming with marginal faulting. (Campana in Glaessner and Parkin, 1958). The western scarp of the ranges may be the result of reactivation of an ancient fault, similar to those of the Adelaide region.

That rapid erosion has occurred in fairly recent times is shown by the occurrence of large alluvial fans to the west of the ranges. A number of hills to the south and east of the area have flat or uniformly sloping surfaces, and these may be the uplifted remnants of a mature landscape which has been dissected comparatively recently. One such surface occurs on the dolerite south of Depot Creek.

The present appearance of the ranges in the area is thus due to recent (late Cainozoic) uplift, and erosion hasproduced immature topography.

There is no indication, however, that the area was a peneplain before the last tectonic movement.

Conclusion: The record of Precambrian sedimentation in the area shows characteristics of an unstable shelf environment - that is, an area which subsided over a long period of time, but in which sedimentation kept pace with subsidence, resulting in continued shallow water deposition.

<u>Comparisons with Other Areas</u>: Sediments occurring below the basal sandstone of the Adelaide Supergroup are known in the Clare district (the River Wakefield Group) (Wilson, 1952), and in the Willouran Ranges and north-eastern Flinders Ranges (the Callanna Beds),(Thomson et al, 1964) Because of the limited exposures at Depot Creek, no correlations are attempted with either of these groups.

There is a marked similarity between the volcanic rocks a t Depot Creek and at Wooltana and Roopena. (Crawford, op. cit.) While no age correlations can be attempted, it seems probable that a genetic relationship does exist.

The Emeroo Quartzite contains a similar opaque heavy mineral assemblage to that found in basal sandstones in other areas, (A.W.G. Whittle, pers. comm.). It is considered that the Emeroo Quartzite is part of the same transgressive sand body known in the Aldgate, Rhynie, Copley and Witchelina areas.

Dolomite-magnesite rocks are best developed in the western and northern Flinders Ranges (Forbes, 1961). Their occurrence in the Adelaide region is restricted to the Montacute Dolomite, the greater part of the Torrens Group consisting of pelitic and arenaceous sediments. Little is known of the extent of the overlying dolomitic sandstone formation, although Dalgarno (1966) records an arkosic sandstone southwest of the Worumba diapir in similar stratigraphic position.

Tillites, with associated fluvioglacial grits, sandstones and dolomites, are recognized over a large area throughout the Adelaide Geosyncline. They represent deposition uhder markedly different climatic conditions from the underlying formations. This is the basis for the erection of another group, the Sturt Group.

The Tapley Hill Formation, also of wide extent, appears to be one of the most uniform and easily recognizable formations. A thin grey dolomite occurs in the type area near Adelaide, interbedded with laminated slates. This has been placed at the top of the Sturt Tillite (Sprigg, 1942). A similar dolomite has been included in the Tapley Hill Formation, in the Depot Creek area, (present authors), and on the Willochra Sheet (Webb and von der Borch, 1962). A dark grey thinly laminated shale occurring in the lower part of the Tapley Hill Formation at Depot Creek, has also been recorded in other localities throughout the geosyncline, and has been named the Tindelpina Member (Thomson et al 1964).

In the area mapped, as in the type area, the Tapley Hill Formation grades up into the Brighton Limestone, passing through calcareous siltstones and laminated dolomites. The upper part of the Brighton Limestone in both areas is oolitic, and in part sandy. The sedimentation of the Sturt Group is terminated by the cessation of carbonate deposition, and is followed by the redbed sedimentation of the Marino Group. The contact is, however, gradational over a greater thickness at Depot Creek than in the type area.

ECONOMIC ASPECTS

Brown (1908) makes a brief mention of copper shows prospected at Depot Creek during the 1860s:

"Situated near Eyre's Depot. The general character of the lodes here is favourable to the production of copper ores of good quality. The lodes contain green carbonate of copper, grey ores, and red oxide (1860-9)."

The prospects are in small dolerite bodies and in the oldest volcanics outcropping along the western scarp, but the limited extent of malachite staining (in isolated pockets a few feet wide) does not appear promising. No other metalliferous mineralization was noted.

An unusual occurrence of an intrusive pegmatite was observed in the Tillite sequence 1 mile NW of the westernmost homestead at Depot Flat. The pegmatite occurs as a vein some 2 ft. wide, containing quartz, feldspar, and muscovite crystals up to 1" in diameter. A number of smaller veins branch off from this. A pit about 8 ft. deep has been dug, probably in search of mica. While no economic minerals were seen in the pegmatite, it is of interest to know that acid intrusive igneous activity has occurred in an area in which none has been reported before.

The magnesite beds have been exploited in other areas (Johns, 1963), the closest of these being at Mundallio. The rock has been used for medicinal purposes, and has been investigated by the B.H.P. company for use as a refractory material. While other more accessible localities are being worked it is unlikely that deposits at Depot Creek are an economic proposition. The greatest difficulty would be encountered in finding a thick enough bed of magnesite which is pure enough to warrant underground mining. The same arguments apply when considering the possibility of utilizing the dolomite.

The only natural deposit, besides ground water, which to date has proved useful are the gravel deposits in the bed of Depot Creek on the alluvial fan. The Commonwealth Railways have quarried a considerable quantity of this for use as ballast on the standard gauge railway to Leigh Creek and Marree. Practically unlimited quantities of gravel are available.

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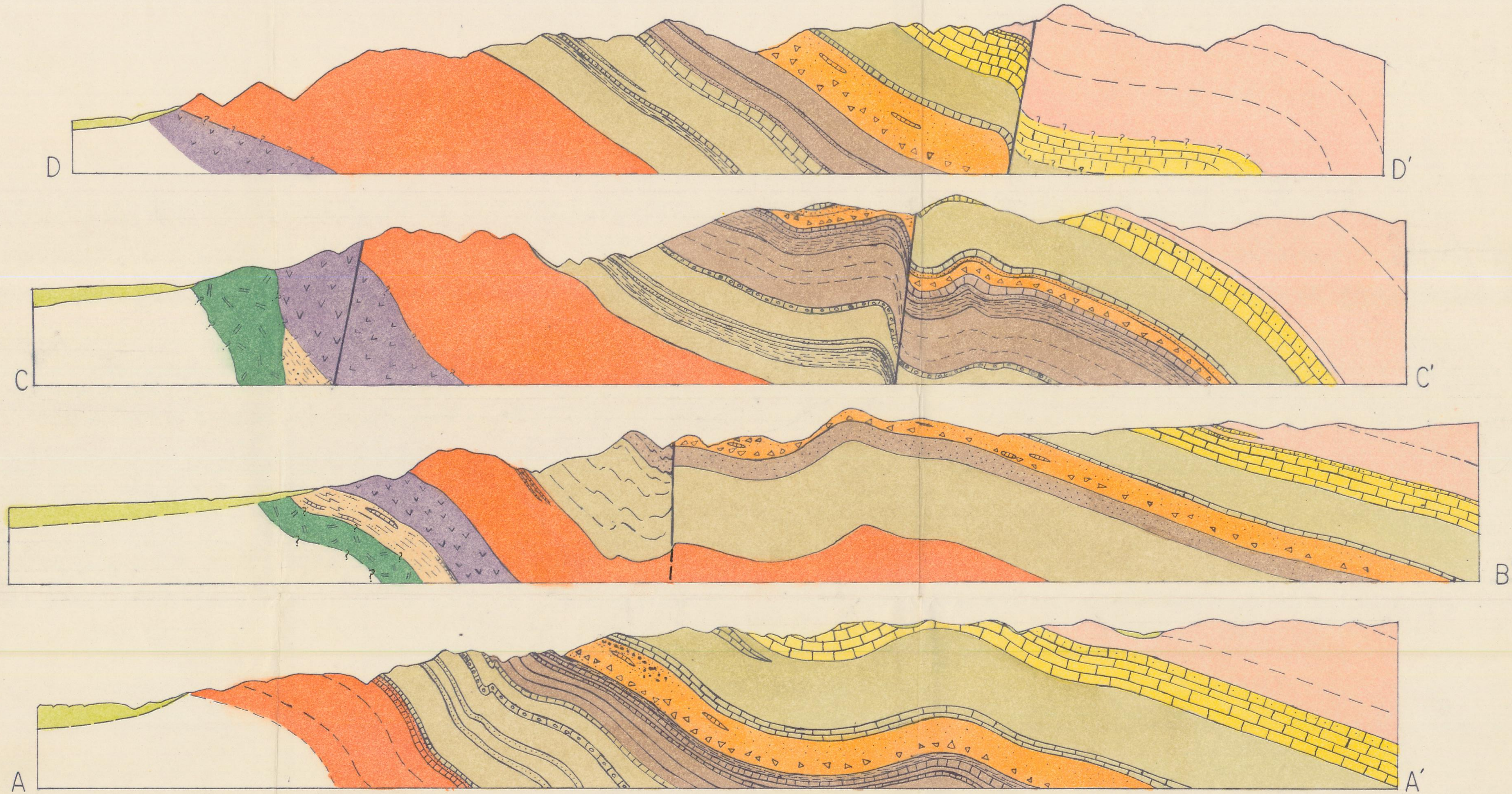
CROSS SECTIONS.

NATURAL SCALE

4 IN. : ONE MILE.



STRATIGRAPHIC COLUMNS

GEOLOGICAL MAP OF THE DEPOT CREEK AREA

FLINDERS RANGES

SOUTH AUSTRALIA

LEGEND

- Quaternary Piedmont Deposits and Alluvium.
- ADELAIDE SUPERGROUP
  - MARINO GROUP
    - Willochra Formation
    - "Brighton Limestone"
  - STURT GROUP
    - "Tapley Hill Formation"
    - Tillite Sequence
  - Unnamed Dolomitic Sandstone
  - Dolomite-Magnesite Sequence.
  - Emeroo Quartzite
- Depot Creek Volcanics.
- Redbed Sequence
- Dolerite
- Diapiric Breccia

- Bedding.
- Breccia.
- Fold Axis.
- Cleavage
- Lava Flow.
- Homestead.
- Dam.
- Spring.
- Fault (observed).
- Fault (inferred).
- Chert
- Stromatolites.