A CONTRIBUTION

to the

GEOLOGY of the HUNDREDS of GOOLWA and ENCOUNTER BAY, SOUTHERN SOUTH AUSTRALIA.

by

D.J. GUPPY, B.Sc.

Honours thesis 1943
Supervisor: Sir Douglas Mawson

INDEX.

1. Introduction.

The areas examined during the preparation of this paper are included in the Hundreds of Encounter Bay and Goolwa (County of Hindmarsh).

The author wishes to point out that the conclusions and results set out in the paper are by no means exhaustive but are more of a general character and if they should serve as a reliable basis for any future more detailed work in the area the aims of the paper will be fulfilled.

The rocks of the area are of widely differing types and ages ranging from the beginning of geological history to the present day. A summary of the geological succession as present in this area is set out below.

GEOLOGICAL SUCCESSION.

ARCHAEOZOIC.

Igneous and sedimentary complex located in Northern and Central Ranges between Myponga Valley and line from Grey Spur to Edinburgh Swamp (unknown thickness).

---Unconformity----

PROTEROZOIC.

Sedimentary succession forming Northern and Central Ranges east of line from Grey Spur to Edinburgh Swamp and extending to Currency Creek in the Central Range. Includes roches moutonnées (Crozier Hill, Stone Hill, Adair Hill) and the outcrop on Middleton Beach (considerable thickness).

EARLY PALAEOZOIC IGNEOUS ACTIVITY.

Granites of Rosetta Head, Granite Island, etc., Pt. Elliot of probably late Cambrian age.

---Unconformity---

CARBO-PERMIAN.

Fluvio-glacials and tillite of Inman and Hindmarsh Valleys and the coastal areas east of Rosetta Head.

---Unconformity---

MIOCENE.

Polyzoal limestone of the Upper Hindmarsh Valley.

PLEISTOCENE - RECENT.

Shell-bed near "The Gap", consolidated sand-dunes from Pt. Elliot to Goolwa, washouts of Hayborough and later dunes.

GEOLOGICAL RECONNAISSANCE OF PART OF THE HUNDREDS OF ENCOUNTER BAY & GOOLWA

The general geological features of much of this area have been touched upon by Howchin[1] and the same author has given an account in considerable detail of the Late-Palaeozoic glacial features there so well illustrated. There are several publications relating to the igneous intrusions of the neighbourhood of Encounter Bay, chief of which is that by W.R. Browne.[2]

The object of the present undertaking has been to complete a general geological examination of the region with special regard for the problem of the continuity of the sedimentary formation based on the Grey Spur conglomerate and extending to the south-east in somewhat broken outcrops to the coast.

2. THE BROADER PHYSIOGRAPHIC FEATURES.

For the most part the area dealt with is a deeply dissected uplifted block, the southern extension of the core of the Mt. Lofty Ranges. Elevated blocks of the older, more resistant rocks exhibit a marked accordance of summit level over wide areas. This ancient peneplain predates the Middle-Pliocene for it is generally accepted that at that early period of Kosciuskan orogeny it was uplifted partly or wholly to its present level. The altitude of this uplift is indicated by the heights of the following more elevated points along the ridge line: Scrub Mount 1436 ft., (Myponga Hill 1412 ft.) Spring Mount 1358 ft., Mt. Cone 1361 ft., ~~Mount Cone~~

Much of the older peneplained surface is now deeply eroded, most markedly in areas occupied by comparatively soft Late-Palaeozoic glacial and fluvioglacial formations and by Tertiary sands and limestones. Howchin was the first to draw attention to the fact that the Late-Palaeozoic glacial beds occupy deep valleys cut by former glaciers in the Precambrian to Cambrian basement formation and that denudation since the block uplift in Late-Pliocene time is rapidly removing the younger softer sediments and re-exposing the

the old Carbo-Permian glacial topography. The Inman Valley is a classical example of this process.

But the old glacial formations are not restricted to former deep glacial valleys cut in the older rocks for local patches are to be found here and there on the surface of the elevated peneplain.

The glacially carved valleys which were originally choked with tillite and fluvio-glacial sands and clays are slowly being re-opened and the topography is gradually approaching that which existed before sediments filled and obliterated the deep glacier-cut trenches of the late-Palaeozoic.s Inman Valley is such a feature. There the rock floor of the original valley, ~~the basement rock~~, polished and striated where freshly exposed, was originally entombed beneath more than 2000 feet of glacial sediments of which quite 1200 feet has already been removed but, as proved by the Back Valley bore, a further 975 feet still remains in that locality.

It is suggested that prior to the Middle-Miocene time these glacial valley fillings had already suffered some degree of denudation, permitting the entry of the sea when the latter invaded Australia's southern shores. Thus may be accounted the presence of Miocene marine limestone in the upper Hindmarsh Valley and in Myponga Valley.

The effect of post-Kosciuskan erosion has been to develop three belts of elevated country, respectively the Northern, Central and Coast Ranges separated by the depressed regions of the Inman and Upper Hindmarsh. These highlands are essentially constituted of ancient sediments and igneous contributions.

<u>The Coastal Range.</u>

This extends unbroken to the west from Rosetta Head where it is truncated by the Inman Valley which reaches the sea at Encounter Bay. There Proterozoic sediments are intruded by early Palaeozoic granite as at Rosetta Head. To the east of Rosetta Head, no further outcrops of the Proterozoic sediments have been located along the sea-front with the exception of the laminated beds of Middleton Beach.

The Central Range.

This is also an east-west directed range extending eastward from Myponga Valley near Yankalilla across the area herein under consideration.

The older-Precambrian (Barossian) core, from which the later sediments were derived, is extensively developed towards the western limits of our area forming for some distance the eastern flank of the Myponga Valley. From there it extends to a line from Grey Spur (Inman Valley) to the south-west corner of the Edinburgh Swamp in the Upper Hindmarsh Valley. Along this line the overlying basal conglomerate, dipping to the east, begins the Proterozoic sequence. The southern margin of this Central Range runs to Mt. Billy and Peeralilla Hills, where it bends to the south parallel to the Hindmarsh River and the main Adelaide raod. At Brown Hill the trend is again easterly and it follows the coast, distant about one mile, as far as Middleton, thereafter diverging further from the coast.

This highland region is notable especially along the southerly face on account of its remarkably abrupt rise from the floor of Inman Valley. For example, it rises from the floor of the valley at about 30 feet above sea-level to Brown Hill (831 feet) in a very short horizontal distance (see section below). At other places the rise is even more remarkable. These features and others such as truncation of the ranges and rounded contours as at Mt. Billy, Peeralilla Hills, Brown Hill, Rosetta Head, etc., are all typical features of glacially carved topography.

Northern Range.

This highland region extends parallel to the Central Range along the northern side of the Upper Hindmarsh Valley and reaches its maximum height at Mt. Cone (1361 feet). As indicated on the accompanying map, the Barossian complex supporting uniformly stunted vegetation extends as far as the middle of section F where it is overlain by conglomerates and grits forming the base of the overlying Proterozoic formation. Here the exposure of Proterozoic sediments is not very extensive for, to the east, it soon passes beneath

Carbo-Permian glacial sediments. The junction between the earlier and later Precambrian formations in this locality was first established by Professor Mawson in 1939, he then having traced that

Personal communication.

horizon intermittantly from Blackfellows Creek near Mt. Magnificent to the neighbourhood of Mt. Wood Cone.

Throughout the paper E.B. = Hundred of Encounter Bay

and G = Hundred of Goolwa.

3. OLDER PRECAMBRIAN: BAROSSIAN COMPLEX.

Rocks of this age are located in the Central and Northern Range situated to the west of the Proterozoic basal conglomerate. They extend through from the Inman Valley to the Myponga Valley. The rocks represented include a diverse range of ortho- # and para-gneisses and schists. Near the Yankalilla cemetry there is located an epidotised igneous magma (related to the well known occurrence at Houghton). Basic types, when present, are in the form of narrow amphibolitized dykes.

Thus far no mineral deposit of proved economic value has yet been found within this complex. However, rutile and coarse mica have been worked on section 60 Myponga, and near the summit of Mt. Cone in an attempt to produce pig iron. a large body of titaniferous magnetite was quarried many years ago and smelted locally.

4. PROTEROZOIC SEDIMENTS.

Outcrops of sedimentary rocks of this period occupy large areas mainly in the higher country but a few inliers appearing from beneath later glacial sediments are to be found in the depressed ~~lower~~ valley regions and coastal plain ~~areas~~. At the base of the succession these rocks bear a ~~some~~ relationship to the Mt. Magnificent Series (Mawson (8)). Similarly, when allowance is made for their somewhat metamorphosed condition, their character and sequential arrangement suggests that the series may be comparable to the lower divisions of the Adelaide Series as studied near Adelaide, Provided allowance is ~~being~~ made for the fact that here ~~these~~ the sediments were originally deposited some considerable distance from the area of deposition of those occurring on the western side of the Mt. Lofty Ranges ~~nearer Adelaide~~.

Subsequent to deposition, they were involved in great mountain building processes (probably of Cambro-Ordovician age) during which it is presumed the granite magma of the Encounter Bay district was intruded. Thus these old sediments are widely affected by a measure of metamorphism. At the granite contacts thermal metamorphism reaches a high grade (cordierite schists of Rosetta Head) but falls off rapidly at a distance to the biotite and chlorite grade. These latter types are very extensive and with them are associated numerous quartz veins.

Structurally these Proterozoic sediments are generally consistent (with some outstanding exceptions) and the strike and dip vary but little over large areas. At the base of the series, where examined the dip approximates to 65°E and as the series is ascended a gradual increase is to be noted until the beds flanking the Hindmarsh Valley stand at an angle of 80°E. Two areas have suffered under earth movements, namely, a strip below Brown Hill and a further area near Middleton. These will be discussed later.

The Proterozoic Sequence.

For information regarding dips and strikes consult the accompanying maps.

1. The Basal Beds. These rest with violent unconformity on the underlying Barossian Complex. The most striking outcrop is the bold formation of the Grey Spur abutting the Inman Valley in the north-east corner of section 361 (E.B.) (Plate I. no.1). The outcrop then passes across the Grey Spur Creek which enters the valley just east of the Grey Spur.

The section exposed at the Grey Spur Creek is as follows:-

- 45 feet - coarse conglomerate with large pebbles usually notably flattened and elongated in a pebbly base with bands of detrital ilmenite.
- 60 feet - coarse grit, with ilmenite bands.
- 40 feet - fine conglomerate.
- 45 feet - grit, banded.
- 300 feet - dark arenaceous slaty rock.
- 315 feet - dark quartzite bringing the section to Deep Creek.

The outcrop of these basal grits and conglomerates was traced for some distance through section 84 (E.B.), through the south-west corner of 93 and cutting the ridge road near the north-west corner of section 94 (E.B.) as shown on the map. The outcrop was then traced down a tributary into the creek which flows through sections 58 and 57 (E.B.) to the Edinburgh Swamp. The basal bed crosses this creek where it passes through the boundary fence between sections 57 and 58 (E.B.) to be lost in the valley.

Thickness and strike throughout the paper are the true values.

If the basal bed continued on the same strike in the hilly country on the opposite side of the valley it should pass through section 51 (E.B.) It is, however, located in a tributary on the western side of the main creek valley running N-S through F and meeting the valley adjacent to Fernbrook Estate. Ruling out the possibility of folding, A study of the map reveals a noticeable displacement of thes bed in crossing the Upper Hindmarsh Valley. This could be explained by a dip fault with a displacement of slightly over 1½ miles or possibly also by a swing in direction of the strike hidden beneath the upper Hindmarsh Valley filling. In section F (E.B.) the change from the Barossian rocks to the Proterozoic sediments is particularly well marked by an abrupt change in the type vegetation (Plate I no.2) and this break can be seen some distance from the actual outcrop. In this area the vegetation types were:-

(a) growing on the belt of Barossian rock outcrop:-

Eucalyptus cosmophylla, Banksia marginata, Isopogon ceratophyllus, Epacris impressa, Casuarina stricta, Zantharrhoea, and Hakea.

(b) growing on the Proterozoic formation:-

Eucalyptus obliqua, and an undergrowth of shrubs, among which Acacia myrtifolia is prominent.

Under shrubs appear to be the same types but are more dense on the more fertile sediments and the only change is the appearance of Acacia myrtifolia.

The break in vegetation when passing from one series to the other is often so sharp that it conforms absolutely to the strike line of the Proterozoic formation at its junction with the underlying Barossian complex.

2. Interbedded Quartzites, phyllites, slates.

Here the argillaceous types are slaty and even phyllitic, but usually somewhat further metamorphosed to a hornfelsic state in which fine mica is notably developed. A group of such sediments grades from the coarse basal conglomerates and grits. The true thickness of this section of the formation where examined to the east of the Grey Spur is 1450 feet. Throughout this belt, the strike is constant, varying but little from N35°E; the dip is to the east, varying between 55° and 65°.

The effect of the moderate degree of metamorphism to which these rocks have been subjected is to impose on them a more uniform appearance masking their fundamental differences. Furthermore, their characteristics suggest that they all belong to a continuous phase of sedimentation. Types included in this group are all rather dark in colour owing to the development of secondary biotite.

3. Grey Marble.

In the north-west corner of section 96 (E.B.), Deep Creek divides. There the northerly branch, after extending for a short distance, swings abruptly back along the strike of the rock formation. The explanation is the existence in the series of a bed of marble which appears at this horizon. The rock changes from a dark phyllite to a phase with interbedded calcite, then to a grey marble which in turn gradually becomes more sandy until of the nature of a calcareous sandstone and ultimately to a coarse quartzite which forms the high easterly bank of the creek.

The marble is a grey medium grained rock with bands of more coarsely crystalline calcite and it weathers in such a characteristic fashion that it is readily identified.

Microscopically it is composed almost entirely of clear calcite ranging up to 0.7mm. across. Small grains of detrital quartz (maximum grainsize 0.35mm.) are scattered throughout the rock. In addition a few small crystals of pyrite and rarely flakes of muscovite are present.

The sandy phase is a harder, finer-grained rock, richer in small crystals of pyrite. In it, the calcite groundmass contains numerous rounded quartz grains averaging 0.3mm. and with a maximum of 0.6mm. in diameter; occasional fragments of fresh albitic plagioclase are present.

Chemical tests shows this marble to contain inappreciable quantities of magnesium. It is therefore, in that respect, dissimilar to the dolomite marbles of Howchin's lower Adelaide Series.

Owing to the roughness of the country and the absence of outcrops the marble was not traced along the whole outcrop and on the map the broken line indicates the inferred position.

4. <u>Alternating White Quartzites and Phyllites.</u>

This succession of sediments overlies the marble. It was examined along a section line along that branch of Deep Creek which enters from the east through section 96 (E.B.). The sequence is as follows:-

6 feet - saccharoidal quartzite.
108 feet - phyllitic slate.
21 feet - dense white quartzite.
66 feet - phyllitic slate.
54 feet - white quartzite with micaceous laminae.
267 feet - phyllite.
9 feet - white quartzite.
648 feet - phyllite.
30 feet - white quartzite.

For some distance ~~alone~~ above this horizon the outcrops were too poor for detailed investigation, but appeared to be an alternating succession of quartzites and argillites, leading to the next notable outcrop, the White Quartzites.

5. <u>The White Quartzites.</u>

These constitute the back bone of Inman Hill (907 feet) and Strangway Hill and Spring Mount (1365 feet), the highest point in the Proterozoic series of this area.

The strike of the main quartzite band is constant although the dip appears to vary, especially in the gorge cut by the Duck Nest Creek, west of Inman Hill. This quartzite is mainly a saccharoidal white variety.

Although the outcrops of this wide band of quartzites were not actually followed it is known from a traverse made across the country that large areas of sections A^2, B and D (E.B.), are covered by lighter coloured quartzites, and it may be assumed that displacement owing to folding or faulting on a large scale is negligible.

Above the wide quartzite belt there is a series of greywacke siltstone hornfels out cropping along the Hindmarsh River above the main falls. At the main branch of the river in section 615 (E.B.) the creek is diverted by a massive greywacke hornfels band and follows the strike for some distance.

East of the Hindmarsh River, observation of the sequence of outcrops is affected by surface cover in the deep valleys on either side of Mt. Billy. However, it appears that the white quartzite series agai continues and Mt. Billy consists entirely of white quartzite with a steep dip to the east. Similarly the outcrops of Peeralilla Hill range from a coarse white banded and cross-bedded quartzite to a darker and less pure quartzite on the eastern side of the hill. There is a strong quartzite band running along the edge of the valley between Mt. Billy and Peeralilla Hill. In section 267 (G) it outcrops between the creek and the road, striking N.34°E. and dipping at 89°E. Here it is a light coloured, feldspathic quartzite with irregular fine dark banding. A further similar outcrop was examined where the road crosses the hundred boundary and in section 161 (G). Here the strike appeared to be N.54°E. and the dip 70°E.

At this stage outcrops on the northern side of the Upper Hindmarsh Valley may be mentioned. Above the basal beds there is a break, without outcrops, which again appear on a ridge forming the western boundary of sections 105, 106, 107 (E.B.). There a strongly developed, light-coloured quartzite outcrops, followed by a hard white persistent band of fine-grained quartzite, which strikes parallel to the road in sections 105, 106, and 107 (E.B.).

6. Upper Members of the Series.

Of particular interest and constituting quite a problem in structural geology is a strip of country west of Brown Hill. As shown on the map a strong undisturbed band of hornfels (strike N30°E, dip 80°E), runs from the edge of the outcrop in section 112 G. through sections 46, 124, 2414 (G) etc. The hills of sections 51 and 69 (G) have outcrops which are again back to the normal structure. The intervening strip which extends for some distance to the north has been strongly folded into an alternating series of pitching anticlines and synclines just as if they had been concertinered between the two undisturbed blocks. The structure of the area is well illustrated in the short steep creek in section 119 (G).

Measurements made in the main creek in section 119 (G) gave a pitch of 40° to the south-east while the cleavage direction remains constant at N10°W. The rocks concerned may be described as quartz-biotite-hornfels.

Above the white quartzite of Peeralilla Hill, there is a monotonous thick series of quartz-biotite hornfels, phyllites and siltstones. The next bed in the succession with definite characteristics is exposed in the large quarry in the middle of section 2314 (G), located on the coastal side of the range. The rock type is an arenaceous banded sediment in which dark and light bands alternate, their colour accentuated by metamorphism. The individual bands are irregular in thickness, some being narrow and others much wider.

When microscopically examined this rock has the following characters. The darker bands are the usual abundant hornfelsic type, so common this area, and are a fine grained aggregate of biotite and quartz with a few grains of yellowish epidote. As the lighter bands are approached the grain-size increases steadily and the amount of epidote and its grain size increases until finally in the light bands the rock is simply an aggregate of coarse grained quartz and yellow epidote. Throughout the quartz grains tend to be angular in shape. The lighter epidotic bands represent former impure calcareous bands in which alumina was an abundant impurity. Under thermal metamorphism the reactions taking place resulted in the complete transformation into epidote.

Other belts in the same formation show well developed puckering of the epidotic bands evidently penecontemporaneous folding.

The only outcrop of older rock on the sea front east of the bluff occurs at Middleton Beach and the type is the epidotic banded rock mentioned above. However, here the strike has changed appreciably to a direction near east-west while the dip is variable but generally steep. The distance apart of the outcrops is 1½ miles and such a sudden change in strike means that either, or both, folding and faulting of some intensity has been at work, at a time possibly connected with the intrusion of the granites. Though more extended, the outcrop along the beach is essentially similar to that in the quarry. One band in the series is of particular interest. This quartzitic band has a number of of apparent pebbles weathering out (see plate I no.3) and at a first glance they suggested tillite. However, they all appear to be similar to the rock in which they are embedded. When dislodged, they leave an impression in the softer rock, and though they have the appearance of pebble bands they may be explained by a concretionary origin.

As has been indicated on the map, the outcrop along the beach is intensely folded into a succession of synclines and anticlines. The outcrop continues along the bed of the creek through section 2258 (G).

In a small quarry just east of the bend in the road running to the west of section 2323 (G) an interesting rock type was located, apparently stratigraphically above the quartzite outcropping in the north-west corner of 2323 (G). The outcrop is a fine-grained white rock with fine red bands of irregular spacing and thicknesses, with the characteristics of bedding planes. Jointing is complicated and on the surface of the broken blocks both pale-green and pale-brown micas are visible. In the quarry a crush zone can be seen in the face running north-south. The rock weathers to a stiff clay and is quite unsuitable for road-making (the purpose for which it has been quarried).

Microscopically this rock is almost a pure feldspar aggregate. The feldspar is in small grains with sinuous boundaries and occasionally shows multiple twinning. The extinction angle in the symmetrical zone on one twinned feldspar is ± 13°. The interference figure in one case at least is biaxial positive. The composition would then be either almost pure albite or basic oligoclase, albite being the probable answer.

In this rock quartz is scarce and occurring only as minute interstitial grains. Rutile in brown, euhedral, pleochroic crystals is the red mineral forming the banding seen in the hand specimen. Apatite is common in small grains and a few tiny zircons are present.

~~The writer was unable to determine~~ The relationship of this rock to the surrounding sediments is uncertain owing to poor outcrops. It is suggested that pneumatolysis connected with the granitic intrusions has here introduced soda into the sedimentary formation.

Outcrops further to the east do not appear to be structurally disturbed, especially those due east of Kerby Hill. There is ~~there~~ an uninteresting sequence of dark hornfels types as far as south of Macfarlane Hill. These beds represent the highest members of the series in the area.

PALAEOZOIC IGNEOUS ACTIVITY.

In southern South Australia and particularly in the area under study, there is good evidence of considerable igneous activity of post-Proterozoic age. Although it is not yet certain, the evidence accumulating, points to Late-Cambrian as the period of this activity (Mawson and Parkin (4)). For the time being at least we may assign to this period the granites of Cape Willoughby (Kangaroo Island) and Encounter Bay.

It is to be observed that the granite outcrops of these areas are strung out in linear arrangement. Although it seems distinctly possible that the granites in the Murray Bridge to Mannum area are related to those of Encounter Bay the present state of our knowledge prohibits such an assumption.

The Encounter Bay outcrops have been described by Browne (5) and more recently Kleeman (6) has dealt with the problem of the "Diorite" of Granite Island.

Until the author's visit, no geologist appears to have visited Pullen Island. This low granite island situated off the entrance to Horseshoe Bay, Port Elliot, is somewhat over 350 yards in length and 100 yards in breadth. The rock varies from the even-grained type of granite met with in portion of the Port Elliot outcrop, to a notably porphyritic variety in which the feldspars weather out in marked relief. Numerous dark transfused xenoliths are distributed through the granite as is the case on Granite Island. Some aplitic leuco-granite was also observed, in one place carrying acicular tourmaline.

6. CARBO-PERMIAN GLACIAL AND FLUVIOGLACIAL SEDIMENTS.

Within the area under consideration there is splendid evidence of a late Palaeozoic glaciation. ~~and~~ Abundant tillite and fluvio-glacial sediments of Carboniferous to Carbo-Permian Age are represented. ~~to be met with.~~ These have been already described by Howchin and others. However, during the progress of this work, delineation of the glacial boundaries was extended and new areas were added to Howchin's previous records. Only new features, areas and types are included in this paper. For further information the papers listed in the bibliography should be consulted.

Over this extended area the glacial sediments range from unconsolidated sands and sandy argillites, with or without erratics, to firmly lithified equivalents. The glacial topography is well illustrated by the characteristic roches moutonnees forms of Rosetta Head, Crozier Hill, Martin Hill and Adair Hill, ~~and~~ also the notable physiographic features of Brown Hill, Peeralilla Hills, Inman Hill and Mt. Billy (Plate II.no.5).

Based mainly on observations of ~~the~~ glacial striae, Howchin showed that the movement of the ice was from a now non-existent high land formerly located to the south of the present coast line. Owing to the wide-spread nature of the glacial deposits and their tremendous thickness the ice formation was evidently in the nature of a continuous ice-sheet. In the Inman Valley, the direction of movement is given by Howchin (2) as W20°N. It seems almost certain that at some stage the glacial material covered almost all of the old land surface, for small outliers of glacial sands, pebbles, and erratics are found scattered over the high land areas and not merely restricted to the valleys. In sections 182, 2100, 2413 (Hd. Goolwa), glacial sediments flank the road which traverses the top of the old peneplain. Also located in the mountainous area within Section F (E.B.) was found a small glacial outlier with smoothed and faceted pebbles.

Of particular interest are the consolidated fluvio-glacial sandstones which outcrop along the shoreline of Encounter Bay from Watson Gap to Rosetta Head. This was examined in some detail at Chiton Rocks where good outcrops occur. In this particular area, the rock shows very clearly, cross-bedding on a small scale. Though the dip varies from place to place, it is generally at a low angle to the south-east with the strike parallel to the shore. A further outcrop appears off-shore where it extends for some distance parallel to the beach as a shelf, which is bared at low tide. Where studied, three main types of rock were recognised, namely: (a) Coarse banded variety, Fig. I, B. (b) Fine banded variety, Fig. I, A. (c) Brown ferruginous variety.

(a) A grey compact, banded sandstone, located 150 yards west of the main ring of rocks (Chiton) and noteable for its resistance and compactness.

Microscopically, this rock is composed of fine grit, the particles being almost entirely very angular, fragments of quartz of all sizes up to a maximum of 0.6 x 0.4mm. together with rarer fragments of fresh, twinned plagioclase (with low extinction angle), perthite and altered orthoclase. Tourmaline is present in small grains. Pleochroic from colourless to blue. To be observed also are brown biotite, green chlorite, muscovite, iron oxides, zircon, sagenitic quartz and long, fine ~~rutile~~ needles of rutile. These constitutents are all embedded in a clear calcite matrix as illustrated.

(b) This is a grey, fine-grained equivalent of (a) and occurs on the beach near the main ring of rocks.

Microscopically it is similar to (a) but finer with minute chips and angular fragments up to0.2 x 0.1mm. Rather notable amounts of zircon are present and a still larger amount of black iron oxide. When fresh, it has an almost flinty nature.

(c) This particular variety, which is found midway between the other two outcrops, differs in that it has a characteristic brown colour with dark spots not unlike minute dendrites. It also contains numerous small grey inclusions of a soft clayey material.

Microscopically this rock is very fine grained with a mineral assemblage similar to (a) and (b). Unlike (a) and (b) the cement is a light-brown iron oxide which was probably derived from an original sideritic cement.

The only other consolidated glacial sediments examined by the writer were (a) the ironstone conglomerate (containing an assortment of glacial pebbles) capping parts of the sandy ridges which run from west of Victor Harbour towards Mt. Billy, and (b) the banded fluvio-glacial sandstone resting on Selwyn's Rock, Inman Valley.

This fluvio-glacial sandstone is rich in iron and on weathering the bedding is (seen to be) horizontal but the overlying till has been contorted either during deposition or subsequently. A specimen of this sandstone, which was collected during one of my visits to the area, is of special interest in that it was broken from the polished basement rock and has carried with it a negative, as it were, of the underlying polished and striated quartzite. The tillite overlying Selwyn's Rock has a thickness of about 20 feet. It is of a notably sandy nature and rich in erratics of many types - red and white quartzites, granite (Encounter Bay types) porphyries and metamorphic rocks mainly hornfels.

Of some interest are the four large washouts, which intersect at regular intervals the elevated coastal cliff between Victor Harbour and Watson Gap. The drainage of the area has developed these deep washouts in the soft tillite. During the wet season the washouts cut-back rapidly at their head and their control is a matter of some urgency. Fortunately the plant Kunzea pomifera covers the ground as a thick mat and has controlled erosion to some extent and would possibly be of use in other areas where similar problems arise.

Four main types of glacial sediments appear in the profile uncovered by the deepest washout. The usual foot of dark sandy topsoil rests on a layer of coarse material with abundant pebbles, many of which are faceted and polished. Fragments of granite are conspicuous in this horizon which owes its richness in coarser material partly to fluvial concentration.

The normal sandy variety into which the coarser material grades with depth is a pale-buff sand associated with which is a certain proportion of rock flour. The chief constituents are sub-rounded particles of quartz with minor amounts of other mineral fragments. The average grain-size of this material is in the vicinity of 0.3mm. Under the buff sand was a harder ferruginous sandstone with coarser fragments (average 0.5mm.) including feldspar and iron oxide as well as abundant quartz.

Finally, there are conspicuous masses of grey sandstone incorporated within the body of the fluvio-glacial sands. These correspond to the "giant's boilers and kettles" and "fossil pumpkins" mentioned by Howchin. Microscopically this particular sand is similar to the others and is mainly quartz together with feldspar and iron oxides ranging up to a maximum grain-size of 0.7mm. with the average in the vicinity of 0.3mm. The outstanding distinction is the presence of calcium carbonate which binds the sand grains together. This accounts for the characteristics of the material; that is the colour, surface hardening, and resistance to weathering. Their origin is difficult to explain but is probably concretionary centered upon lime-rich erratics incorporated in the tillite.

Mainly as a matter of interest but also to obtain an idea of the underlying sediments a bore was sunk on Section 28 (G) to a depth of 25 ft. After passing through 1 foot of dark sandy top-soil a hard white limy layer was met with a thickness of 2 feet. From this stage samples were taken at regular intervals. This fluvio-glacial sand is of a homogeneous nature; the average grain-size increasing slightly with depth from 0.5mm. at 5 ft. to 0.8mm. at 22 feet (Fig. I, G). The lime content gradually decreased with depth until the water table was reached at 13 feet 6 inches when effervescence with dilute hydrochloric acid ceased. Quartz constitutes the bulk of the sand with minor amounts of feldspar, zircon, iron oxides, and fragments of various types of rock. When shaken with water a large number of tiny flakes of mica can be seen in suspension.

A percentage grainsize analysis of this sand from a depth of 11 feet below the surface was undertaken under direction of Mr. A.W. Kleeman. The result graphically recorded below suggests that it is an uncontaminated fluvioglacial sand. For comparison the beach sand from Chiton Rocks was also sieved and graphed. On the graph, also, are shown the figures of Trask's (9) constants for describing sediments. It will be noticed that in both sediments the skewness is negligible. The beach sand

The morainic material on section 467 (E.B.) was observed to be ... erratics. Further possible boulders were found just below the road

(So = 1.45) is very well sorted and the fluvio-glacial sand (So = 3.9) is moderately well-sorted.

Granite erratics were located in the north-east corner of section 217 (E.B.) and in the corner of section 132 adjacent to the road.

Further points of interest that have come under observation are the following: (1) The parallel sandy ridges west of the Hindmarsh River with their topping of leached sand grading in places to reddish clay e.g. road junction at southern corner of section 135 (E.B.). (2) Deep washouts south of Peeralilla Hill and in the Hindmarsh Valley. (3) The road leading to the higher country along the eastern boundary of section 631 (E.B.) passes through sandy glacial rich in pebbles and larger erratic some of which show striations. (4) Not far from the base of the Adelaide series in wild country towards the N.E. corner of section F (E.B.) a further small outlier of sand and pebbles at a much higher altitude indicated the extent of the deposits. (5) The Edinburgh Swamp situated in a basin at the western end of the upper Hindmarsh Valley is surrounded by precipitous country, with the Barossian Complex to the west and Proterozoic sediments to the east. This depression in the surrounding country, is choked with glacial sands, pebbles and clays.

Situated in a valley immediately behind the coastal hills north of Port Elliot and Middleton is a further glacial valley, possibly originally connected with the Hindmarsh Valley. It begins in section 2439 (G), and extends for some distance more or less along the axis of the country and leads towards the Murray River plains.

Vegetation.

The scrub vegetation of the glacial areas is especially characteristic, most notable in the higher areas where the surface soil has become ~~badly~~ effectively leached and drained of soil water. Perhaps the most typical areas are those, as yet uncleared, in sections 138 and 134 (G) just below the highlands, with characteristic acacias, casuarinas, Xanthorrea and other minor vegetation including plentiful heath, orchids in favourable areas.

7. MIOCENE SEDIMENTARY ACCUMULATIONS.

The Miocene encroachment of the sea over the land in southern South Australia is recorded within the area under review. Occurrences of Miocene sediments are however, very limited though no doubt originally extensive but since removed by denudation.

The presence of Miocene limestone in the upper reaches of the Hindmarsh River was reported by Howchin (2) and a search of the area revealed four separate small outcrops (which are shown on the map). Two small outcrops are located in the river banks itself in section 601, another in a similar position just through the fence in section C, and a further more massive outcrop, which has been quarried, was found in a small tributary on the side of the rise in Section D, all in the Hundred of Encounter Bay. By ~~aneroid determined~~ aneroid observations made height the highest outcrop is about 600 feet above sea level, thus indicating a post-Miocene elevation of the land surface in this area of more than 600 feet.

These outcrops are of marine limestone weathering out as large boulders with the fossils and fragments in relief. Fresh faces of the bright pink rock have a handsome appearance as compared with the cream colour of weathered surface. It is a compact mass of fossils, mainly polyzoans, with occasional foraminifera visible.

A partial analysis of a typical specimen of the limestone where free from obvious sand gave the following results:-

SiO_2	... 2.24%
Fe_2O_3, Al_2O_3, etc..	... 0.52
CaO	...51.93
MgO	... 1.38
P_2O_5	... 0.01

8. POST-TERTIARY FEATURES.

Elevatory earth movements which began in late Tertiary times have continued in this area, to the present day. Just east of Watson Gap in the railway cutting (section 29, Encounter Bay) a richly fossiliferous shell-bed of early Pleistocene age is located. (Howchin (2) mentione a further shell-bed in a cutting at the junction of the railway and the Hindmarsh River). This latter shell-bed extends along the railway for 250 yards, the width being undeterminable. From aneroid measurements its present elevation is in the vicinity of 45 feet above sea-level. The outstanding shells, Anadara and Ostrea, are very thick-shelled suggesting that they were living near the shore-line. Fragment of granite and masses of clear and dark quartz of glacial origin are abundant in this formation.

A list of fossils, kindly identified by Mr. B.C. Cotton of the South Australian Museum, is as follows:- Ostrea sinuata (L.K.), Anadara trapezia (Des Hayes), Anapella pinguis (Crosse & Fischer), Benbicium imbricata, Brachyodontes hirsutus (L.K.), Glycimeris striatularis (L.K.), Liotia australis, Macoma deltoidalis (L.K.), Mactra australis (L.K.), Nassarius pauperatus, Turbo undulata, Venerupes crebrelamellata (Tate).

The consolidated Sand-dunes.

West of Watson Gap are the outcrops of the fluvio-glacial sandstone while to the east of this point the consolidated sand dunes appear in irregular outcrops on the beach and in the shallow water. The fact that parts of this formation are now below sea-level indicates a recent rise of the latter. The most conspicuous part of this formation is found in the cliffs against the granite of Port Elliot where the dune rock rises to a height of about 80 feet and is capped by Kunkar travertine. The face has been deeply weathered and sculptured into a jagged surface on which the cross-bedding, typical of the dune formations is clearly visible. The extent of the dune rock, both here and in other areas, is indicated by the surface kunkar which covers quite an area in this vicinity, (e.g.) sections 32 and 29½. The dune rock appears again as sea-cliffs east of Middleton Beach. This outcrop which exhibits fine examples of cross-bedding on a large scale, was followed as far as the end of section 2248 (G), at which point the height of the cliffs has greatly diminished. Inland from the Goolwa Beach large areas are covered by kunkar indicating the extent of the dune rock.

A sample of the dune sandstone from the cliffs at Port Elliot was examined in detail with the following results. Macroscopically it is a pale brown sandstone with abundant shelly material in shades of brown to white giving the colour to the rock.

Microscopically examined, it is even-grained and consists mainly of well-rounded quartz grains with minor amounts of other minerals, feldspar, tourmaline, garnet, spinel, monazite (or staurolite), and rarely rutile, and mica together with organic remains. The cementing material is finely crystalline calcium carbonate.

The grain-size is constant, the extremes being 0.70mm. to 0.30mm. while the majority of the rounded quartz grains are in the vicinity of 0.5mm. in diameter. A Rosiwal estimation gave the following percentages of minerals present.

Quartz...	67.1
Garnet...	2.8
Monazite, tourmaline, etc..	0.2
Cement ($CaCO_3$).	29.9

Heavy tidal wash and strong prevailing winds have developed a surface film of gem sands at various places along coast line, notably near the mouth of the Hindmarsh River and the stretch of beach west of Middleton (Thomas(7)).

Acknowledgements.

My sincere thanks are due to the University of Adelaide for the use of its laboratory facilities and particularly to Sir Douglas Mawson, Professor of Geology, whose guidance and assistance has been an inspiration throughout the preparation of the paper. I am also grateful to Mr. A.W. Kleeman, Mr. H.E.E. Brock and other members of the Geological Department (Adelaide) for their advice, criticism and practical assistance. I am also indebted to those good people who assisted me in the field and finally to my parents without whose cooperation the work could never have been attempted.

REFERENCES.

(1) FENNER, C. "The Major Structural and Physiographical Features of South Australia". Trans.Roy.Soc.S.Austr. vol.liv (1930).

(2) HOWCHIN, W. "The Geology of the Victor Harbour, Inman Valley and Yankalilla Districts, etc." Trans.Roy.Soc.S.Austr.vol.l, (1926)
(This paper contains a full list of previous paper on the Carbo-Permian glaciation).

(3). ENGLAND, H.N. "Petrographic Notes on Intrusions of the Houghton Magma in the Mt. Lofty Ranges. Trans.Roy.Soc.S.Aust.vol.lix(1935)

(4) MAWSON, D and PARKIN, L.W. "Some Granitic Rocks of South-Eastern South Australia". Trans.Roy.Soc.S.Aust. vol.lxvii (1943).

(5) BROWN, W.R. "The Igneous Rocks of Encounter Bay, South Australia". Trans. Roy. Soc. S.Austr. vol.lxiv (1920).

(6). KLEEMAN, A.W. "The Nature of the Origin of the So-called Diorite Inclusions in the Granite of Granite Island. Trans. Roy. Soc. S.Austr. vol lxi (1937).

(7) THOMAS, R.G. "The Gem-Sands of Encounter Bay". Trans. Roy. Soc. S. Austr. vol.lxvii (1923).

(8). MAWSON, D. "The First Stage of the Adelaide Series: As Illustrated at Mount Magnificent". Trans.Roy.Soc.S.Austr. vol.lxiii (1939).

(9) Trask, P.D "Origin and Environment of Source Sediments of Petroleum". The Gulf Publishing Co., Houston, Texas, (1932).

PLATE I.

No. 1. Basal Beds (Grey Spur).
References page 9.
(Photographed by A.W. Kleeman).

No. 2. Illustrating the Vegetation Break between Barossian and Proterozoic Strata. Looking west in Section F. (E.B.) Reference page 10.

No. 3. Concretionary structure in Proterozoic Strata, 100 yards west of main Middleton Beach Road. Reference page 15.

PLATE II.

No.4 Pullen Island (Looking East).
Reference page 17.

No.5. Panorama from Brown Hill vicinity looking towards Peeralilla Hill and the Hindmarsh Tiers. Reference page 18.

No. 6. View across Selwyn's Rock with loose glacial sediments forming river bank in the background with protruding granite erratic. Reference page 20.

PLATE I.

No. 1. Basal Beds (Grey Spur).

No. 2. Illustrating the Vegetation Break between Barossian and Proterozoic Strata. Looking west in Section F. (E.B.) Reference page 10.

No. 3. Concretionary structure in Proterozoic Strata, 100 yards west of main Middleton Beach Road. Reference page 15.

PLATE II.

No.4 Pullen Island (Looking East).
Reference page 17.

No.5. Panorama from Brown Hill vicinity looking towards Peeralilla Hill and the Hindmarsh Tiers.
Reference page 18.

No. 6. View across Selwyn's Rock with loose glacial sediments forming river bank in the background with protruding granite erratic. Reference page 20.