# "The South Maslin Sand and its Relations to the Eocene Sequence of St. Vincent Basin."

by

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# The South Maslin Sand and its relations to the Eocene sequence of the St. Vincent Basin.

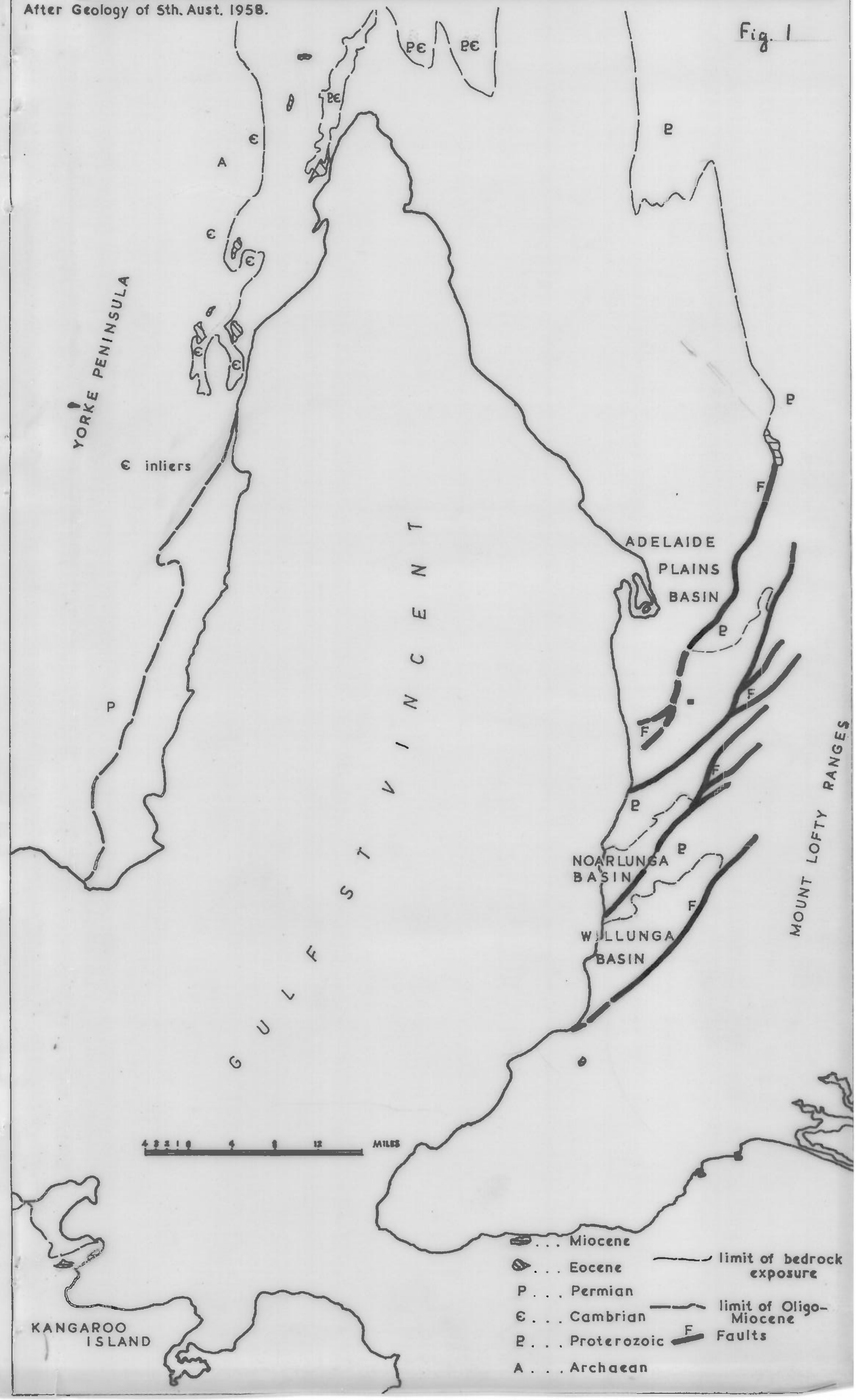
## Abstract.

Field and laboratory investigations of the North and South Maslin Sands, and to a lesser extent, the Tortachilla Limestone, have been carried out. Lithological and organic features of the South Maslin Sands have been compared with corresponding features of the North Maslin Sands and the Tortachilla Limestone. The stratigraphic relationships of the South Maslin Sands and each of the adjoining Eocene formations have been examined. Conclusion have been made as to the depositional environments of each of the three formations, and discussed in connection with their stratigraphic relationships.

# LOCATION OF SUB BASINS IN ST VINCENT BASIN

After Geology of Sth. Aust. 1958.

Fig. 1



# I INTRODUCTION

## 1) Location and geological setting.

The area bounded by the Mount Lofty Ranges to the east, Yorke Peninsula to the west, and Kangaroo Island to the south, contains a sequence of Cainozoic sediments, at least 3,000 feet thick in places, and is known as the St. Vincent Basin. Much of the area is covered by the present St. Vincent Gulf, but ~~east of~~ around the gulf Tertiary sediments are known from surface outcrop and bore-holes. The now subaerial tectonic embayments along the eastern margin of the basin have been named, from north to south, the "Adelaide Plains Basin", "Noarlunga Basin" and "Willunga Basin", the extent of which are shown in the map figure 1. (Glaessner and Wade, 1958)

The "South Maslin Sands" is a formation in the type sequence of the Tertiary sediments in the St. Vincent Basin, defined in coastal exposures along Maslin and Aldinga Bays by Reynolds, (1953). The formation has been recognized in other parts of the basin.

## 2) Previous investigations.

Early workers include Tate (1878, 79, 99) and Howchin (1911, 23). Later stratigraphic studies include those of Glaessner (1951, 53 a and b), Crespin (1954) and Cochrane (1956). Detailed mapping of the Noarlunga and Willunga Basins was carried out by Woodard (1952), Reynolds (1953), Wade (1953) and Daily (1953). Reynolds (1953) established the sequence along Maslin and Aldinga Bays as the type sequence for Tertiary sediments of the St. Vincent Basin.

## 3) The stratigraphic sequence.

Reynolds (1953) defined a number of formations in the type Tertiary sequence, and many of these have been recognized in other parts of the basin. The sequence, shown in table 1, (~~opposite page 2~~), rests with angular unconformity on folded and eroded Proterozoic and Cambrian sediments, except in parts of the Maslin Bay area, where a thin sequence of sands, clays and boulder-beds, probably of Permian age, separates the Proterozoic and Tertiary rocks (Reynolds, 1953, page 115).

Table : The Tertiary Sequence of Maslin and Aldinga Bays, after Reynolds (1953).

| Formation | Lithology | Thickness |
|---|---|---|
| Pliocene Limestones. | Limestones, sands and clays | 18-20 feet. |
| Angular | Unconformity. | |
| Port Willunga Beds. | Polyzoal Limestones sands and marls. | 111½ feet. |
| Chinaman's Gully Beds. | Non-marine sands, silts, clays. | 5½ feet. |
| Blanche Points Marls. | Marls. | 101½ feet. |
| Tortachilla Limestone. | | |
| i) Glauconitic Limestone Member. | Fossiliforous glauconitic limestone. | 3 feet. |
| ii) Polyzoal Limestone Member. | Fossiliferous polyzoal sands. | 3-6 feet. |
| South Maslin Sands. | Limonitic Sands. | 100-160 feet. |
| North Maslin Sands. | White gravels, sands with some clays. | 64 feet. |
| | Total | 338½-451½ feet. |

### 4) Age of the lower part of the stratigraphic sequence

In the lower beds of the Blanche Point Marls, Parr discovered *Hantkenina alabamensis compressa* Parr, of Upper Eocene age and other Eocene fossils (Glaessner (1951, page 275)). This dates the sediments below as pre-Upper Eocene. On this basis, Reynolds (1953, page 138-9) considers the Tortachilla Limestone is probably Middle to Upper Eocene age, the South Maslin Sands lower Eocene, and the North Maslin Sands "basal Tertiary". No distinctive index fossils were recovered during the current investigation, so that no further conclusion could be drawn on the matter of the age of the South Maslin Sands.

### 5) Nature and scope of the present investigation

#### a) Object.

The object of this investigation was to examine the textural, structural and compositional features of the South Maslin Sands, to determine the conditions of its deposition, and to determine in as much detail as possible the stratigraphic relationship of the formation to other sediments of the St. Vincent Basin. Lithological and organic features of the formations immediately above and below the South Maslin Sands were briefly examined and compared with similar features of the latter in order to elucidate the stratigraphic relationships of the three formations.

#### b) Field investigation

These included mapping controlled by aerial photographs with a scale of 330 feet = 1 inch where outcrop was more extensive, and military survey maps with scale 1" = 1 mile elsewhere. Most outcrop is confined to scattered, near-vertical cliff sections of limited extent. The nature and extent of the upper and lower limits of the formation, sedimentary structures and macro-fossil content were recorded at outcrops, and the attitude of the contacts and bedding plane features measured.

Cross-bedding was recorded with a Brunton compass on bedding planes exposed with a small trowel. The measurements were restricted to one reading for each set of foresets, and to the axis of trough-type sets.

An attempt was made to map subdivisions, on lithological grounds, within the formation. This was possible on a well exposed wave-cut platform along Maslin Bay, but the units mapped there could not be traced back into the cliff exposures. The mapping was carried out with measuring-tape and compass, using a line of base-stations along the foot of the cliffs, and the resulting map fig. is reproduced in figure 32, at the end of the paper

## c) Laboratory investigations.

Samples of North and South Maslin Sands, and Tortachilla Limestone were collected for laboratory investigations. Microscopic examination allowed observation of textural, compositional and organic features. Macro- and micro-fossils were collected, and some mounted on slides.

Mechanical grain size analyses of North and South Maslin Sands were used to determine grain size, degree of sorting and distribution of mineral components. Grain size distributions were recorded in the form of cumulative curves, many of which are presented in figures figs. 24-30, ~~follow~~ at the end of the paper

X-ray analyses, using the powder photograph method, of several constituents of the sediments were used to identify specific minerals.

## d) Descriptive terms used.

### i) Grain size.

For simplicity in preparation and interpretation of cumulative curves, grain sizes have been expressed in terms of Krumbein's φ unit, as defined in Krumbein and Pettijohn (1938, page 84). Below is a table relating diameter in mm. and in φ units to Wentworth grain size classes, (as given by Krumbein and Pettijohn (1938, page 84)), and the BSS sieves used in the current investigation.

| Diameter in mm | Diameter in $\phi$ unit. | Wentworth class | B.S.S. sieve. |
|---|---|---|---|
| $>4$ | $<-2$ | pebble | $\simeq \frac{3}{16}$" |
| 4 to 2 | -2 to -1 | granule | +8 |
| 2 to 1 | -1 to 0 | very coarse sand | +16 |
| 1 to $\frac{1}{2}$ | 0 to 1 | coarse sand | +30 |
| $\frac{1}{2}$ to $\frac{1}{4}$ | 1 to 2 | medium sand | +60 |
| $\frac{1}{4}$ to $\frac{1}{8}$ | 2 to 3 | fine sand | +120 |
| $\frac{1}{8}$ to $\frac{1}{16}$ | 3 to 4 | very fine sand | +240 |
| $<\frac{1}{16}$ | $>4$ | silt + clay | -240. |

ii) Sorting

Quartile measures as described for $\phi$ units by Krumbein and Pettijohn (1938, page 233) were used to obtain quartile deviation (QD$\phi$) from the cumulative curves. Values of QD$\phi$ were converted to values of Trask's sorting coefficient, $S_o$, by means of a graph in Krumbein and Pettijohn (1938, page 235). Using data as given by Pettijohn (1957, page 37) on values of $S_o$ and their meaning, it has been decided to use the following terms.

$S_o$ values 0 - 1.0 = good sorting
$S_o$ values 1.0 - 2.0 = moderate sorting
$S_o$ values >2.0 = poor sorting.

iii) Cross bedding.

The descriptive terminology of McKee and Weir (1953) has been used to describe cross-bedding. The following terms were used:

planar-type cross-bedding: sets whose lower bounding surface is one of planar erosion

trough-type cross-bedding: sets whose lower bounding surface is a curved surface of erosion.

lenticular shaped sets : sets bounded by converging surfaces, at least one of which is curved.

wedge shaped : sets bounded by converging planar surfaces.

tabular shaped : sets bounded by planar, essentially parallel surfaces.

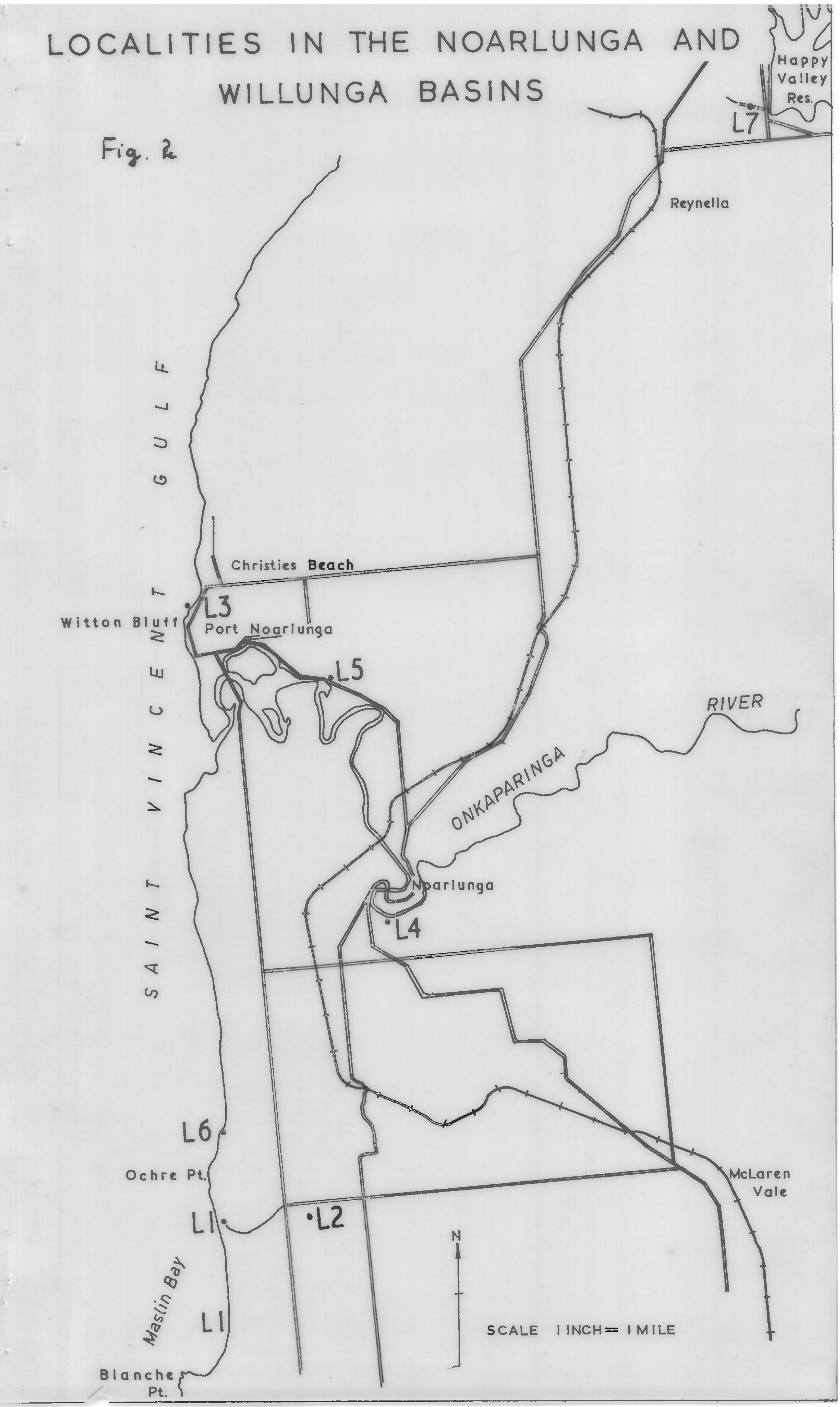
Small scale cross-bedding : cross strata $< 12$ inches in length.

Medium scale cross-bedding : cross-strata 1 to 20 feet in length.

Large scale cross-bedding : cross-strata $> 20$ feet in length.

# LOCALITIES IN THE NOARLUNGA AND WILLUNGA BASINS

Fig. 2



## II THE NORTH MASLIN SANDS

### 1) General.

The sands and clays at the base of the Tertiary sequence at Maslin Bay were included by Reynolds (1953) in his "North Maslin Sands". The formation has been recognized in several parts of the Saint Vincent Basin. The characteristics of these sands will be described briefly for later comparison with the overlying South Maslin Sands.

### 2) Exposures of the formation associated with South Maslin Sands.

#### a) Willunga Basin

i) Along the shore of the northern part of Maslin Bay, and in the Noarlunga sand pit. This is the type area for the sands (Reynolds (1953). (See map, figure 2 at L1).

ii) In Albert's sand pit, about ½ mile east of L1. (L2)

#### b) Noarlunga Basin.

i) Witton's Bluff, Christies Beach. (L3)

ii) Noarlunga township. (L4).

### 3) Lithology.

#### a) Mineralogical composition.

The formation includes quartz gravels, sands and silts, with some clay bands. Material of silt size and larger consists of about 99% quartz, with minor quantities of dark coloured minerals and colourless muscovite flakes. Some bands of quartz grains, normally white or colourless, are stained by red or brown iron oxides. Small inclusions of black minerals, probably the same as black grains, are found in some quartz grains.

#### b) Texture.

i) Size and sorting.

The North Maslin Sands show variation in grain size from pebbles to clays, with the greater proportion in sand-sized classes. There is a general lessening of grain size from the base to the top of the formation in the Noarlunga Sand Pit, where bands rich in pebbles and granules tend to be most common in the basal parts, while sands at the top tend to be medium or coarse grained. In Albert's sand pit a similar gradation was found from grain size analyses, as tabulated below:

Table 2.

| Sample No. | Stratigraphic position | Modal Class | Wentworth grade. |
|---|---|---|---|
| A196/190 | Top of Nth. Maslin Sands, under Sth. Maslin Sands. | 2φ to 3φ | fine sand |
| A196/171 | Approx. 60 feet below top of Nth. Maslin Sands. | 1φ to 2φ | medium sand |
| A196/172 | Approx 85 feet below top of Nth Maslin Sands, (in Bore 1, 24-26 feet). | -2φ to -1φ | very coarse sand. |

Grain size, expressed as the modal class for each sample, decreases upwards in a broad trend. The location and cumulative curves for the above samples are shown in figure 24. ~~respectively~~

Grain size analyses of 5 samples show quartile deviations (QDφ) in the range 0·35 to 0·90, corresponding to a range 0·5 to 1·7 for Trask's sorting coefficient, So. The latter range indicates good to moderate sorting.

The degree of sorting can be correlated with grain size, as shown in table 3, where there is only one exception to a trend for increase in degree of sorting with decrease in average grain size, as represented by the median diameter.

Table 3.

| Sample no. | Median diameter. | Sorting coefficient, So. |
|---|---|---|
| A196 / 172 | -0·6φ (coarsest) | 1·7 (poorest sorting) |
| 197 | 0·2φ | 0·5 |
| 171 | 1·3φ | 1·2 |
| 189 | 1·75φ | 1·0 |
| 190 | 2·1φ (finest) | 0·7 (best sorting) |

Fig 3.
Current-bedded North Maslin Sands, Noarlunga Sand Pit

Fig 4
Current-bedded North Maslin Sands, Albert's Sand Pit.

Fig 5.
Closer view of bottom-set developement of fig 3, Noarlunga Sand Pit.

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### ii) Other textural features.

The grains are predominantly sub-spherical, with angular to subangular edges and corners. Up to 10% of the grains may be rounded to well-rounded. The angular grains are pitted, but the surface of rounded grains show no pitting. No frosted surfaces were observed.

## c) Colour.

Most of the sands are grey-white or various shades of yellow and brown. Bands of red and purple sands have been uncovered in Albert's sand pit.

Colour is due to the presence or absence of thin films of iron oxides around white and colourless quartz grains in most cases. Fine interstitial fragments of the oxides cause development of deep red and brown colours.

## d) Sedimentary structures

The sands are well bedded, mainly due to alternations of grain size in laminae less than 1 cm. thick. Fine sands and clays show thin laminations, less than 2 mm. thick, often accentuated by differential colouring.

Cross-bedding is a common feature in beds of sands and coarser material. Scale varies from small scale sets less than one foot long to medium scale sets, one to twenty feet long.

Using the descriptive terminology of McKee and Weir (1953) (pages 5, 6 of this thesis), the cross-strata may be described as being mainly planar-type, with either a tabular or a wedge-shaped outline, as shown in figures 3 and 4. Trough-type sets, with lenticular outline, were observed in the Noarlunga sand pit, where they are far less common than are the planar type.
The sets show well developed foresets, mostly with a planar surface and poorly developed bottomsets, (figure 4), but well developed bottomsets are shown in parts of the Noarlunga sand pit (figure 5).

Foresets in Albert's sand pit dip westwards at angles between 20° and 30° (figure 10, page 19). No measurements were taken in the Noarlunga sand pit.

### 4) Organic remains.

Plant remains from the Noarlunga sand pit have been described by Chapman (1935), and were also reported by Reynolds (1953). In the Christie's Beach sand pit, plant remains ~~are~~ have been reported by Daily (1953). Lignite has been recorded in bores and shafts inland - Daily (1953), Cochrane (1956) and Woodard (1952). Wade (1953) records the discovery of a fauna of arenaceous foraminifera in the Christie's Beach ~~sand~~ outcrop by Crespin. Daily (1953) reports the presence of sponge spicules in this formation at Noarlunga. No fossil remains were observed during the current investigation.

### 5) Contacts and thickness.

The base of the formation generally rests unconformably on a weathered and eroded surface of Proterozoic ~~rocks~~ rocks. In the Noarlunga sand pit, the sands rest on 26 feet of what Reynolds (1953) regards as Permian sands and clays.

In the localities listed on page 7, the North Maslin Sands are overlain by the succeeding formation of the type section, the South Maslin Sands. The contact is an ~~un~~disconformable one and will be discussed in more detail in section V.

The base and top of the formation are seldom seen in one outcrop, so that its thickness must be measured indirectly. In the Noarlunga Basin, a thickness of at least 60 feet is reported by Wade (1953) in the Christie's Beach sand pit. In the Willunga Basin, Reynolds (1953) measured directly a complete section of 64 feet in the Noarlunga sand pit. Stripping of sand and boring near the base of the South Maslin Sands in Albert's sand pit indicate a thickness of at least 90 feet of North Maslin Sand. Nearby boring indicates that the basement rock is undulating, with the thickness of North Maslin Sands varying between 30 feet and 120 feet.

## III The South Maslin Sands.

### 1) General

The North Maslin Sands of the Maslin Bay type section is succeeded by a sequence of ~~co~~ cross-bedded sands and clays of a markedly different facies. Reynolds (1953) named the higher unit the "South Maslin Sands". The formation has been recognized in the same stratigraphic position in other localities.

### 2) Exposure.

The formation is exposed in cliffs along the eastern edge of Gulf St. Vincent in the Noarlunga and Willunga Basins. Inland, exposure ~~is~~ are restricted to the banks of the Onkaparinga River and to man-made cuttings. No positive identification of the formation has been made in bores owing to the difficulties in recognizing either basal or top contact (as discussed in sections V and VI), and possible facies changes (see section VII). For these reasons, discussion of the South Maslin Sands has been restricted to its exposures in the Noarlunga and Willunga Basins listed below:

a) Willunga Basin.

i) Maslin Bay - the type area for the formation, described by Reynolds (1953). (Maps figures 2 and 31)
The exposures form steep cliffs and gullies, with patches of Recent sands, clays and alluvium causing discontinuous outcrop.

ii) Maslin Bay - Albert's sand pit (L 2 on map 2)

b) Noarlunga Basin

i) On the northern side of Witton's Bluff, Christie's Beach (L 3 on map 2)

ii) In the south bank of the Onkaparinga River, Noarlunga (L 4 on map 2)

iii) In the east bank of the Onkaparinga River, (L 5)

iv) At the northern limit of Ochre Point. (L 6)

## 3) Lithology.

### a) Mineralogical composition.

The sands are predominantly clear quartz grains, with a high content of brown pellets. X-ray powder photographs of these pellets showed them to be goethite, $\alpha\text{-}Fe_2O_3 . H_2O$. Reynolds (1953) and others called the pellets limonite, which is a term applied to several similar hydrated ferric oxides, including goethite. Goethite was also found to be the constituent of laminated ferruginous bands within the formation. The term "limonite" will be used in connection with occurance of goethite in the remainder of this paper, as this term is firmly established in past descriptions of the sands, ~~[illegible]~~ although it is not as strictly defined as "goethite".

Examination of different grain size fractions has shown that fractions of very fine sand size and coarser contain an average mixture of $\frac{2}{3}$ quartz and $\frac{1}{3}$ limonite. Clay minerals dominate the finer fractions. Average mineralogical composition was calculated to be 60% quartz, 30% limonite and 10% clay minerals. The percentage of limonite pellets in different size classes shows a maximum of 30% to 50% in the modal classes, falling to values less than 20% in the coarser and finer classes.

Powder photographs of the clay content, found as encrusting "envelopes" on sand grains and as pellets, have shown that one mineral is present. The pattern identifies this mineral as either glauconite or illite, two clay-micas with similar lattice-structures, which produce virtually indistinguishable patterns.

Optical data on the clay envelopes could not be obtained, but lamellibranch tests, preserved in the same mineral, gave some fragments from which refractive index values were measured. No interference figures could be obtained, so that specific refractive indices could not be determined. Observations of what appeared to be random refractive index values gave values all greater than 1.59. Refractive index values for glauconite and illite are tabulated below (after Rogers and Kerr, 1942).

| R.I. values | Illite | Glauconite |
|---|---|---|
| $n_\alpha$ | 1·535 – 1·570 | 1·590 – 1·612 |
| $n_\beta$ | — | 1·609 – 1·643 |
| $n_\gamma$. | 1·565 – 1·605 | 1·610 – 1·644. |

Random determinations for illite should produce some values less than 1.59 whereas for ~~illite~~ glauconite all randomly determined values ~~should~~ could be greater than 1.59. It appears likely that the mineral tested is glauconite. The same mineral has been shown by X-ray analyses to constitute fossil tests, faecal pellets, clay-galls or clay pellets as well as clay envelopes. Throughout this thesis, the composition of this clay mineral is regarded as glauconite, bearing in ~~mind~~ mind the possibility of its being illite.

## b) Texture

### i) Grain size.

Mechanical analyses were used to determine distribution of grain size and sorting, with most samples coming from the type area.

Modal classes of 34 samples have been tabulated in table 4. The samples were not collected in a manner to give an exactly representative distribution of modal classes, but do reflect, to a large extent, the proportions of different modal classes as estimated from field observations, which showed, in many cases, alternating laminae differing in grain size by about 1 φ value.

Table 4.

| φ limits of modal class | Wentworth grade. | Number of samples. |
|---|---|---|
| -2 to -1 | granules | 1 |
| -1 to 0 | very coarse sand | 1 |
| 0 to 1 | coarse sand | 5 |
| 1 to 2 | medium sand | 16 |
| 2 to 3 | fine sand | 11 |
| 3 to 4. | very fine sand. | 0 |
| | | Total 34 |

The commonest sands are medium to fine grained, usually with a relatively large admixture of each class on either side of the mode. Sands with modal values > 2 φ occur as bands two to three feet thick, throughout the formation, but being more common in basal sands in the region of the Canyon at Maslin Bay (map figure 31). Some medium and fine sands contain prominent, scattered coarser grains of limonite and quartz.

Bands and lenses of silty clay are a common minor constituent of the formation. They vary from laminae less than two mm. thick and a few cm. long to bands up to 25 cm thick and several metres long.

The fraction with grain sizes less than 4 φ - silts and clays - could not be further differentiated owing to the nature of the glauconite envelopes. These could be broken down only after excessive mechanical abrasion in the laboratory. This caused small limonite pellets to disintegrate, and would destroy any original grain size distribution of this fine fraction, thus giving spurious results. For this reason all silt and clay sized particles have been regarded as a single class in the grain size analyses. This does not affect the the relative or absolute distribution of sand sized particles in the cumulative curves.

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The silt + clay sized fraction averages nearly 10% of the sediment. This is relatively high when the distribution of coarser material, shown in the cumulative curves (figures 25-30) is taken into account, and indicates that a secondary modal value exists somewhere within the formation's silt + clay fraction.

ii) Sorting.

cc

Values of Trask's sorting coefficient, So, determined from the cumulative curves in figures ~~25-30~~ 25-30, have been tabulated below in order to give some measure of the degree of sorting in sediments of the formation.

Table 5.

| Degree of sorting. | So. | Number of samples |
|---|---|---|
| good | 0 - 0.5 | 3 |
| | 0.5 - 1.0 | 11 |
| moderate | 1.0 - 1.5 | 16 |
| | 1.5 - 2.0 | 3 |
| poor. | > 2.0. | 1 |
| | | Total = 34 |

Thus the values of So between 0.5 and 1.5 are most common, i.e. the sediments mainly show good to moderate sorting.

Some correlation between degree of sorting and grain size is shown by correlation between So and modal class. Sands with modal class less than 0 ϕ tend to show So values ~~less~~ greater than 1·3, while those with modal class greater than 0 ϕ show So values less than 1·3, i.e. coarse sands and finer show better sorting than very coarse sands and granules.

Values of So tend to be higher at the base of the formation in the Canyon region than higher in the sequence, reflecting the more common appearance of granule sized beds in that area. In Albert's sand pit, although there is no systematic variation of grain size with height of the sample above the base of the formation, there is a slight tendency for higher values of So to occur higher in the sequence, as shown in table 6. The tendency is ~~most~~ more likely to be due to the greater distance over which the sample was collected than to a systematic variation within the formation.

Table 6.

| Sample No. | Height above base of the formation | So |
|---|---|---|
| H196/192 | 10' | 1·3 |
| 182 | 3'6"-5' | 1·0 |
| 183 | 2'6"-3'6" | 1·6 |
| 185 | 6"-2' | 0·8 |
| 186 | 3"-6" | 0·9 |
| 187 | 0"-3" | 0·9 |

It is concluded, therefore, that there is a slight decrease in degree of sorting as grain size increases, but no significant correlation between degree of sorting and stratigraphic position within the South Maslin Sands.

### iii) Shape and roundness.

Subspherical and spherical shaped grains predominate in all size grades of quartz grains. Limonite grains show more variation, but are most commonly ellipsoidal or slightly distorted. Tabular grains, with an oval outline, like flattened ellipsoidal pellets, are found in all size grades, but are most commonly found in coarse sands and coarser material. In these more coarse fractions, aggregates of small pellets, cemented by limonite, are common, and, together with tabular grains, constitute most of the coarse limonite grains. Many irregularly shaped tabloid masses of limonite occur in granule-sized bands, sometimes showing thin lamination parallel to the tabloid surfaces. Where the sands have been weathered, limonite pellets lose their shape, partly due to ~~mechanical~~ physical disintegration, and partly by solution, which has been observed to have taken place within glauconite envelopes. Irregular coagulations of limonite develops interstitially.

Roundness of the edges and corners of quartz grains shows variation with grain seize. The following variations were noted in Samples from Marlin Bay.

(1) Very coarse grains and granules tend to be sub angular, with few rounded grains.

(2) Coarse to fine grains tend to be subrounded to rounded, with varying percentages of rounded to well rounded grains. Maximum roundness is generally shown in the medium sand class, where the proportion of rounded to well rounded grains varies between 30% and 50%, with the remainder mainly sub rounded to rounded. In coarse and fine sands, the proportion of well rounded grains is about 20% to 30%.

(3) Very fine sands are subangular, with a low percentage of rounded grains.

Basal sands at Marlin Bay, in the Noarlunga and Albert's sand pits, show less rounding close to the basal contact than higher in the formation. In the Noarlunga Basin, the sands are predominantly subrounded.

Most unweathered limonite pellets are well rounded, but tabloid masses are subrounded to rounded.

### iv) Surface features.

Quartz grains are highly polished, except those of the very fine sands, which tend to be pitted. Unweathered limonite grains are polished, and the ellipsoidal pellets often show sinuous cracks, which Reynolds (1953, page 121) regards as shrinkage cracks.

### v) Fabric.

Bedding in South Maslin Sands along wave-cut platform, Maslin Bay.

Figure 6

Bedding in sands marked by clay lenses

Figure 7

Bedding marked by clay-galls

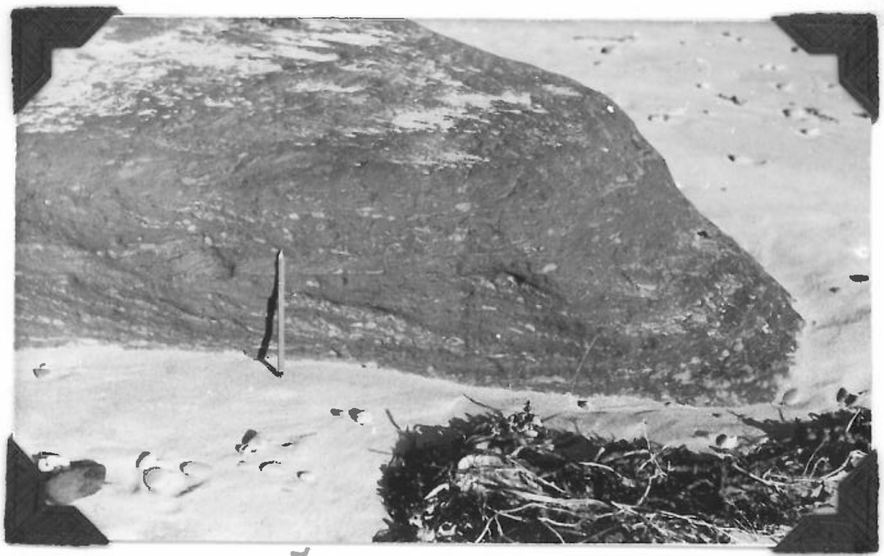


Figure 8.

Cross-bedded sands with clay galls in foresets aligned // to bedding

The well sorted nature of nearly spherical quartz grains renders the sands porous and permeable; both properties have been reduced by the development of glauconite envelopes.

Large tabloid limonite fragments and clay-galls tend to be oriented parallel to bedding planes, particularly in the bottom-set beds of cross-bedded units (figures 7 and 8 ).

### c) Colour.

The South Marlin Sands show striking variation in colour, when dry, with brown, green and purple sands occurring in outcrops. Colour is controlled by the presence or absence of glauconite, and limonite. ~~Colour is contr~~. Limonite pellets impart a dark brown colouration, which is almost completely transmitted by the clear quartz grains of the formation. This brown colour is modified by the development of glauconite envelopes around the grains of sand size.

In dark brown sands, the envelope, if present, is seen as a thin, transparent film, which does not affect colour. Purple and green sands show glauconite envelopes which are much thicker and opaque. These mask the brown colouration of limonite, and impart a green or purple colour to the sand, depending on whether the envelope itself is pale green or pale purple. In wet sands, the envelopes become transparent, so that wet sands are dark brown.

Both green and purple envelopes gave glauconite-type X-ray diffraction photographs. The only difference between the two was that halite was present in the purple envelopes ~~tested~~, but not in green envelopes. Whether or not halite causes the difference in colour between green and purple envelopes could not be determined.

Purple and brown sands are found in all unweathered surface outcrops, but green sands are confined to the Marlin Bay area and ½ mile inland at Albert's sand pit. No correlation between colour and grain size, stratigraphic position or relation to present erosion surfaces could be determined.

### d) Sedimentary structures ~~Structural features within the formation~~.

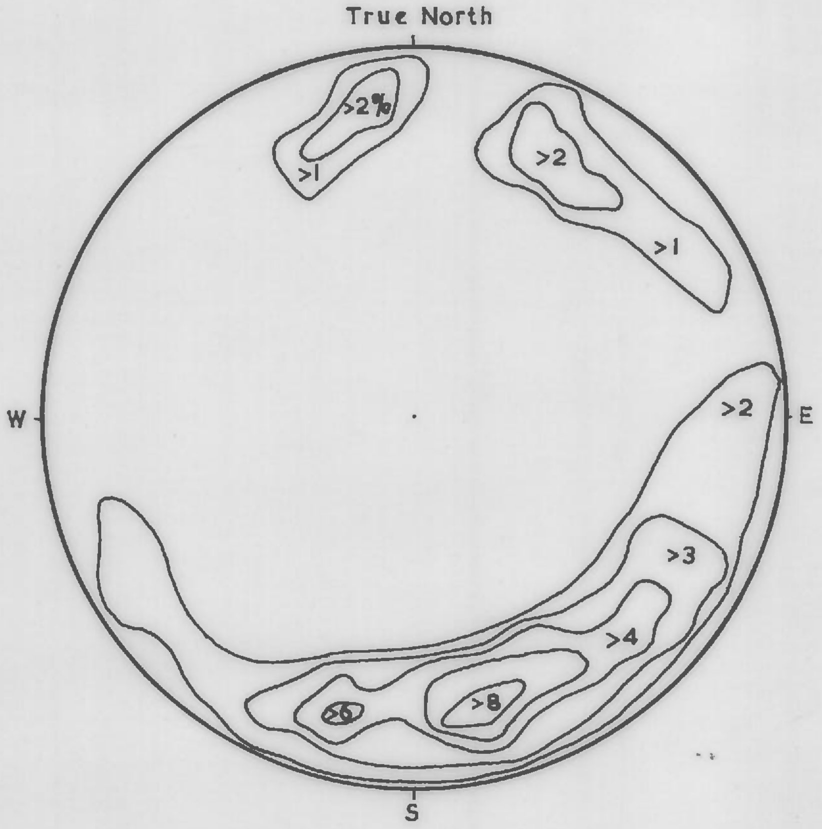
#### i) Bedding plane features.

Bedding is marked by slight variation in modal ~~grain~~

Fig 9.

# CURRENT BEDDING IN SOUTH MASLIN SAND
# MASLIN BAY

POLES OF FORESET BEDS PLOTTED ON SCHMIDT EQUAL AREA DIAGRAM

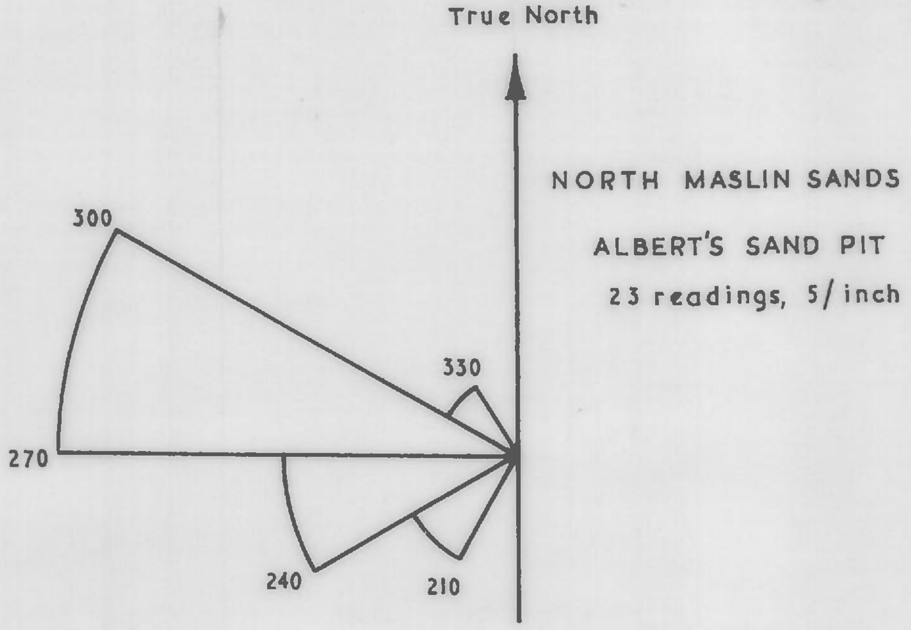


220 readings

1% 2·2 readings
2% 4·4 "
4% 8·8 "
6% 13·2 "
8% 17·6 "

# DISTRIBUTION OF DIP DIRECTIONS OF FORESETS FROM CURRENT BEDDING

Fig 10

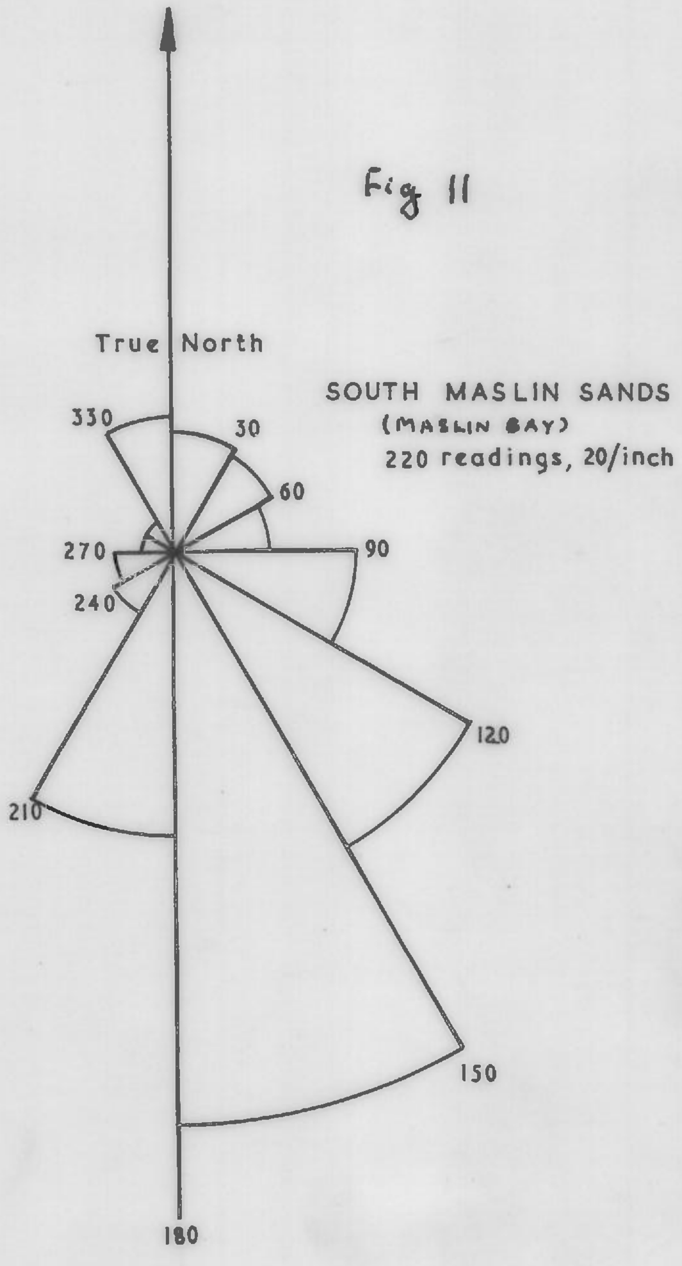


NORTH MASLIN SANDS

ALBERT'S SAND PIT

23 readings, 5/inch

Fig 11



SOUTH MASLIN SANDS

(MASLIN BAY)

220 readings, 20/inch

grain size between adjacent strata, or by variation in the content of small numbers of grains much coarser than the modal size. It may also be indicated by alignment of tabular clay-galls (figure 7 and 8 ) or development of thin clay laminae (figure 6)

fig

In the Maslin Bay area, the sands are more often cross-bedded than regularly bedded. The scale of cross bedding varies from small-scale sets less than one foot long to large-scale sets, up to 30 feet long. Medium-scale sets, 4 to 15 feet long are most common. The sets are usually trough-type, with a curved lower surface, ~~and~~ lenticular shape and trough bottom-sets. Planar-type sets are rare.

Measurements of the altitude of foreset beds were recorded at Maslin Bay, and the results tabulated as a "rose diagram" (figure 11 ) and plotted and ~~contour~~ contoured on a Schmidt equal area net (figure 9 ). These diagrams indicate a predominance of southward dipping foresets, with the most common angle of dip about 20°.

fig

In Albert's sand pit, bedding of South Maslin Sands is poorly developed, and cross-bedding is very rare. Bedding is here best shown by clay lenses and aligned pellets. Close to the basal contact, the erosional nature of the top of the North Maslin Sands (see below) is reflected by bedding planes, dipping at angles up to 25° to the west. The dips tend to flatten out away from the contact. ~~(figure~~ F.

fig

The Christies Beach and Onkaparinga River exposures show limited development of cross bedding. Bedding is mostly horizontal and less well marked than at Maslin Bay, except in clay bands, which are prominently laminated.

ii) <u>Pellets</u>.

Green ellipsoidal pellets of glauconite, about ½ mm long and ¼ mm wide, occur scattered throughout the sands as a minor constituent, or concentrated as infillings of worm burrows, 1 or 2 mm in diameter, and about 4 cm. long.

Brown limonite pellets of similar shape to the glauconite pellets or with a slightly distorted ellipsoidal shape, are common. Limonite pellets, as discussed previously, constitute an average of 30% of the formation, ~~= sand sized~~. These pellets may show shrinkage cracks on their exteriors, but no internal structure.

Larger clay-pellets or clay-galls are a common feature in the sand sized sediments. Most are flattened and tabular, with an irregular to oval outline, 3 to 10 mm thick, and up to 20 mm long. Larger, more irregular pellets are rarer. These pellets ~~have been, and~~ will be called "clay-galls" in this thesis in order to distinguish them from the smaller green pellets of the last page.

Clay-galls are greenish-yellow colour, often tinted brown, probably by limonite. They consist of glauconite, as shown by X-ray analysis.

Some clay-galls show regularly branching networks of rod-like glauconite, and a few show regular branching shapes, both features suggestive of sponges which have become preserved in glauconite. Most show a solid homogeneous interior, sometimes with concentric banding, and are probably of inorganic origin.

Clay-galls may show orientation parallel to bedding planes, particularly in some of the flat-bedded sands of the wave cut platform (see figure ~~7 and 8, p.17~~ 12). Others occur in foresets of cross-bedded units, as in figure (7 and 8, p.17.), but most clay-galls in cross-bedded sands are concentrated in bottomset beds.

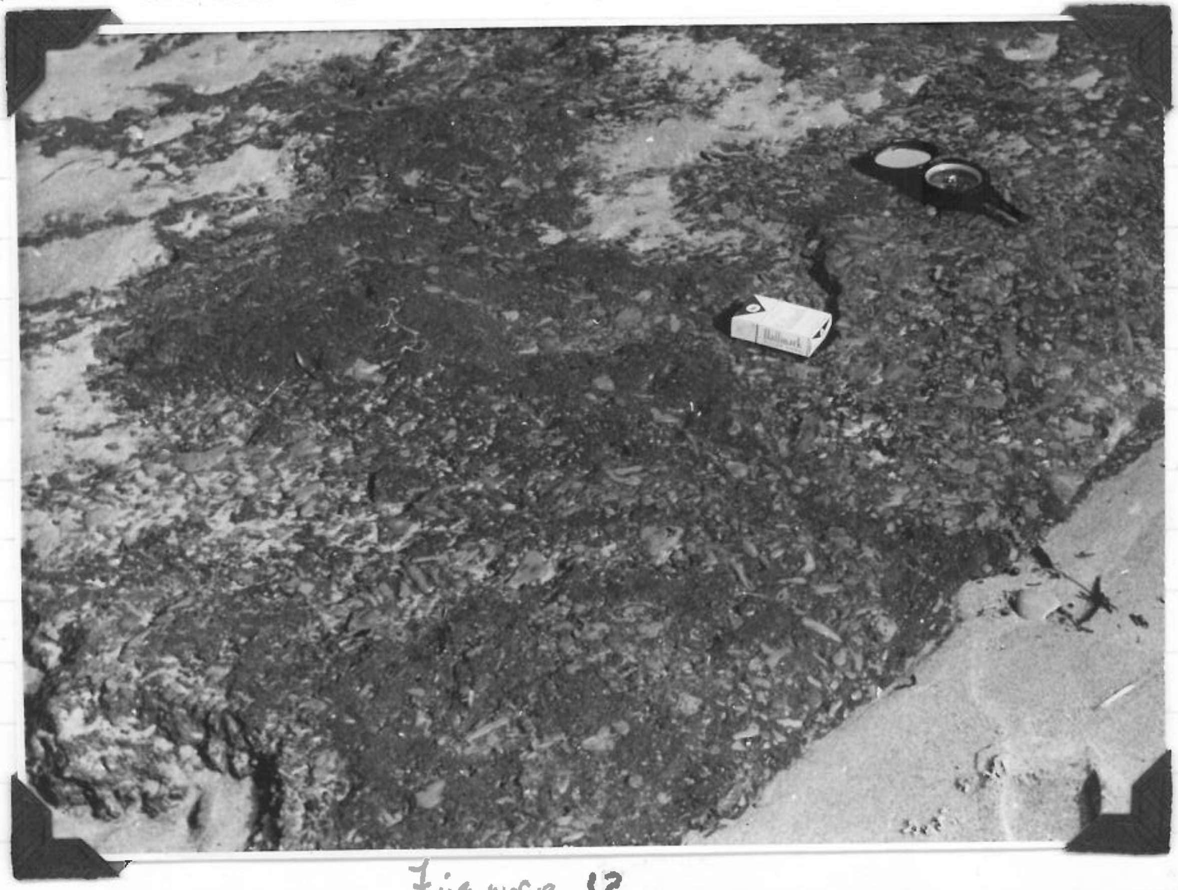


Figure 12
Concentrated, large clay-galls, wave cut platform, Marlin Bay

### iii) Concretions.

Many clay bands within the South Marlin Sands have been ferruginized, and now appear as laminated bands of limonite. These commonly show contorted laminae, and concretionary nodules. Limonite concretions ~~may~~ also occur in sands not associated with ferruginized clay bands. Most concretions are 2 to 10 cm in diameter, and up to 20 cm long. They occur most commonly north of Bennett's Creek, and south of that creek where the Gortachilla Limestone has been eroded away.

## 4) Organic remains.

### a) Invertebrate ~~remains~~ tests.

### i) Fauna

The South Marlin Sands at Marlin Bay show scattered complete and fragmental remains of invertebrate tests. Large, complete tests are rare, but fragmental remains a few mm across are more common. A micro-fauna of small gastropods, lamellibranchs and rare foraminifera and ostracods is present. The following organisms were found in the formation:

| | |
|---|---|
| (1) Lamellibranchia. | Tests range in size from 3 cm long to 1mm or so long. Most are fragmental, 1 to 2mm across. |
| (2) Gastropoda | Tests up to 3 cm long are rare. A large variety of microscopic forms, mostly complete tests, is preserved in the formation. |
| (3) Bryozoa | Fragmental colonies are common as a minor fraction of the fossil remains. |
| (4) Porifera | Isolated, fragmental spicules are common. Complete spicules are mainly tetraxon type. Fragmental networks of spicules and possibly complete sponges in ~~a~~ clay-galls, are preserved. |

(5) Echinodermata. Echinoid spines have been collected from a few samples, but no plates were observed.

(6) Foraminifera. Reynolds (1953) reports finding *Gyroidina*? and other foraminifera in basal sands of the formation. As reported by Reynolds, casts of Polymorphinidae occur in the uppermost beds.

On the wave cut platform along Martin Bay, one specimen of *Crespinina kingscotensis* Wade, (1955), (identified by Dr. Wade) was collected from each of samples A196/113 and A196/119, (localities on figure 32)

(7) Ostracoda. Two specimens of ostracoda were collected from sample A196/113.

## ii) Mode of preservation.

### (1) Lamellibranch, gastropod, ~~bro~~ bryozoal and echinoid tests.

These tests are preserved as pale green glauconite walls; no calcite was detected. The tests show original surface features of the original, including hinge teeth, sockets and plications in lamellibranchs, and columellar folds and external ornamentation in gastropods. In most cases the glauconite test is internally homogeneous and massive, but in rare cases internal structures, analogous to those of the original test, are shown.

A few lamellibranch fragments show, in transverse section, an internal structure of two layers. The inner layer consists of an interlocking network of oblique glauconite rods. Overlying this is a layer of parallel prisms, perpendicular to the surface, (figure 14, next page) These two layers probably represent the lamellar and prismatic layers of the original test.

Echinoid spines commonly show preservation of

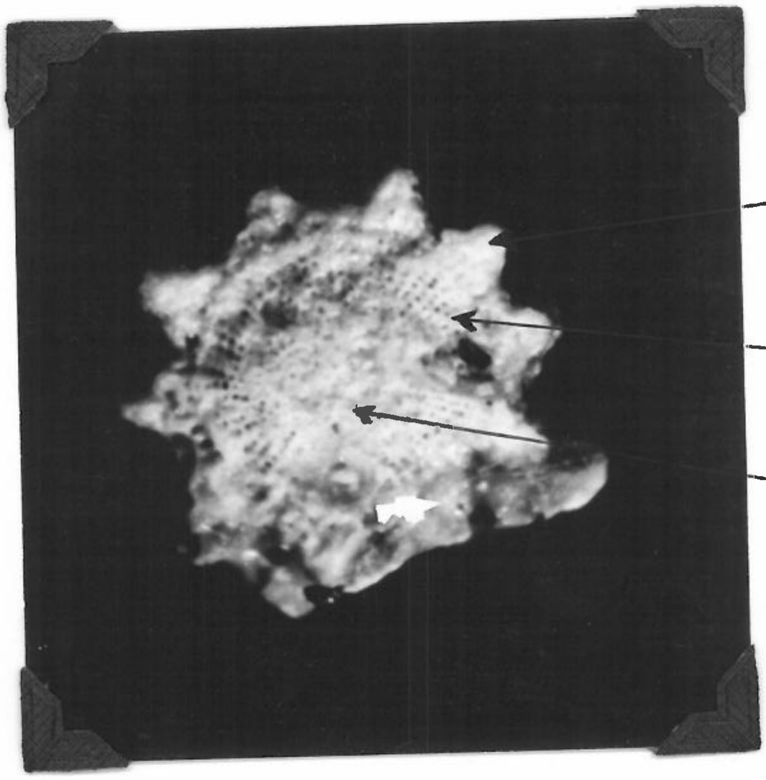


Figure 13

10-rayed echinoid spine, sample A196/125, wave cut platform, Marlin Bay, showing how glauconitized spines may preserve internal structure (The spine is approximately 0·6 mm across).

Figure 14

Preservation of internal structure of lamellibranch test, possibly by preservation of lamellar and prismatic layers of original test.

internal structure, in fine detail. Two or three concentric zones were found. The outermost zone is massive glauconite, showing external ornamentation such as the 10-rayed exterior shown in figure 13. Within this layer is a zone of finely porous, lace-like glauconite, consisting of radial and concentric threads of glauconite. In some cases there is a central zone of more dense glauconite, with irregular perforation (figure 13). This appears to be absent in other specimens examined.

These lamellibranch and echinoid remains ~~the~~ indicate glauconitization by a process of molecule-by-molecule replacement of the original carbonate. In addition, tests with no internal ~~structures~~ structures often show fine surface ornamentation, preserved in detail. The sands in which these fossils are found are of a too coarse grain size for the grains to have formed moulds in which such detail could be preserved and impressed on subsequent secondary infilling material. There is insufficient interstitial clay to account for the preservation of detailed casts. It appears likely, therefore, that these organic remains have also been preserved by detailed replacement of carbonate (calcite or aragonite) by glauconite. The replacement is complete, for no calcite has been detected, either in X-ray ~~analyses~~ or chemical analyses. Although most of these completely replaced tests show destruction of internal structure, some show that internal structure may be preserved following complete glauconitization.

Fragments of glauconite showing no characteristically organic features have been observed. In size and general shape they strongly resemble fragmental molluscan tests, and are dissimilar to any glauconite pellets or galls. It is considered that these fragments are glauconitized shell fragments in which the process of glauconitization has lead to complete destruction of organic features, in the manner described by Carozzi (1960), who describes how glauconitization ~~which~~ either emphasizes or destroys organic structures. In the latter case, he finds that grains are produced whose "peculiar general shape is the only testimony of their original organic origin."

(2) Sponge spicules.

Sponge spicules are rather peculiarly preserved in the South Marlin Sands in the form of hollow cylindrical tubes, with an axial rod. The wall of the tube, ~~and~~ its pointed end and its base, if present, ~~is~~ are constituted by glauconite. The central rod is glauconite and limonite, often with a very thin glauconite coating on its exterior.

It seems probable that the original spicule was covered by an envelope of glauconite, probably in the same manner, and at the same time, as the detrital grains of the formation. The axial canal of the spicule was filled with limonite and glauconite, both in the case of broken rays and complete spicules. Subsequently, the original spicule dissolved, leaving a fragile mould of glauconite and limonite. Because the sponge spicules were not replaced with other carbonate tests, it is suggested that they were siliceous spicules, ~~similar to~~ like those of the Blanche Point Marls (Reynolds (1953, page 126)).

(3) Foraminiferal tests.

Tests of foraminifera are preserved as internal moulds of glauconite formed by infilling of the chambers by clay minerals, which were subsequently glauconitized. The walls of the tests were then dissolved, leaving their impression well preserved in the casts of Crespinina.

b) Vertebrate remains.

The only vertebrate remains discovered to date are a few teeth, similar to the sharks' teeth of the overlying Tortachilla limestone. Teeth up to 2 cm long have been recovered from the topmost South Maslin Sands at Maslin Bay and Noarlunga. They show no apparent mineralogical modification of their original form.

c) Tracks and burrows.

Burrows are preserved in the formation in two different manners.

Small cylindrical burrows, 1 or 2 mm in diameter and a few cm. long, are preserved as cylindrical infillings of massive glauconite or of glauconite pellets. These burrows are common in several parts of Maslin Bay, either as isolated burrows, or in concentrations of ten or so burrows per square foot of outcrop. They are found parallel ~~to~~ or at angles to the bedding.

Larger burrows are found preserved in brown sands, marked by infillings of darker and lighter brown sands, (figures 15 and 16)

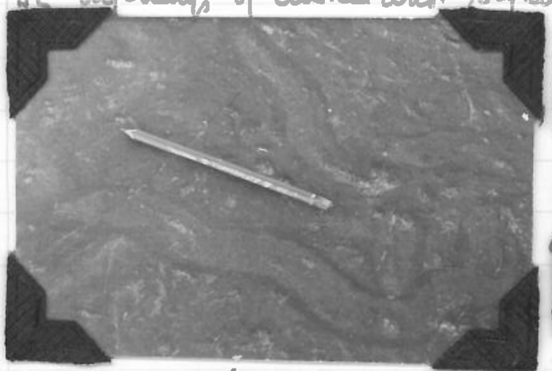


Fig. 15

Figure 16

Worm-~~tube~~ burrow casts

Such casts are generally 5 to 15 mm in diameter and several cm. long. Some, like ~~those~~ that in figure 16 are 40 to 50 ~~mm~~ cm. long. ~~The~~ Smaller casts are generally infilled with white clayey sands, as in figure 17 . These casts, too, are found at varying angles to bedding planes. They are more sinuous than the glauconitic casts.

Burrow casts are more common in normally bedded fine sands, as shown in the wave cut platform along Maslin Bay, where they are found in the fine sands.
They may occur in concentrations of a few burrows per square foot in the foresets of cross-bedded sands. Casts are most common in the Maslin Bay outcrops, being less common at Christie's Beach and Noarlunga.

Tracks left in bedding planes by some unknown invertebrate have been observed along the Maslin Bay wave cut platform

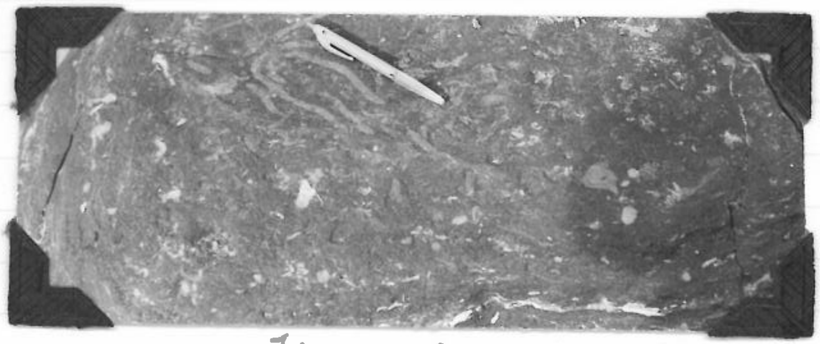


Figure 17
Worm-burrow casts

### d) Faecal Pellets.

The small glauconite pellets discussed on page 18 as occurring in burrow casts are probably faecal pellets of worms. Those which are scattered in the sands may be of a similar nature. Some of the ~~glauco~~ limonite pellets, particularly the sutured varieties, are probably faecal pellets.

### 5) Contacts and Thickness.

Both top and basal limits of the formation are disconformable, as discussed in sections V and VI.

In the Noarlunga Basin, the formation is about 15 feet thick, but in the Willunga Basin it is many times thicker. Direct measurement of thickness is impossible here because the top and base of the formation occur in outcrops about ½ mile apart. Reynolds (1953) calculated a thickness of 100 to 160 feet.

# IV The Tortachilla Limestone

## 1) General.

The thin limestone overlying the South Maslin Sands at ~~the~~ Maslin Bay was named the "Tortachilla Limestone" by Reynolds (1953). He distinguished two members in the type locality: a lower Polyzoal Limestone member (a polyzoal limestone, sandy in part) and an overlying Blanche Point Glauconitic Limestone member (a hard limestone). Such a division is often impossible away from the type area.

## 2) Exposure.

The Tortachilla Limestone overlies the South Maslin Sands in the following localities:

### a) Willunga Basin

fig At Maslin Bay, along the cliffs at the southern end of the beach to Blanche Point (see maps 2 and 31)

### b) Noarlunga Basin

i) Witton's Bluff (L3)
ii) Noarlunga township (L4)
iii) In the banks of the Onkaparinga at (L5).

## 3) Lithology.

The basal member consists of a poorly sorted calcareous ~~sand~~ sediment containing quartz, limonite and calcite. Quartz and limonite grains are richest in ~~to~~ the bottom few inches of the member, and become progressively less common towards its top, where calcite is the dominant mineral, and glauconite becomes common. The lower member grades upwards into the hard shelly limestone of the Glauconitic Limestone member~~, which~~. Both members have changed facies in the Maslin Bay outcrops (see figure

fig

## 4) Organic remains

Both members contain a rich invertebrate fauna of bryozoa, foraminifera, echinoids, brachiopods and mollusca, partly described by Reynolds (1953). Teeth similar to those found in the South Maslin Sands are common in the lower member.

The fossils are fragmentary and complete, with far more complete fossils and fragments than in the South Maslin Sands. Calcitic tests and moulds are preserved, but there is no evidence of glauconitization of carbonate tests.

### 5) Contacts and thickness.

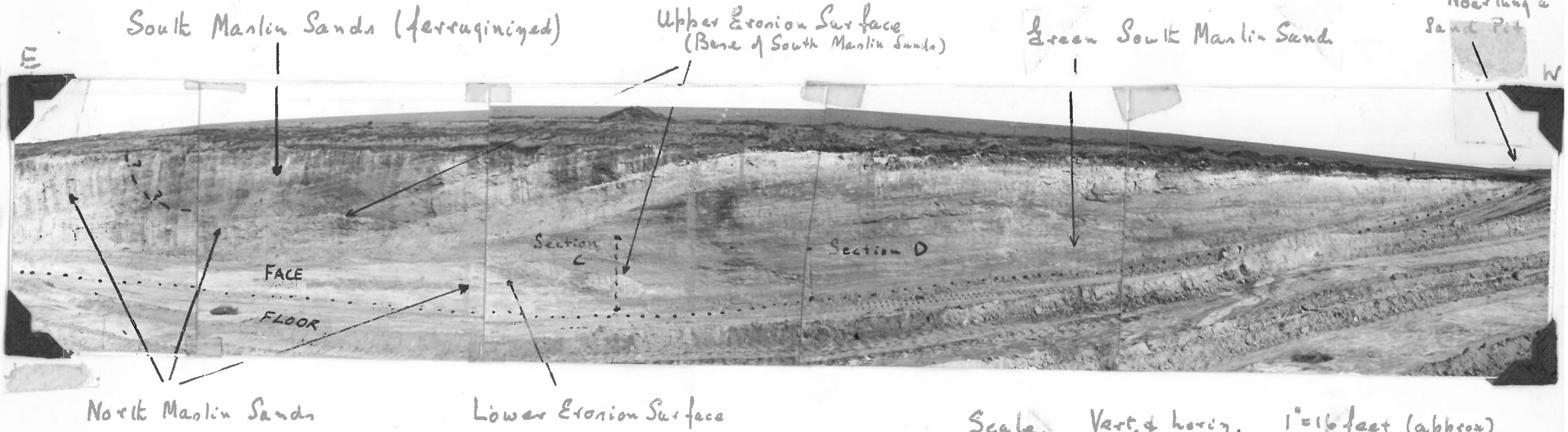
The base of the formation rests disconformably on the South Maslin Sands in all localities listed above. (This contact will be discussed in detail in section VI). Its top is a conformable contact with the overlying Blanche Point Marls.

The thickness of the formation at Maslin Bay varies from 3 to 7 feet, with 3 to 4 feet of the Glauconitic Limestone member, and from a few inches to 3 feet of ~~polyzoal~~ the Polyzoal Limestone member.

### 6) Attitude of the formation.

According to Woodard, (1952) the formation shows a dip of ½° S.W. in the Willunga Basin. Reynolds (1953) calculated a dip of 2° in a direction 235° (True) for the basal contact. The formation may be regarded as dipping at a flat angle to the south-west.

# The south face of Albert's Sand Pit, as seen in June - August, 1960



Scale. Vert. & horiz. 1"=16 feet (approx).

Figure 18.
The South face of Albert's Sand Pit,
as seen in June - August, 1960.

# V The Relationship between the North and South Marlin Sands.

## i) Nature of the contact.

Near the Marlin Bay coast the contact between the North and South Marlin Sands is exposed in a few places only. At the southern end of the Noarlunga sand pit, green South Marlin Sands abruptly succeed the white and yellow North Marlin Sands. The base of the green sands is gently undulating. Reynolds (1953) calculated the height of this contact as 88 feet above his mean sea-level. An exposure of the contact in a gully in the southern wall of the Canyon is found at a height of 15 to 20 feet above sea-level. Between these two outcrops, scattered outcrops of both formations occur, but their contact is hidden by alluvium and wind-blown sand, except for one exposure mentioned by Reynolds (1953), which was not observed during the current investigation. Reynolds reports a dip of 7½° in a direction 20° true for the contact here, and considers that this dip must flatten out to 2½° or so in the region of the Canyon. These contacts indicate erosion of North Marlin Sands prior to deposition of South Marlin Sands.

Similar erosion is indicated in Albert's sand pit, shown in the southern face of the pit (figures 18, 19.        ). Two distinct erosion surfaces are exposed in the part of the face around section "C" (figure 18        ), the upper surface truncating the lower somewhere under an obscured section of the face to produce a wedge of sand between the two.

figure 19.
The two erosion surfaces of the south face, Albert's sand pit.

The lower erosion surface truncates horizontally

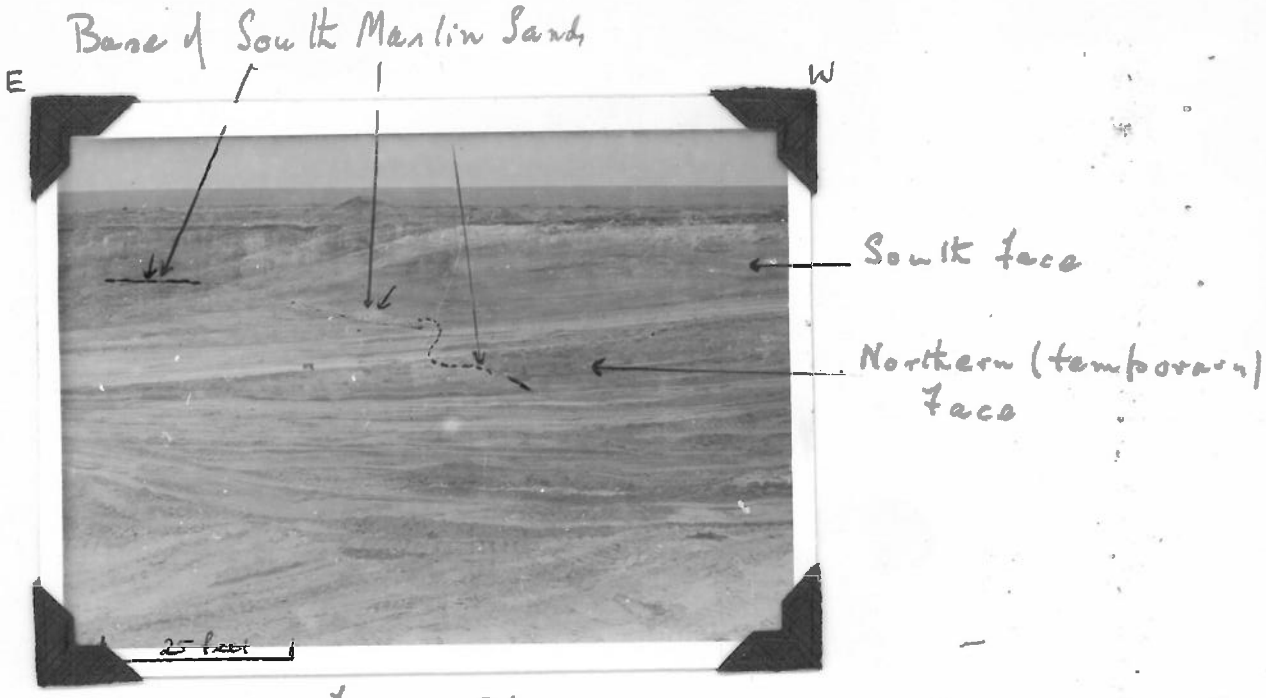


figure 21

Location of northern face, Alberts sand pit

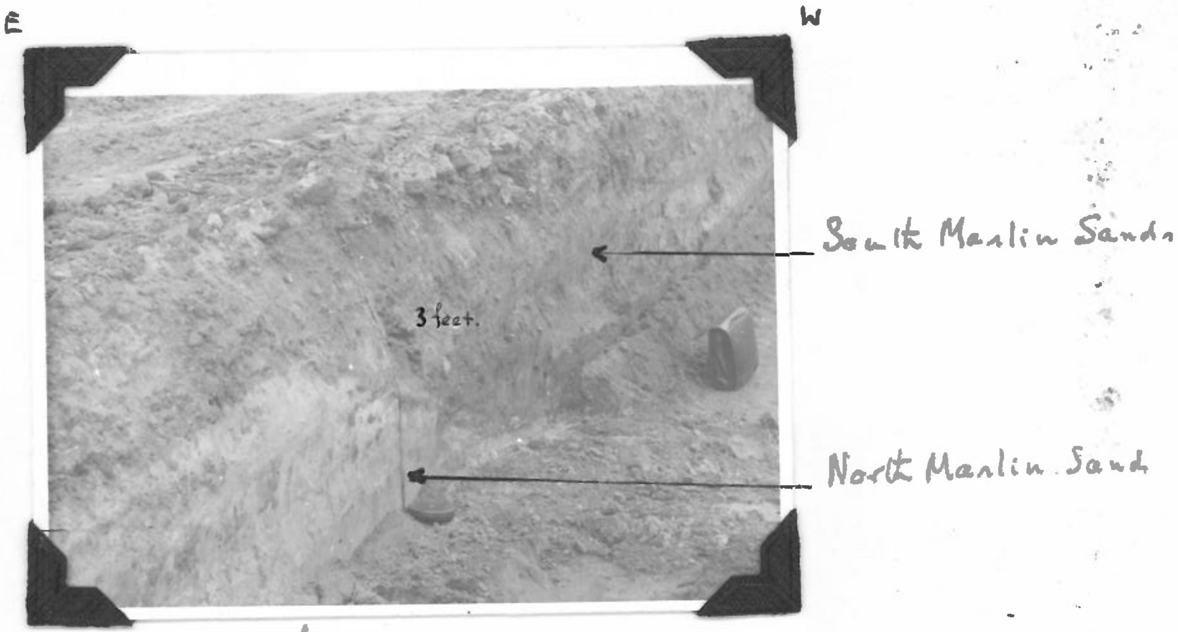


figure 22

Base of the South Marlin Sands, northern face.

bedded North Maslin Sands. The wedge of sand immediately above this surface, when first exposed, appeared as a fine grained white sand, showing no well developed bedding. A diffuse band, 2 inches wide, and containing 5% very coarse grains, reflected irregularities in the lower erosion surface, paralleling the latter about 3" above it. Weathering has since produced thin brown laminations in this sand, in curving and irregular bands. Whether this differential colouring reflected subtle textural differences between true bedding planes could not be determined. This sand is lithologically identical with the underlying sands, except in the ~~development~~ development of bedding, and it is therefore regarded as a wedge of reworked North Maslin Sands between the two converging erosion surfaces.

The upper erosion surface cuts both reworked and undisturbed North Maslin Sands. It is overlain by brown limonitic sands, grading upwards into green sands similar ~~to~~ to those of the type locality of the South Maslin Sands. A few inches above the base of these sands, regarded as South Maslin Sands, a band 3 inches thick, of medium grained sand containing 8% very coarse grains and granules, parallels the erosion surface (figure 20) Higher in the sequence, bedding shows progressively less influence of the uneven basal contact.

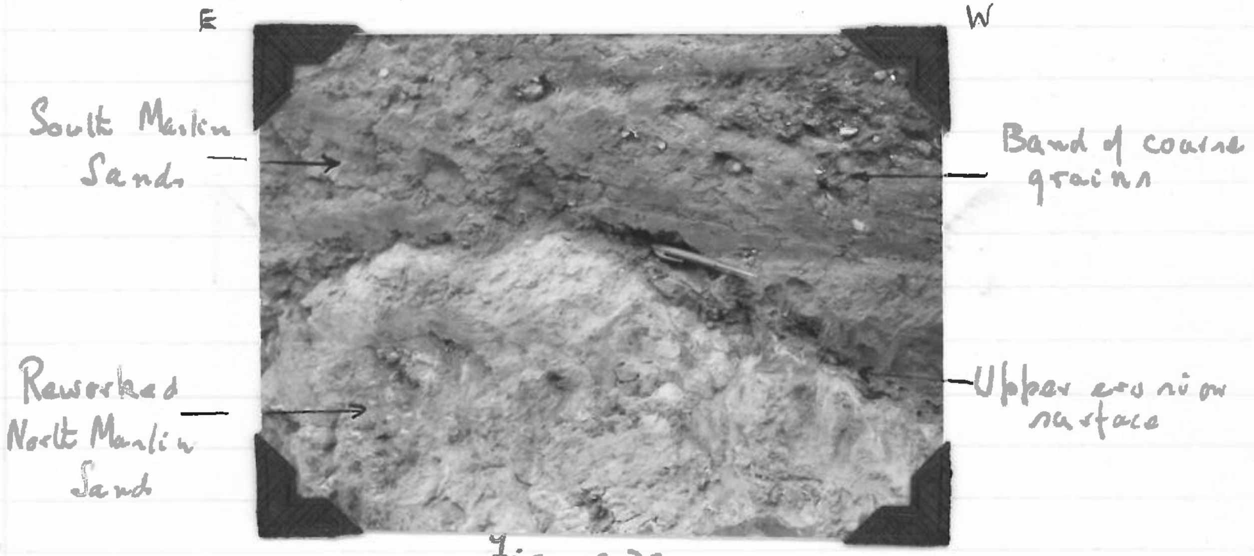


Figure 20
Basal Contact of South Maslin Sands, Albert's Sand Pit

The upper erosion surface may be traced northward across the floor of the pit for 100 feet or so, as a line dividing white sands from brown limonitic sands. Developmental work during 1960 exposed a small face 50 feet north of the southern face, and in it the contact between the two formations was temporarily exposed (figures 21 and 22, opposite).~~to next page~~).

NOTHING

Both faces showed magnetic bearings of 85°. The strike of the base of the South Maslin Sands as determined from these two faces was 175° (Mag.), so that each face showed true dip magnitude. ~~and the~~ The angle of dip of the base of the upper sands is mainly in the range 0° to 25° west, with an almost vertical dip in the eastern extremity of its exposure. Flat dips of the order 5° west are indicated by ~~borings~~ bore-holes west of the pit. ~~as shown in figures~~

Thus, both exposures of the contact between the North and South Maslin Sands ~~at~~ near Maslin Bay show erosion of the former prior to deposition of the latter. There is no indication of the North Maslin Sands having suffered much tectonic displacement at ~~the~~ the time of erosion, so that the erosional contact is a disconformity. During the break in deposition, at least 35 feet of the lower sand was removed, and in the Noarlunga sand pit – Canyon area, possibly 60 feet was eroded.

Variation in the magnitude and direction of dip of the erosion surface are large. The direction of dip at Albert's sand pit is about 70° west of that given by Reynolds for the coastal area. Such variation is ~~to~~ be expected from the unconsolidated nature of the lower sands. This latter also makes it unlikely that the erosion of up to 60 feet of sand reflects an appreciable erosion interval.

In the Noarlunga Basin, the contacts between the two formations differs from those above. In the exposures at Wilton's Bluff and Noarlunga, the top few feet of North Maslin Sands have been extensively ferruginized, producing mottled red and yellow sands. The overlying South Maslin Sands show no such ferruginization. Whether or not the top of the lower formation is strictly a laterite, the ferruginization probably reflects a period of emergence prior to deposition of the South Marlin Sands, with less marked erosion of the lower sand than at Marlin Bay.

In the outlet channel of Happy Valley Reservoir, North Marlin Sands grade upwards into ~~ferruginy~~ ferruginized and clayey sands, with pockets of glauconite. The glauconitic sand may be South Marlin Sand, but the outcrop gives no information as to the nature of the contact.

## 2) Comparison of lithological and organic features of the two formations.

The two formations differ in several features. The nature of the differences renders them susceptible to masking or destruction in some cases, and in other cases the changes are gradational, so that the two formations may not be sharply differentiated in samples from bores.

### a) Mineralogical composition.

Both formations are predominantly quartz sands. The North Marlin Sands contain little limonite and other iron oxides. Basal South Marlin Sands contain 10% to 15% limonite, and higher sands an average of 30% limonite. In unweathered sands, the presence of limonite pellets constituting 10% to 30% of the sand is characteristic of the South Marlin Sands.

In weathered sands encountered in exposures and bore holes at Albert's sand pit, limonite from disintegrated pellets has migrated into medium and coarse grained North Marlin Sands (but only to a slight extent in fine sands), which may contain 10% interstitial limonite. A gradation in limonite content develops across weathered contacts.

The presence of a glauconite envelope on sand grains is characteristic of the South Marlin Sands in surface outcrop. However, it may be poorly developed or may be destroyed by weathering. A sample of limonitic clay from weathered sands in a bore from Albert's sand pit gave a green clay residue after chemical removement of goethite. X-ray analysis of this residue revealed the presence of glauconite (or possibly illite). It is possible that such glauconite in the clayey limonite could be carried into the North Marlin Sands on weathering. Daily (1953) reports the presence of glauconite in the North Maslin Sands at Noarlunga. Hence, it must be concluded that the presence of glauconite in a sample does not diagnostically mean the sand is South Maslin Sand.

b) Textural features.

Analyses of grain size ranges ~~show~~ of the two formations show that there is much overlap. Pebbles with diameter > 4~~mm~~ cm are restricted to the lower formation.

The respective ranges in degree of sorting overlap to such an extent that any difference ~~mu~~ must be ~~concluded~~ considered insignificant.

Although most grains of the North Maslin Sands are angular or subangular, a minor proportion of rounded and well rounded grains occurs (usually less than 10%). Basal South Maslin Sands show no significant deviation from this degree of rounding in the Noarlunga and Albert's sand pits. Higher degree of rounding is shown in the Maslin Bay coastal exposure, but no gradational change could be observed there because of the nature of outcrop. In Albert's sand pit, ~~the section~~ "C" of figure 18, p 27) showed the following variation in roundness, with a slight increase in roundness upwards through the South Maslin Sands:

Table 7

| Formn. | Sample No. | Height above quarry floor. | Average roundness. |
|---|---|---|---|
| South Maslin Sands | A196/182 | 7'6" - 9' | Sub rounded to rounded |
| | 185 | 4'6" - 6' | " |
| | 187 | 3'9" - 4' | angular to sub angular |
| North Maslin Sands (reworked) | 188 | 2' - 4' | " |
| | 189 | 1' - 2' | " |
| | 190 | 0' - 1' | " |

Within the South Maslin Sands at Albert's pit are patches of white sand, lithologically identical with the North Maslin Sands, the most distinctive feature being their lack of limonite (see figure 23, ~~next~~ next page). These irregularly shaped lenses are ~~roughly~~ probably reworked North Maslin Sands within the higher

~~the high~~er formation, where they are restricted to within a few feet of the base.

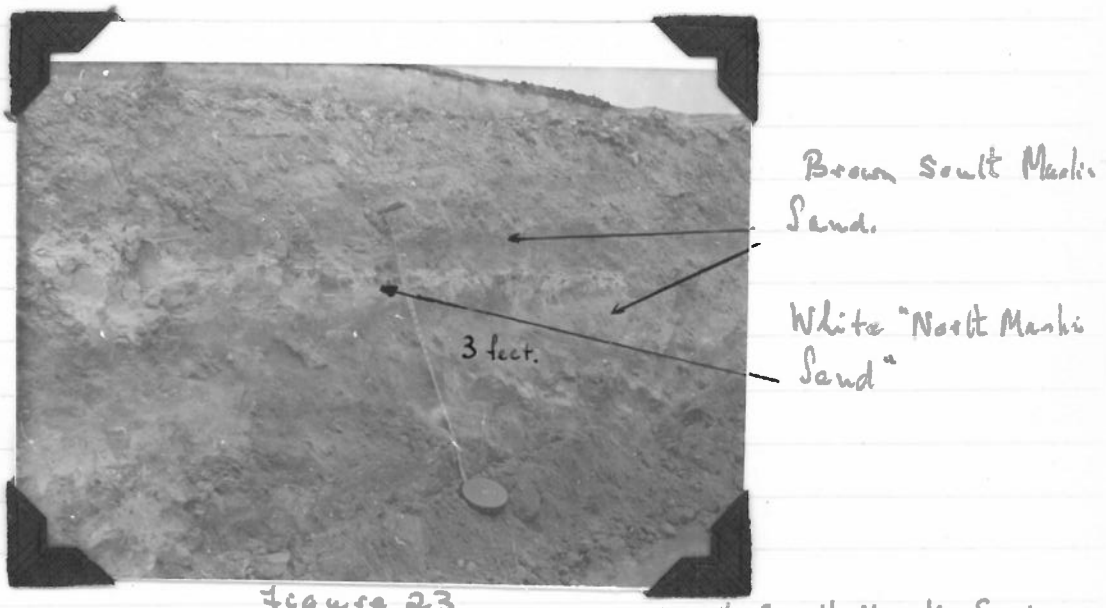


Figure 23
A lens of reworked Nth Marlin Sand within the South Marlin Sand, northern face, Albert's sand pit

## c) Organic remains ~~content~~

The sparsely fossiliferous North Marlin Sands contain mainly plant fossils, indicating a fresh water environment; a few marine fossils have been reported, (page ). This contrasts with the essentially marine fauna of the South Marlin Sands. Invertebrate tests preserved in glauconite are characteristic of the Marlin Bay area, but are rare to absent elsewhere.

## d) Structural features

Both formations may show extensive development of cross-bedding, with no significant difference in scale. The type and shape of sets differ between the two formations. Those of the North Marlin Sands are predominantly of the planar type, with tabular or wedge shaped outline, whereas those of the South Marlin Sands are mainly lenticular trough-type sets. Bottom-set beds are best developed in the South Marlin Sands. Clay pellets of various types, discussed earlier, are restricted to the South Marlin Sands.

Thus, the contact between the North and South Marlin Sands is a disconformity, with erosion of North Marlin Sands preceding deposition of the higher formation. Across the contact, gradational changes in rounding of grains, content of limonite and glauconite may be present. Pellets and glauconitized fossils are restricted to the South Marlin Sands, but are not present everywhere in that formation, so that their absence is not diagnostic of North Marlin Sands. Features such as glauconite envelopes and cross-bedding are distinctive, but usually observed only in outcrop.

## VI The relationship between the South Maslin Sands and the Tortachilla Limestone.

### i) Nature of the contact.

Along the Maslin Bay coast, the upper contact of the South Maslin Sands is marked by an erosion surface. In places the top few inches of the sands contain small, slightly displaced blocks of sands within mottled grey clays and sands, with ~~many~~ worm burrow casts producing much of the mottling. This "brecciated" sand is capped by a gently undulating surface, above which is found a mottled, clayey, medium-grained sand, containing many scattered very coarse grains of quartz and limonite. The mottled clayey sand is slightly calcareous, and its content of lignite decreases progressively upwards from its base. It is from ~~2 feet~~ a few inches to 3 feet thick, variation being due to irregularities of its base, which shows undulations over eroded South Maslin Sands. Red-brown ferruginous bands, ¾ inch to 9 inches thick are found near the top of the mottled clayey-sand.

The mottled clayey-sand is overlain conformably by the ~~a~~ fragmental limestone of the typical Polyzoal member. Vertical and lateral gradations between these two sediments commonly show bedding planes continuous across the contact. In appearance and mineralogical composition the mottled clayey-sand is intermediate between the South Maslin Sands and the Polyzoal Limestone member. Because of the indications of a discontinuity between the mottled clayey-sand and undoubted South Maslin Sands, and vertical and lateral ~~gradation and~~ facies changes between ~~it and~~ the former and the ~~Tortachilla~~ Polyzoal Limestone, the ~~top~~ clayey-sand is regarded as the basal part of the Tortachilla Limestone, and the top of the South Maslin Sands is ~~an unconformable~~ a disconformity. In places, the mottled clayey sand has been observed to grade vertically into the sandy facies of the Tortachilla Limestone. (~~Fig~~ ).

In the Noarlunga Basin, at Christie's Beach and ~~along~~ in the Onkaparinga River outcrops (L3, L4 and L5), the contact is again disconformable. The Tortachilla Limestone appears as a hard calcareous rock, containing lithified patches of South Maslin Sands up to 6 inches long by 6" high in its basal part. The limestone rests on a gently undulating surface, in which undulations are 1 to 2 inches high and a few inches apart, indicating some erosion of South Maslin Sands, and a disconformable contact.

## 2) Comparison of lithology and organic ~~content~~ remains.

The major difference in lithology between the two formations is summarized by their respective names. The ~~former~~ South Maslin Sands is a sand rich in quartz and limonite, and the Tortachilla Limestone a highly calcareous rock. There is a gradation between the two in the basal beds of the Polyzoal ~~ss~~ Limestone member. Glauconite is common in both formations, but differs in its mode of occurrence; in the lower formation it occurs as pale green or purple envelopes, and in the higher formation as dark green aggregates and scattered grains. Bedding in the limestone is regular wherever shown, with no cross-bedding, whereas cross-bedding is well developed in the South Maslin Sands.

The fauna of the lower formation is much poorer in both variety and abundance than that of the normal limestone facies. The green sandy-facies of the Tortachilla Limestone carries few fossils, and for this and its lithological similarity, it is difficult to distinguish from the South Maslin Sands in subsurface sequences.

VIII   i)   ~~16~~ 17.12.60

# ~~VIII~~ VII Depositional Environment of the Eocene formations.

## i) The North Maslin Sands

### a) Nature of the depositional medium.

The common developement of medium to large scale planar-type cross bedding in the North Maslin Sands, and the prespence of cross-bedded sands rich in granule-sized grains indicate that the formation was deposited by aqueous currents in shallow water, rather than by aeolian action. Aeolian deposits tend to show curved foresets, giving trough-type cross bedding, and it is unlikely that the competancy of wind is often high enough to produce cross-bedded deposits of granule-sized sediments.

The ~~prespence~~ presence of lignites within the formation indicates that some of the sediments were deposited in fresh water swamps. In the sands which contain no lignite, the general absence of marine fossils is significant. The overlying South Maslin Sands show a broad similarity in such features as grain size, degree of sorting and developement of medium scale cross-bedding. This indicates that the mechanical features of the depositional environment were of a similar nature, and could therefore be expected to affect biological activity and organic remains to the same degree in both formations. The preservation of marine fossils in the South Maslin Sands therefore indicates that their absence in the North Maslin Sands is best explained by the absence of marine influence on the depositional environment ~~at certain~~, except ~~on~~ on limited occasions, such as are indicated by Daily's (1953) report of sponges and glauconite at Noarlunga, and Crespin's foraminifera at Christies Beach (Wade, 1953).

### b) Facies variation

The lignitic sands discussed by Woodard (1952), Daily (1953), and various authors in Cochrane (1956), differ lithologically from the clean cross-bedded sands discussed in section II to such an extent that they may be regarded as a different facies of the formation, so that the North Maslin Sands may be regarded as having two facies, discussed here as the "clean sand facies" and the "lignitic facies".

The clean-sand facies shows lithological features such as cross-bedding, good to moderate sorting, and low clay content, which indicate deposition in an environment of current activity. Although experimental work has been carried out by McKee (1957) on cross-bedding, by ~~Kuenan~~ Kuenen (1956, 7, 9, 60a and b) on the textural features of sand grains, and by other workers, quantitative results are of ~~a~~ limited ~~[illegible]~~ value in determination of environmental properties from sedimentary features.

Surface outcrops and recent extensive boring in the area between Marlin Bay and the Adelaide - Aldinga Road, show that low content of silt and clay, and absence of carbonaceous material ~~are~~ are consistent features throughout the vertical sequence in this area.

The lignitic facies shows extensive development of clayey and silty sands, lignites and carbonaceous sediments. These are likely to have been deposited in fresh water swamps, where mechanical action such as current activity is not so important.

c) Sedimentary environment

Reynolds (1953, page 135) considers the sands of the Noarlunga sand pit are probably of deltaic origin. According to van Straaten (1960), ~~Barrell~~ Barrell defines a delta as "a deposit partly subaerial and partly sub-aqueous built by a river into or adjacent to a permanent body of water. The development of at least 120 feet of North Marlin Sands, in the ~~[illegible]~~ places, and at least 60 feet of current bedded sands which were probably of shallow-water origin indicates a sinking basin or series of basins of permanent water, into which streams transported sands and clays. Such a deposit would fit Barrell's definition of a delta.

A delta is a complex of many different sedimentary environments, most of which show development of characteristic sediments, which show differences in lithology, organic content and ~~spatial~~ spacial extent. Association of these characteristic features may be used to determine the parts of deltas in which sediments have been formed in the geological past, by comparing these associations with ~~those~~ those of Recent deltaic deposits. In the case of the North Marlin Sands, only two broad divisions of the sedimentary environments can be made, owing to the lack of fossils in parts, and insufficient detailed knowledge of the spacial relationships of its two facies.

In the Willunga Basin a broad distribution pattern of the two facies shows the clean sands are restricted to the northern margin of the basin, at Marlin Bay, around Albert's sand pit, VIII 3) 19.12.60

and in the Baker's Gully area, where Woodard (1952 page 5) correlates the Baker's Gully Gravels with the North Maslin Sands. Bore-holes indicate that the lignitic facies predominates in the remainder of the basin.

A similar distribution is shown in the Noarlunga ~~and~~ Basin, where the clean sand facies is found at Christies Beach and near Happy Valley, and in the Adelaide Plains Basin, where it is restricted to certain marginal areas such as the Golden Grove, and Hope Valley ~~and~~ ~~[illegible]~~ ~~Valley~~ areas. The remainder of the basins, both centrally and marginally, show developement of ~~lignitic~~ carbonaceous sediments or silty and clayey sands. Lignitic sediments "end abruptly against faults, without re-appearing as expected in the upthrown continuation of the same formation" - Glaessner (1953 b , page 36-7). These faults are regarded by Glaessner as forming scarps which limit the extent of the swampy basins.

map fig. The upthrow side of the above-mentioned faults forms divisions between the three basins (see map, figure 1..). The previously discussed ~~section~~ distribution of the clean sand facies is restricted to

same fig. the upthrow side of these faults, (see figure 1..). The distribution can be explained by regarding the sands as deposited by streams entering the basins along restricted parts of the margin. ~~Near~~ In the basin, ~~margin~~, streams lost capacity and competancy because of the effect of the water body in the basin, and part of their sedimentary load was deposited in ~~the~~ marginal ~~parts~~ area, ~~in~~ under influence of currents, producing well sorted, ~~current~~ cross-bedded sands, with little clay. The remainder of the stream-loads was carried further into the basin, where lower current activity allowed deposition of finer material, producing more poorly sorted silty and clayey sands, silts and clays. ~~The basin~~ Water was shallow, ~~few~~, so that fresh water swamps contributed carbonaceous material to the sediments.

In summarizing this section, it may be said that the North Maslin Sands are deltaic sediments, deposited in essentially fresh-water basins, with limited marine influence. Clean sands were deposited in and near channels of entering streams, and more poorly sorted sediments in swamps which developed in the ~~remainder~~ remaining parts of the basins. The shallow water nature of the deposits and thickness in excess of 100 feet in places, indicate that relative subsidence occured at the time of deposition.

VIII 4) 20.12.60.

Lateritization of the top of the North Marlin Sands at Christies Beach and in other marginal parts of the basin (Glaessner and Wade, (1958, page 117)) indicates emergence for a time. This is also suggested by the erosion of 30 to 60 feet of sands below the South Marlin Sands at Marlin Bay, for no comparable erosion occurs within either formation. Some relative ~~[illegible]~~ lowering of water level was necessary to allow this depth of erosion in an environment which had previously produced erosion of the order of a few feet of sediment ~~as cross~~ in the development of cross-bedding. Following the relative lowering of water level in the basin, a return to sub-aqueous conditions is indicated by the South Marlin Sands.

## 2) Depositional environment of the South Marlin Sands.

### a) Nature of the depositional medium.

~~Physical features of the formation, such as good sorting of sand size material, extensive development of trough-type cross-bedding on a medium scale, large scale scour-and-fill structures and minor content of silt and clay bands, indicate deposition in~~

The scale of cross bedding, ~~and~~ development of long bottomset beds and worm-burrow casts in cross-bedded sands indicate a shallow subaqueous environment, rather than ~~an~~ aeolian dune deposits.

Phy

Physical features of the formation, such as good sorting of sand sized grains, extensive trough-type cross-bedding on a medium scale, large scour-and-fill structures and minor content of silt and clay, indicate an environment of ~~much~~ much current activity, actively eroding ~~the~~ ~~[illegible]~~ newly ~~be~~ deposited sands at frequent intervals. Current movement was predominantly north to south in the Marlin Bay area, as shown by the orientation of foresets recorded in figures 9 and 11 on page 18. The regular bedding and laminated clay bands in the Noarlunga Basin indicate sub-aqueous deposition in a less ~~rigorous~~ rigorous environment.

figs

The occurrence of echinoid, bryozoal and foraminiferal remains show ~~the~~ marine influence on the environment. The low density of fossils could mean a normal marine fauna in the area was "diluted" by rapid sedimentation, or that the environment was marked by abnormal turbidity and subnormal salinity, with a reduced faunal assemblage. It is likely that both factors ~~are~~ were responsible, and that the environment

VIII 5) 20.12.60.

~~was tidal or~~ was estuarine.

## b) Nature of the depositional environment.

The very high content of clastic quartz and probable terrigenous source of limonite (page 40) suggest that the sands are deltaic deposits in the sense of Barrell's (1912) definition (page 36 of this thesis).

The ~~formation~~ sands appear to be limited in extent to the outcrops listed on page 11. (~~[illegible]~~). Elsewhere, bores show only clayey and silty sands, often lignitic, under sediments which can be correlated with the limestones overlying the South Maslin Sands in the coastal exposures (Woodard, (1952) page and Daily (1953 ~~page~~ , Cochrane (1956)).

As discussed earlier, the North Maslin Sands show a lignitic facies, and the two limestones overlying the South Maslin Sands show non marine sandy facies (Woodard, 1952, page 21). In the absence of evidence for a period of non-deposition within the lignitic and sandy non-marine sediments from bores to date, it is probable that the South Maslin Sands shows a non-marine and probably lignitic facies. The fact that the lignitic sediments cannot be differentiated to any great extent reflects similarity of ~~sedimentary~~ depositional environment.

The South Maslin Sands may therefore be regarded as forming only part of a deltaic environment. The typical sands of the formation were deposited in channels into which marine water were able to enter. In other parts of the deltaic areas, swampy conditions developed under the influence of fresh-water, producing lignitic sediments, lithologically distinct from the sands of the formation defined by Reynolds (1953). Their fresh water nature rendered them more like the North Maslin Sands, and they were ~~practically~~ identical with the lignitic facies of the latter.

Marine influence on the deltaic environment of the South Maslin Sands is probably the cause of the ~~chemical~~ mineralogical differences shown between that formation and the North Maslin Sands, namely the presence of large quantities of glauconite and limonite in the former. The environmental conditions under which these minerals were formed will be discussed briefly.

~~PTO~~.

VIII 6) 20.12.60.

i) Limonite.

Abundance of limonite pellets ~~suggests~~ indicate an environment into which much ferruginous material is being carried and deposited. Glaessner (1953b, page 38) suggests that the limonite is detrital and "occurs ~~as~~ in a form suggesting denudation of earlier laterites." from neighbouring high areas. Reynolds (1953, pages 121-2 and 136) suggests that some of the pellets were formed from glauconite under oxidizing conditions.

Reynolds' (1953) suggestion (above) does not seem a likely explanation. Glauconite pellets occur scattered within the sands, commonly ~~in burrow casts~~ as infillings of burrows, or rarely in thin glauconitic tubes, and are regarded as being of organic origin. These pellets, together with the larger glauconitic clay-galls show no trace of limonite. There is a marked contrast in colour and surface texture between the green, earthy pellets and the shiny, brown limonite pellets, with no intermediate stages. No interaction or conversion between limonite pellets and glauconite envelopes has been observed. Hence, it appears unlikely that limonite pellets were formed from glauconite pellets unless there was some subtle, but well defined compositional difference between the limonitized pellets and those which were not limonitized.

The limonite pellets were probably deposited as such, either in the manner described by Glaessner (1953b, above) or precipitation of iron oxides from solution, or coagulation of colloidal oxides. The very coarse sands and granules show tabloid limonite which may be thinly laminated. This indicates ~~that~~ deposition of limonite in bedded form by precipitation or coagulation. Such deposits could form in temporarily quiet waters within parts of a delta, and be subsequently eroded; if the bedded limonite had compacted to any substantial degree, it ~~could~~ would form tabloid fragments, either laminated or homogeneous, but if compaction had not proceeded to a sufficient extent, agglomerations of limonite would form pellets. Some of the limonite pellets, a small minority, are sutured, and cylindrical rather than ellipsoidal. These are probably ~~of organic origin, a~~ faecal pellets, and therefore of organic origin.

~~ii) Glauconite.~~

VIII 7) 20.12.60.

ii) Glauconite.

The glauconite in the South Marlin Sands occurs in four separate forms:

i) Fossil replacement and ~~moulds~~ casts.
ii) Envelope around ~~the~~ sand grains.
iii) Clay-galls.
iv) Pellets of sand-size and ellipsoidal shape.

Burst (1958, page 315 etc) considers that the discrepant and contradictory conclusions about many specific environmental characters, which many authors regard as "necessary" for the formation of glauconite, are due to the fact that none of these specific characters "is in itself the controlling feature of glauconitization." This conclusion has been ~~lately~~ more recently borne out by observations of Turnau-Morawska (1960). Burst (1958, page 315) gives three broad requirements for the formation of glauconite, considering that ~~these~~ they allow for the number of described specific origins for the mineral. which have been describes His prerequisites are

described

a) Minerals with a layered ~~lattice~~ silicate lattice.
b) Plentiful supplies of iron and potassium in the environment.
c) A favorable oxidation potential in the environment.

The first step in glauconitization, according to Burst (1958 page 318) is deposition or collection of argillaceous material in pelletal form. The next step is "ionic fixation" and adjustment to environmental conditions. "In this process, the fecal material and cast fillings are probably the most amenable to adjustment" (Burst 1958, page 320).

In the South Marlin Sands, the occurance of fecal pellets means that ~~suitable~~ clays, ~~were~~ amenable to glauconitization, were present in the depositional environment, where they were produced by ~~or in the~~ burrowing organisms or originally present in the ~~muds~~ clays on which these organisms fed. Their ~~provenance~~ presence close to the depositional environment is indicated by glauconitic infillings of foraminifera and clay galls, which may have suffered transport prior to ~~the~~ burial. Suitable quantities of iron and potassium were probably derived from the same source as limonite pellets.

Exactly what conditions constitute "a favourable oxidation potential" is not agreed upon by some authors. Most consider slightly reducing conditions are necessary, but others suggest slightly oxidizing conditions, or even alternations of both (Burst 1958, page 320 and Turnau-Morawska (1960)). Few conclusions in this respect can be drawn from the South Maslin Sands. Glauconite in pelletal form and foraminiferal infillings, was probably produced in reducing conditions associated with traces of organic matter. The clay galls, if glauconitized at the time of, or soon after deposition, were formed in an ~~oxidizing~~ environment of much bottom current activity, with probable oxidizing conditions. Alternatively they could have been formed in reducing conditions in other parts of the delta and transported to the site of burial. The conditions under which the glauconitic envelopes developed is even less clear. Two possible origins are discussed in page 44.

~~The glauconite envelopes may have formed~~

### 3) Depositional environment of the Tortachilla Limestone.

Reynolds (1953, page 137) considers that the marine fauna of this formation is indicative of shallow water deposition, with little wave action. A non fossiliferous sandy facies inland from the present coastline (Woodard 1955 page 21) indicates that a shore line was not far from the area in which the formation was deposited. The formation represents a marine transgression over the deltaic areas of the lower ~~formation sand~~ South Maslin Sands.

The nature of the underlying formation influenced the lower beds of the transgressive formation and its basal contact. The mottled clayey-sands (page 33)) contain quartz and limonite grains and blocks of sand derived by erosion of the underlying formation. Increased marine current and wave action on unconsolidated South Maslin Sands was caused by the transgression, and erosion and redistribution of sediment from the lower formation produced ~~a~~ the ~~disconformable~~ disconformity discussed in section VI. As the transgression proceeded, bottom erosion lessened, and the typical limestones were developed, gradually with decreasing quantities of clastic materials.

gradually

### 4) The Relation of the South Maslin Sands to the Eocene sediments of St. Vincent Basin.

VIII 9) 20.12.60.

~~The~~ Cainozoic sedimentation in the Saint Vincent Basin commenced with deposition of fresh-water deltaic sediments in a basin floored by folded and eroded Proterozoic ~~and~~ and Cambrian rocks, or unconsolidated Permian sediments. Some marine influence indicates that marine conditions existed close-by. Glaessner and Wade (1958, page 123) regard the source of ~~those~~ these sediments as low hills to the east, west and south of the basin. Deposition of these sediments ceased with relative uplift in marginal parts of the basin. Then followed a return to sub-aqueous deposition, with increased marine influence in ~~p~~ the two southern sub-basins of the Saint Vincent Basin. Further deltaic deposits ~~the South Maslin Sands~~, with estuarine conditions in channel-ways, produced the ~~H~~ South Maslin Sands, with lignitic deposits in adjacent fresh water swamps.

marginal.

Deltaic deposition in most areas was stopped by a marine transgression of more permanence than any within the ~~North~~ underlying formations. A ~~disconformable~~ disconformity at the top of the South Maslin Sands indicates increased bottom erosion at the beginning of the transgression. These conditions were followed by ~~calm~~ deposition of marine limestones in calm, ~~clear~~ and shallow water, producing the Tortachilla Limestone and Blanche Point Marls, the equivalents of which may be recognized in most parts of the Saint Vincent Basin.

~~The South~~ Maslin

IX 1) 20.12.6

## ~~VIII~~ ~~IX~~ Post depositional changes within the South Maslin Sands

### 1) Mineralogical changes

### a) Limonite.

Limonitic concretions have developed within the formation, probably by solutions ~~dem~~ deriving ferruginous material from limonite pellets. These concretions are commonly associated with ferruginous clay bands, found where the sands have suffered weathering, mainly in areas from which the Tortachilla Limestone has been eroded. In part this ferruginization ~~may~~ be due to Recent weathering, and in Local. some areas north of L.I. (map 31) it is due to pre-Pliocene erosion and weathering.

### b) Glauconite.

Glauconite replacement of calcitic and aragonitic tests is probably a post-depositional feature, but the time of replacement is unknown. Glauconitization of foraminiferal infillings preceded solution of the carbonate test, for the moulds of the walls are preserved clearly ~~in~~ within the infilling.

The developement of glauconite envelopes could have been due to introduction of glauconite into the formation after deposition. No ordered distribution of glauconite was observed (page ~~[illegible]~~ 17)), and clay minerals amenable to glauconitization were found in the sedimentary environment (page 41 ~~[illegible]~~ ?)). It is ~~therefore~~ concluded, therefore, that the glauconite developed within the formation.

The absence of glauconite envelopes on all fossils except sponge spicules is a striking feature. Glauconite counts or ~~counts~~ do form on fossil fragments, according to Carozzi (1960 pp 47-8) and Turnau-Morawska (1960). If the fragments had been calcitic at the time of envelope-formation, it is expected that the fossils would have been enveloped too. The fact that they show no envelope suggests that they had already been replaced by glauconite at the time of envelope development, and that the envelopes developed on all non glauconitic fragments within the sands but not on glauconite fragments. Formation of the envelopes

~~counter~~ envelopes

preceded solution of sponge spicules, for the envelope preserves the morphological shape of the now-absent spicules.

Glauconite is apparently involved in a number of post depositional changes, which may be summarized thus:

1) Developement of glauconite in foraminiferal infillings and faecal pellets at, or soon after, burial. This is in agreement with Burst (1958, page 41 of this thesis).

2) Replacement of carbonate tests by glauconite, ~~[illegible]~~

3) Developement of a glauconite envelope on quartz and limonite grains and on sponge spicules.

Following these changes, the sponge spicules (probably siliceous - see page ~~21~~ 23)) dissolved.

Recent weathering of brown sands in the cliffs of Maslin Bay shows ~~[illegible]~~ small scale developement of glauconite envelopes in restricted areas. In steep gullies, ~~[illegible]~~ a crust of purple sand one to two inches deep may develope in the bottom of water courses where alluvium does not accumulate. This ~~crust represents~~ crust shows a thicker glauconite envelope than the very thin film found in the brown sands. It may represent redistribution of glauconite ~~with~~ during weathering.

## 2) Tectonic changes

Because of the disconformable nature of the top and base of the formation, ~~the~~ its original ~~altitude~~ and its present altitudes cannot be accurately gauged. Hence, any ~~tectonic changes must~~ post-depositional tectonic changes can only be indirectly determined.

~~Along~~ Together with other sediments of the Saint Vincent Basin the South Maslin Sands ~~would~~ have been lightly folded and tilted in the Miocene and later movements mentioned by Glaessner (1953b, page 41).

## IX Summary and conclusions

Field and laboratory investigations of the three lowermost formations of the Cainozoic sequence of the St. Vincent Basin have been carried out, with particular emphasis on the sedimentary characteristics of the South Maslin Sands.

North Maslin Sands, the basal Tertiary formation of the sequence, have been studied in outcrops associated with South Maslin Sands. The former in these outcrops are generally well to moderately sorted, angular to subangular sands, with extensively developed tabular and wedge-shaped sets of planar-type cross-bedding. Fossils are very rare, and predominantly plant remains, with restricted occurrences of marine invertebrate remains.

Disconformably overlying the North Maslin Sands in the Noarlunga and Willunga sub-basins of the St. Vincent Basin is the ~~succeeds~~ succeeding Eocene formation, the South Maslin Sands, a sequence of up to 160 feet of green, purple and brown sands, with minor bands of clay- and granule-rich sediments. The average mineralogical composition of the sands is 60% quartz, 30% limonite and 10% glauconite. They are mainly well to moderately sorted, medium to fine grained sands, with subrounded to rounded polished quartz, and near ellipsoidal limonite pellets. ~~The grains~~ Each quartz and limonite grain is coated with a glauconite envelope in purple and green sands. Cross-bedding is developed on an extensive scale, with medium-scale, trough-type sets most common. Clay-galls are a common feature. Fossils are widely scattered in a low density, mainly fragmental remains of marine invertebrate tests. They are most commonly preserved as glauconitized tests. Burrow casts and faecal pellets are common traces of organic activity.

A thin limestone, the Tortachilla Limestone, overlies the South Maslin Sands with a less marked disconformity than the basal contact of the latter formation. The limestone carries a rich marine fauna, and lies, conformably, immediately below undoubtedly Upper Eocene sediments – the basal beds of the Blanche Point Marls.

Based on these features, conclusions have been made as to the probable conditions of sedimentation of the three formations, in an endeavor to ascertain the manner in which the South Maslin Sands fits into the pattern of Eocene sedimentation within the St. Vincent Basin.

It was concluded that Tertiary sedimentation in the basin commenced with the development of fresh water deltaic sediments, with clean, well to moderately sorted sands deposited in parts of the basin, and fresh water swamps producing lignite elsewhere. Following some relative change in water level, with erosion of sediments within parts of the basin, followed a period of sedimentation, with increased marine influence in channel-ways ~~in~~ within the deltaic environment in the Noarlunga and Willunga Basins. This lead to the deposition of the limonitic and glauconitic South Maslin Sands. Deposition of the South Maslin Sands was stopped by a further increase in marine influence, associated with a general Upper Eocene transgression throughout the St. Vincent Basin. Associated with the transgression, the top of the South Maslin Sands was eroded, and the sediments incorporated in the basal beds of the Tortachilla Limestone.

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# References

Burst, John F., 1958, "Glauconite" pellets: their mineral nature and applications to stratigraphic interpret-~~atim~~ations: Am. Assoc. Petroleum Geologists Bull., vol. 42, pp 310-27.

Carozzi, Albert V., 1960, "Microscopic Sedimentary Petrography": John Wiley and Sons Inc., New York and London.

Chapman, F., 1935, Plant remains of Lower Oligocene age from near Blanche Point, Aldinga, South Australia: Trans. Roy. Soc. S. Aust., 72, pp 252-258.

Cochrane, G.W., 1956, The geology and hydrology of the Willunga Basin: Geological Survey of S. Aust. Report of Investigations No. 8.

Crespin, I., 1954, Stratigraphy and micropalaeontology of the marine Tertiary rocks between Adelaide and Aldinga, ~~Bay~~ South Australia: Rep. Bur. Min. Resour. Aust., 12, 65 pp.

Daily, B., 1953, Stratigraphy and geology of the Noarlunga Basin: Unpublished thesis, University of Adelaide.

Glaessner, M.F., 1951, Three foraminiferal zones in the Tertiary of Australia: Geol. Mag., 88, pp 273-283.

~~Glaessner~~, 1953a, Conditions of Tertiary sedimentation in southern Australia: Trans. Roy. Soc. S. Aust., 76, pp 141-146.

—, 1953b, Some problems of Tertiary geology in southern Australia: J. Roy. Soc. N.S.W., 87, 2, pp 31-45.

—, and Wade, Mary, 1958, The Saint Vincent Basin; In "Geology of South Australia", edited by Glaessner, M.F., and Parkin, L.W., Melbourne University Press.

Howchin, W., 1923, A geological sketch-section of the sea-cliffs on the eastern side of Gulf St. Vincent, from Brighton to Sellick's Hill, with descriptions:

Trans. Roy. Soc. S. Aust., 47, 301-307.

Krumbein, W.C., and Pettijohn, F.J., 1938, "Manual of Sedimentary Petrography": D. Appleton-Century Company Inc., New York and London.

~~Kuenen~~ Kuenen, Ph. H., 1960a, Experimental ~~[illegible]~~ abrasion; 4; Eolian action: Jour. Geology, vol. 68, no 4, pp 427-449.

— 1960b, Sand: Scientific American, April, 1960, pp 95-110

McKee, Edwin D., 1957, Flume experiments on the production of stratification and cross-~~bedding~~ stratification: Jour. Sed. Petrology, vol. 27, pp 129-134.

— , and Weir, Gordon W., 1953, Terminology for stratification and cross-stratification in sedimentary ~~rocks~~: Bull. Geol. Soc. America, vol. 64, pp 381-390.

Pettijohn, F.J., 1957, "Sedimentary Rocks": Harper and Brothers, New York.

Reynolds, M., 1953, The Cainozoic succession of Maslin and Aldinga Bays, South Australia: Trans. Roy. Soc. S. Aust., 76, pp 114-140.

Rogers, Austin F., and Kerr, Paul F., 1942, "Optical Mineralogy": McGraw-Hill Book Company Inc., New York and London.

Tate, R., 1878, Notes on the correlation of the coral-bearing strata of South Australia, with a list of the fossil corals occurring in the Colony: Trans. Phil. Soc. Adel. for 1877-78, 120-123.

— , 1879, The anniversary address of the President, Ibid., for 1878-79, 51-58.

, 1899, On some older Tertiary fossils of uncertain age from the Murray Desert: Trans. Roy. Soc. S. Aust., 23, (1), 102-110.

Turnau-Morawska, Maria, 1960, A glauconitic conglomerate from the Lower Ordovician in Miedzygórz, Holy Cross Mountains, Central Poland: Acta Geologica Polonica, vol. X, pp. 121-148. English summary pp. 142-145.

Wade, Mary, 1953, The Tertiary succession of the Christie's Beach-Seaford coast: Unpublished thesis, University of Adelaide.

—, 1955, A new genus of the Chapmanininae from southern Australia: Contributions from the Cushman Foundation for Foraminiferal Research, vol VI, part 1, pp 45-49.

Woodard, G.D., 1952, Stratigraphy and geology of the Willunga Basin; Unpublished thesis, University of Adelaide.

# Appendix.

Figures 24 - 30 : cumulative curves

Figure 31 : map of Maslin Bay area.

figure 32 : map of wave cut platform, Maslin Bay.

figure 33 : Scour-and-fill structure - unit "H" of map 32.

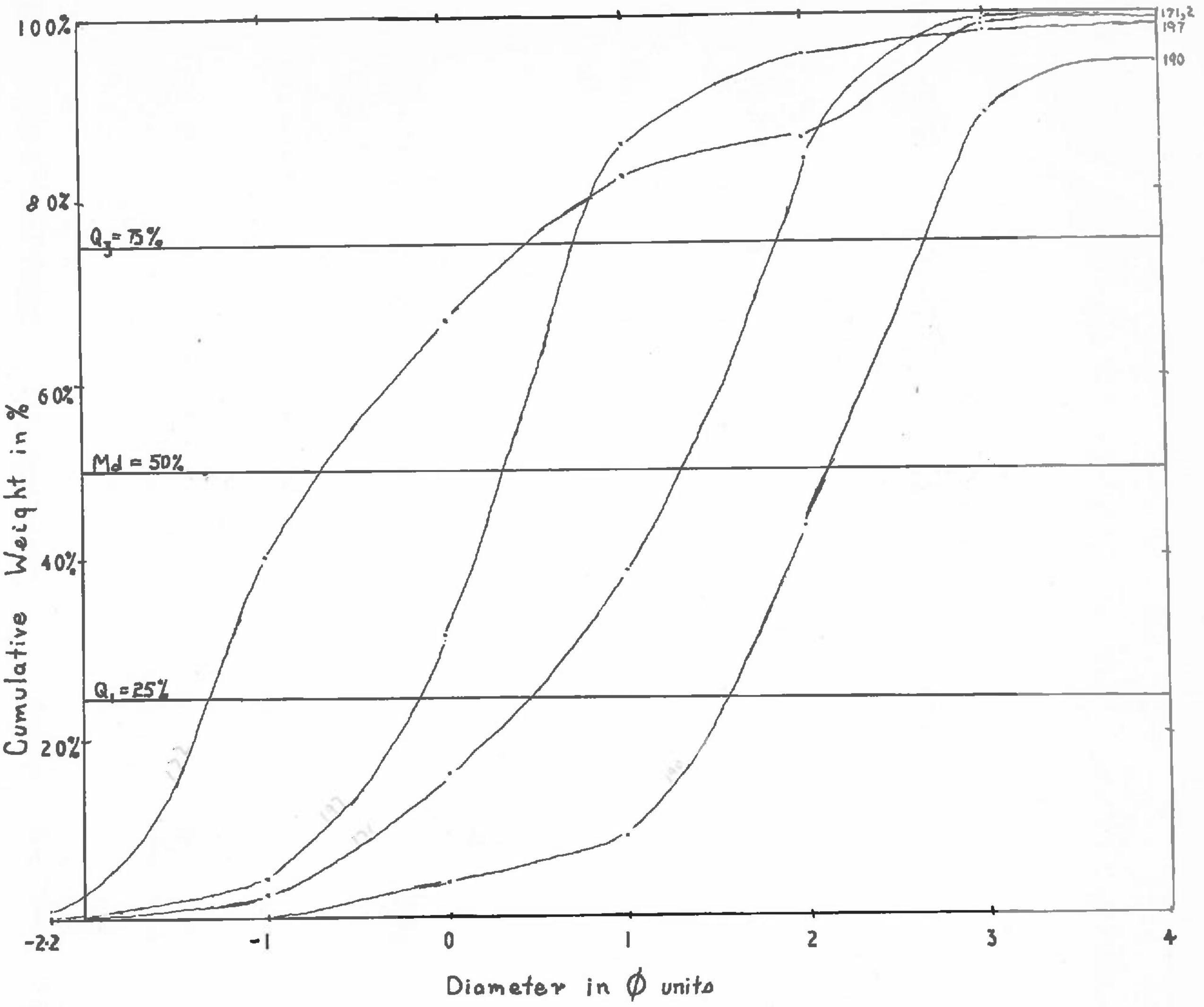


Figure 24

Grain size distribution for North Marlin Sand

| Sample No. | Locality |
|---|---|
| A196/171 | Albert's pit, bore 1, surface |
| 172 | Albert's pit, bore 1, 24±-26' |
| 190 | Albert's pit, section "C" - see fig. |
| 197 | South wall of the Canyon. |

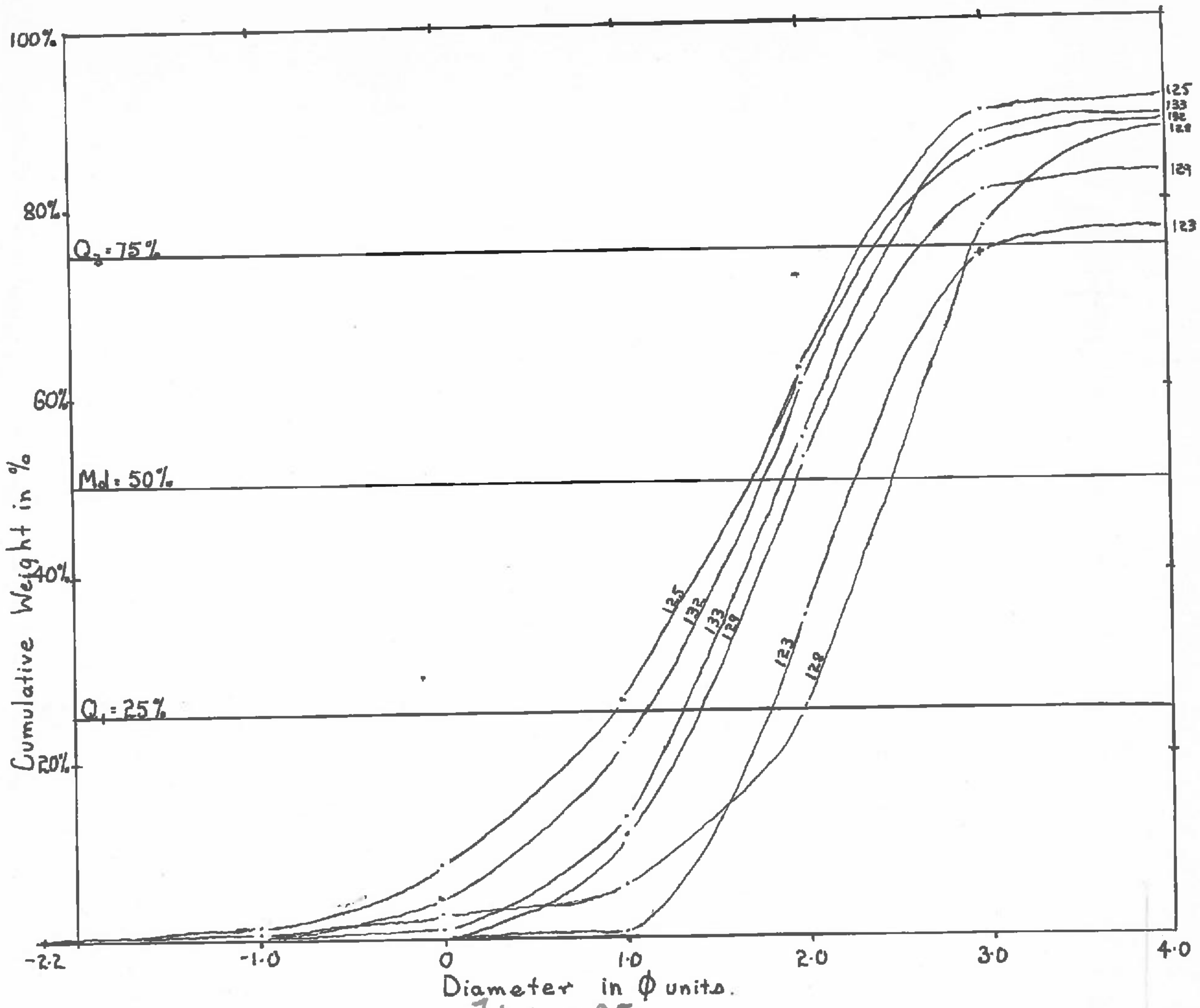


Figure 25

Grain size analyses for South Marlin Sands on wave cut plat form, Marlin Bay.

| Sample No. | Location |
|---|---|
| A196/123 | Unit A, representative sample (see map, fig 31) |
| 125 | Unit B. " " " " " |
| 128 | Unit C " " " " " |
| 129 | Unit D " " " " " |
| 132 | Unit F " " " " " |
| 133 | Unit D west of station 2. |

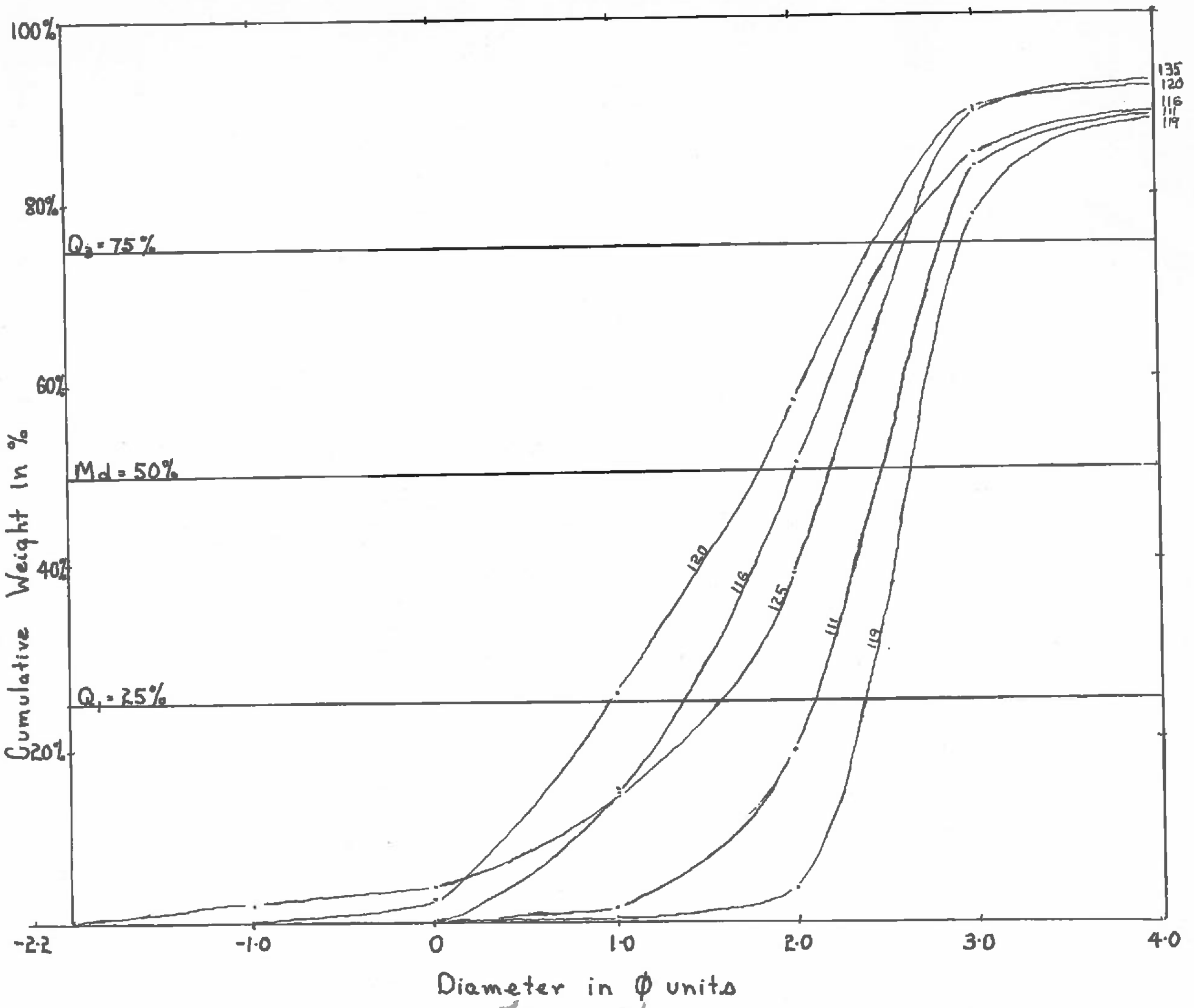


Figure 26

Grain size distribution for South Maslin Sands on wave cut platform, Maslin Bay.

| Sample No | Location |
|---|---|
| A196/111 | Unit I, representative sample (see map fig 31) |
| 116 | Unit K, ″ ″ ″ ″ ″ |
| 119 | Unit L, ″ ″ ″ ″ ″ |
| 120 | Unit M, ″ ″ ″ ″ ″ |
| 125 | Unit B, between station -500' and -600' |

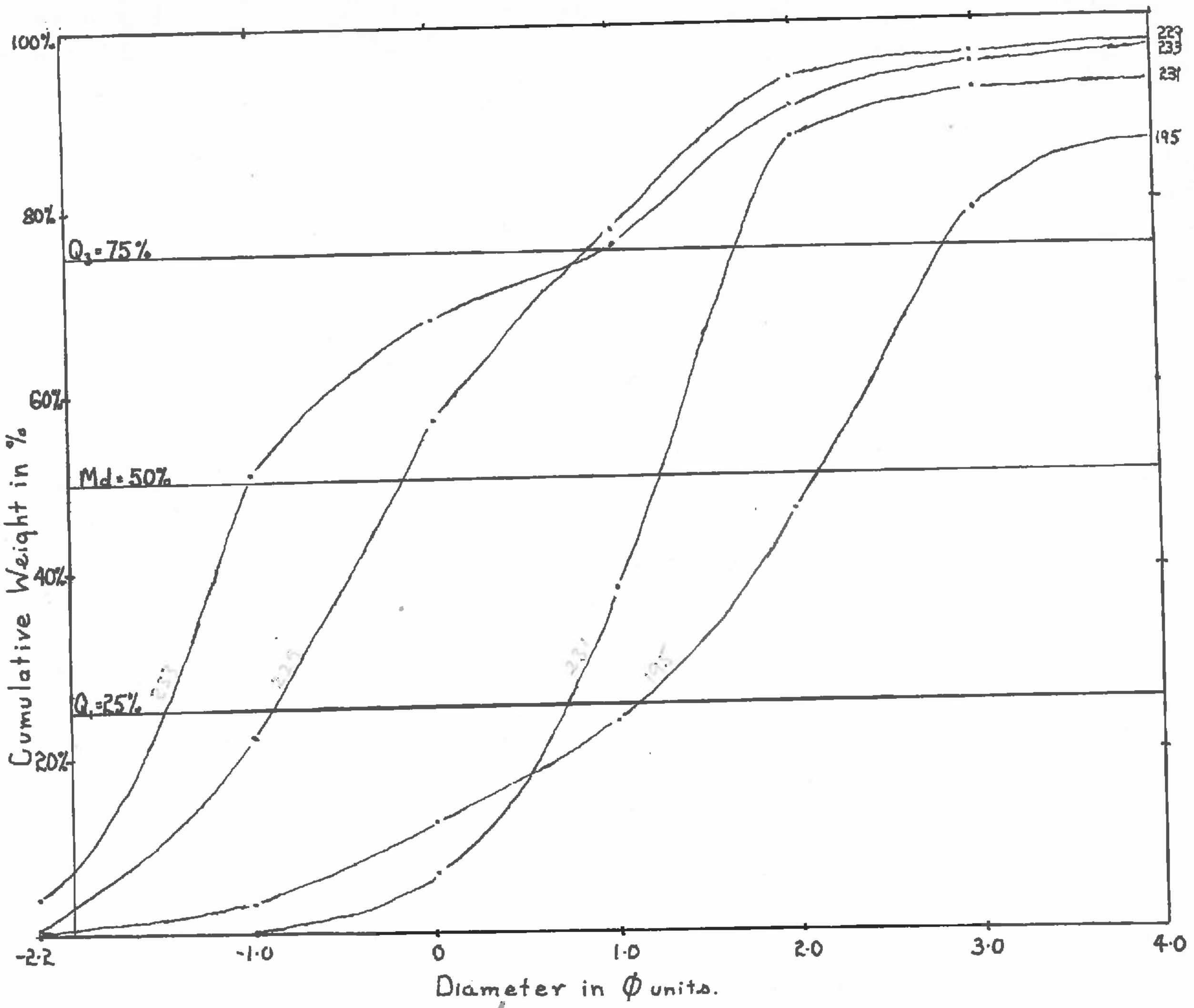


figure 27

Grain size distribution of South Maslin Sands in cliff section, Maslin Bay

| Sample No. | Location |
|---|---|
| A196/195 | Basal Sth. Maslin Sands in Noarlunga pit. |
| 229 | Coarse grained and granular sands |
| 231 | Medium grained sand (brown) |
| 233 | Granule sized South Maslin Sands |

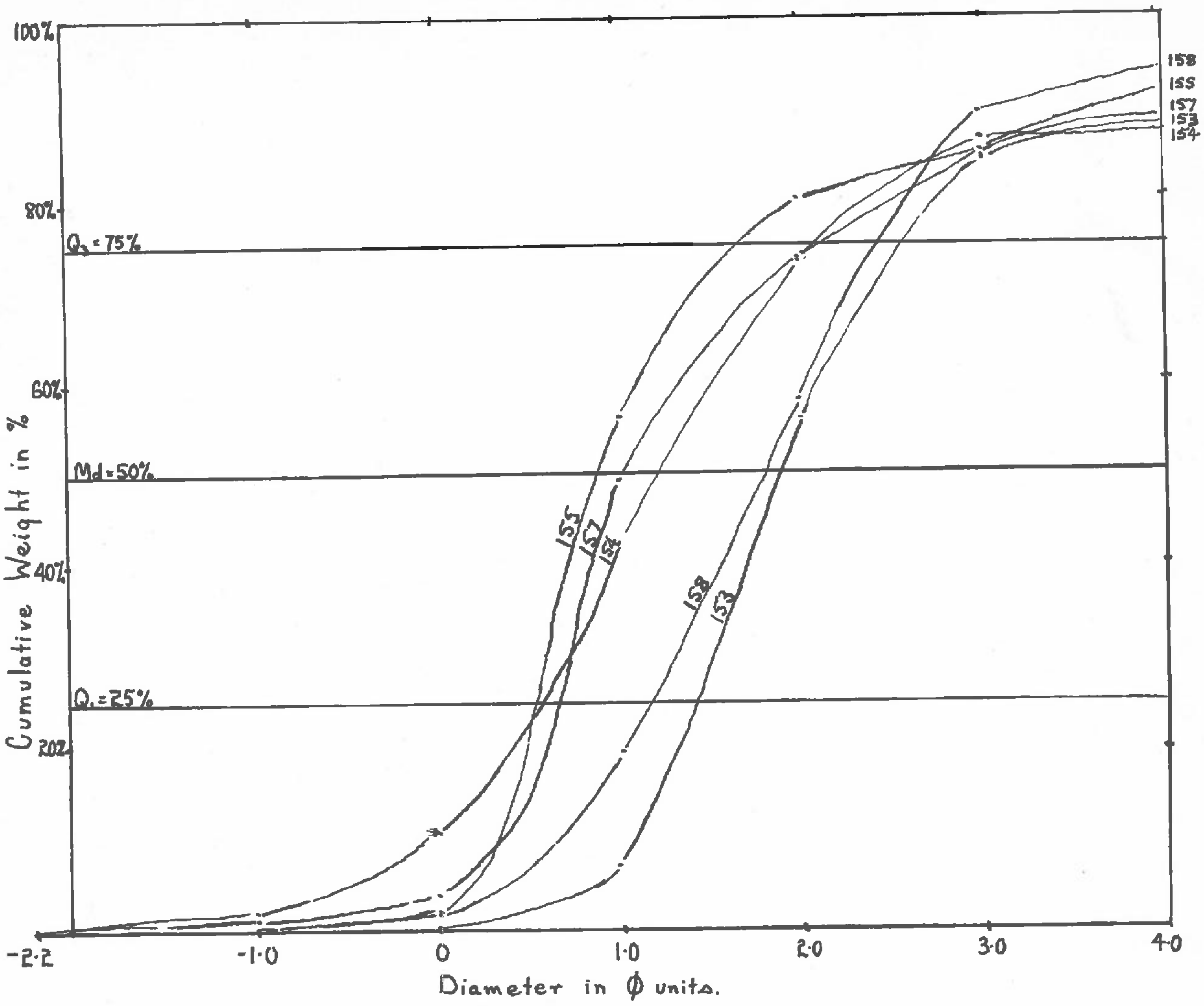


Figure 28

Grain size distribution of sands in section D,
Albert's Sand Pit, Maslin Bay
(Photograph fig 18).

| Sample no. | | Location | |
|---|---|---|---|
| A196/153 | (Top) | 8'–6' | green Slt. Maslin Sands |
| 154 | | 6'–4' | brown .. .. .. |
| 155 | | 4'–2'6" | .. .. .. .. |
| 157 | | 2'–1' | .. .. .. .. |
| 158 | | 1'–0' | lens of reworked North Maslin Sands |

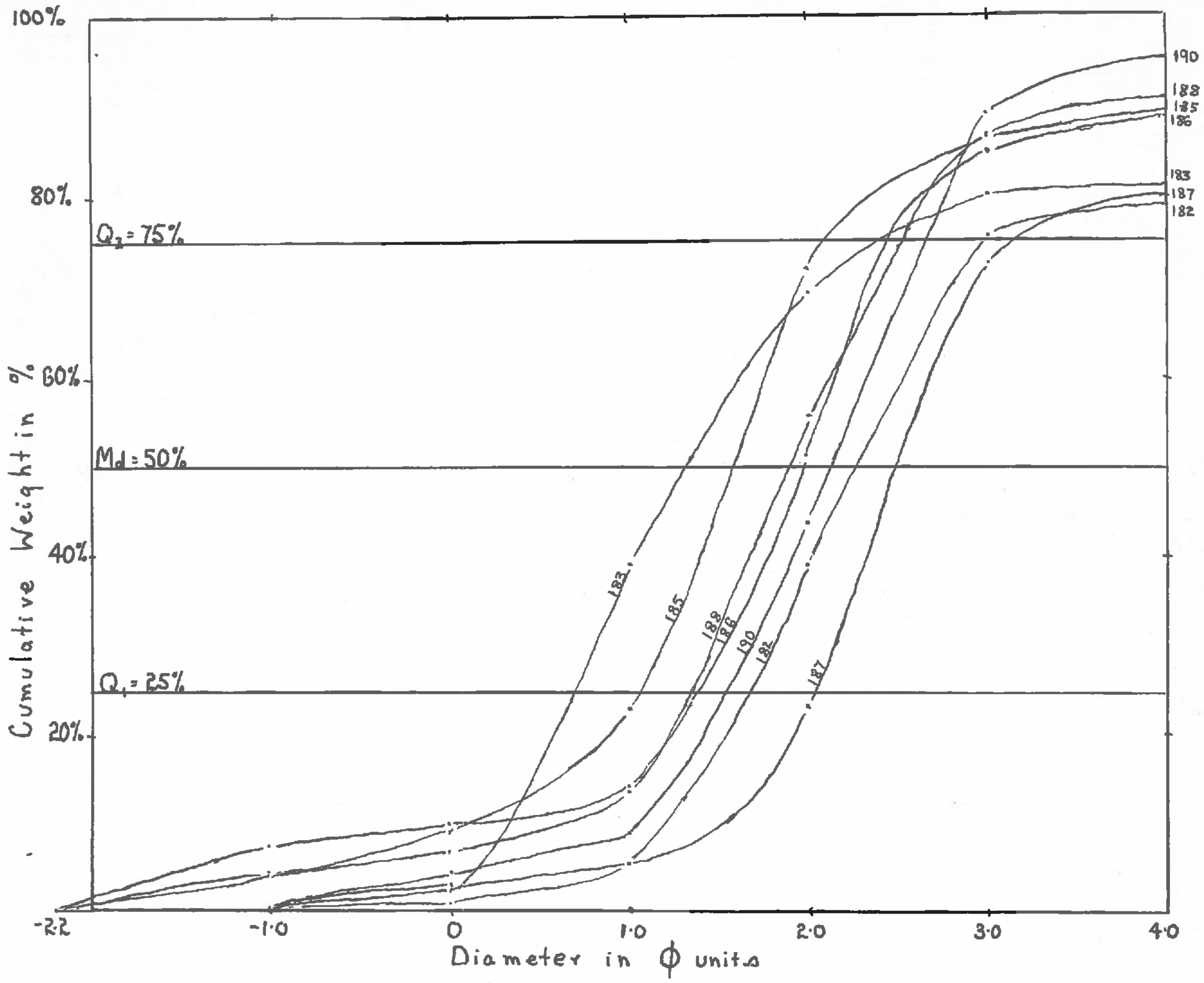


figure 29

Grain size distributions of sands in section "C", Albert's Sand Pit, Maslin Bay.
( Photograph figure 18. ).

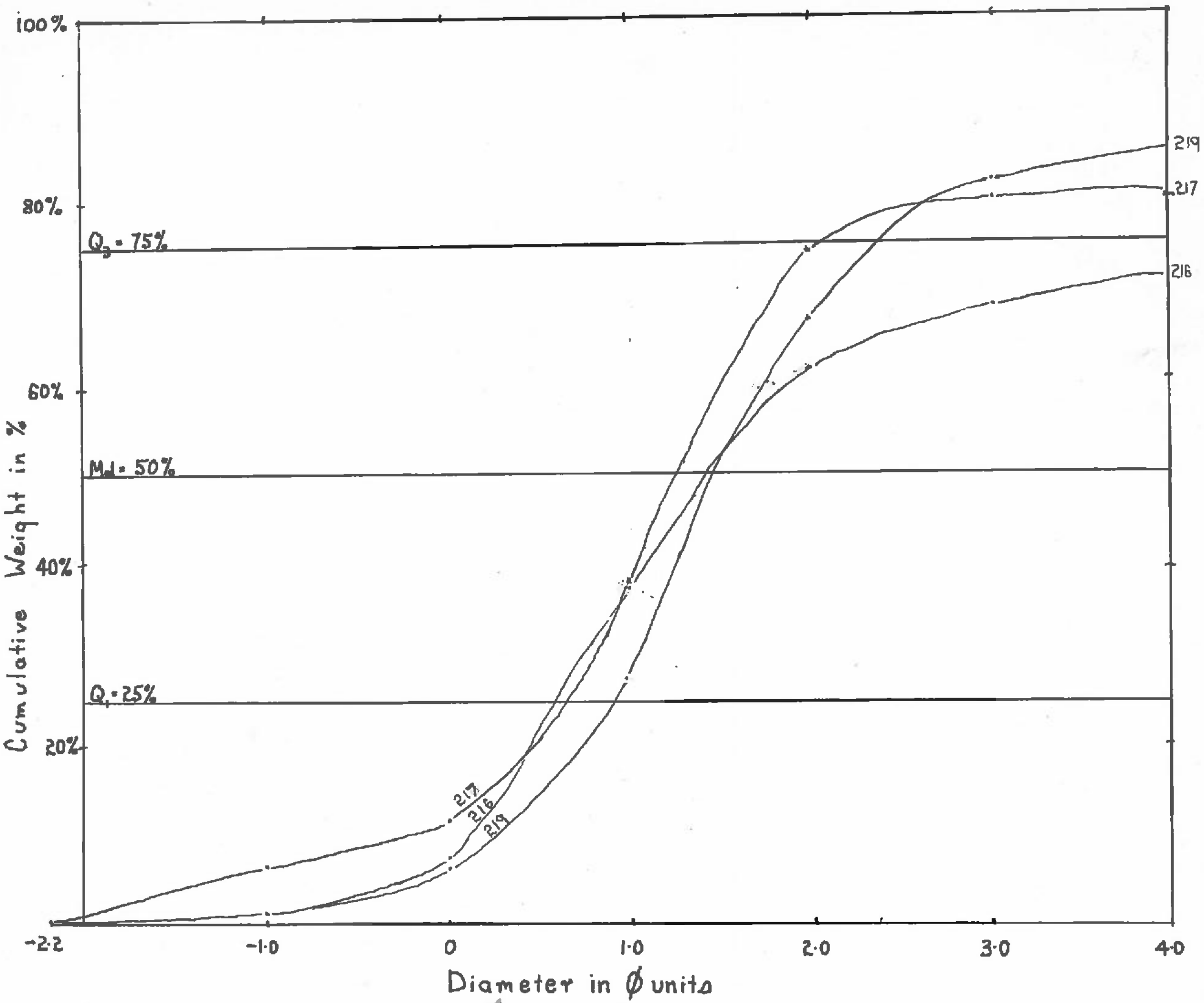


Figure 30

Grain size distribution for sands from bore 13, Albert's Sand Pit.

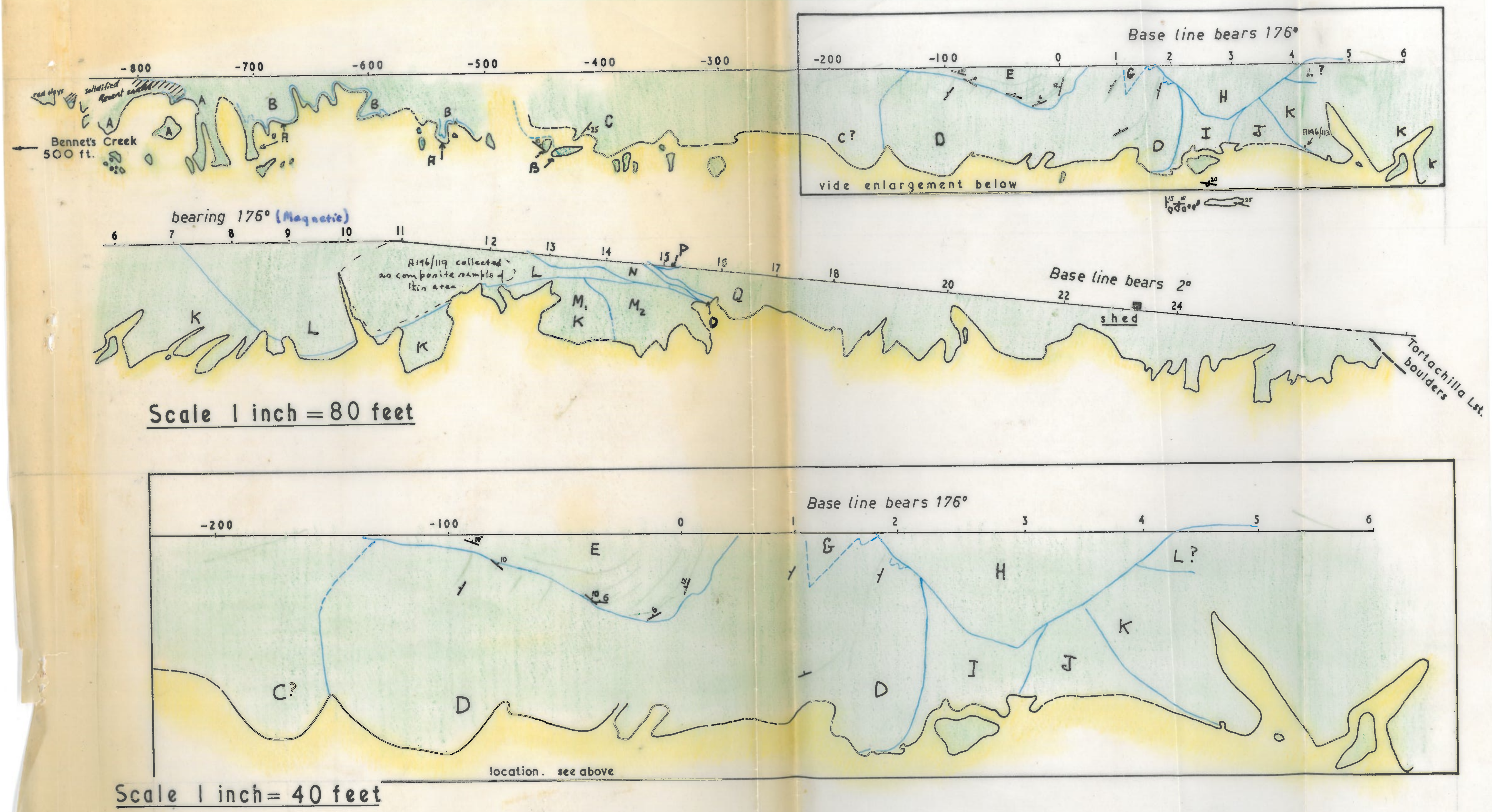
| Sample No. | Location | |
|---|---|---|
| A196/216 | bore 13, [illegible]' 8' from top | } South Marlin Sand |
| 217 | " , 12' " " | } |
| 219 | " , 18' " " | } North Marlin Sand. |

Fig 31.

EOCENE EXPOSURES MASLIN BAY

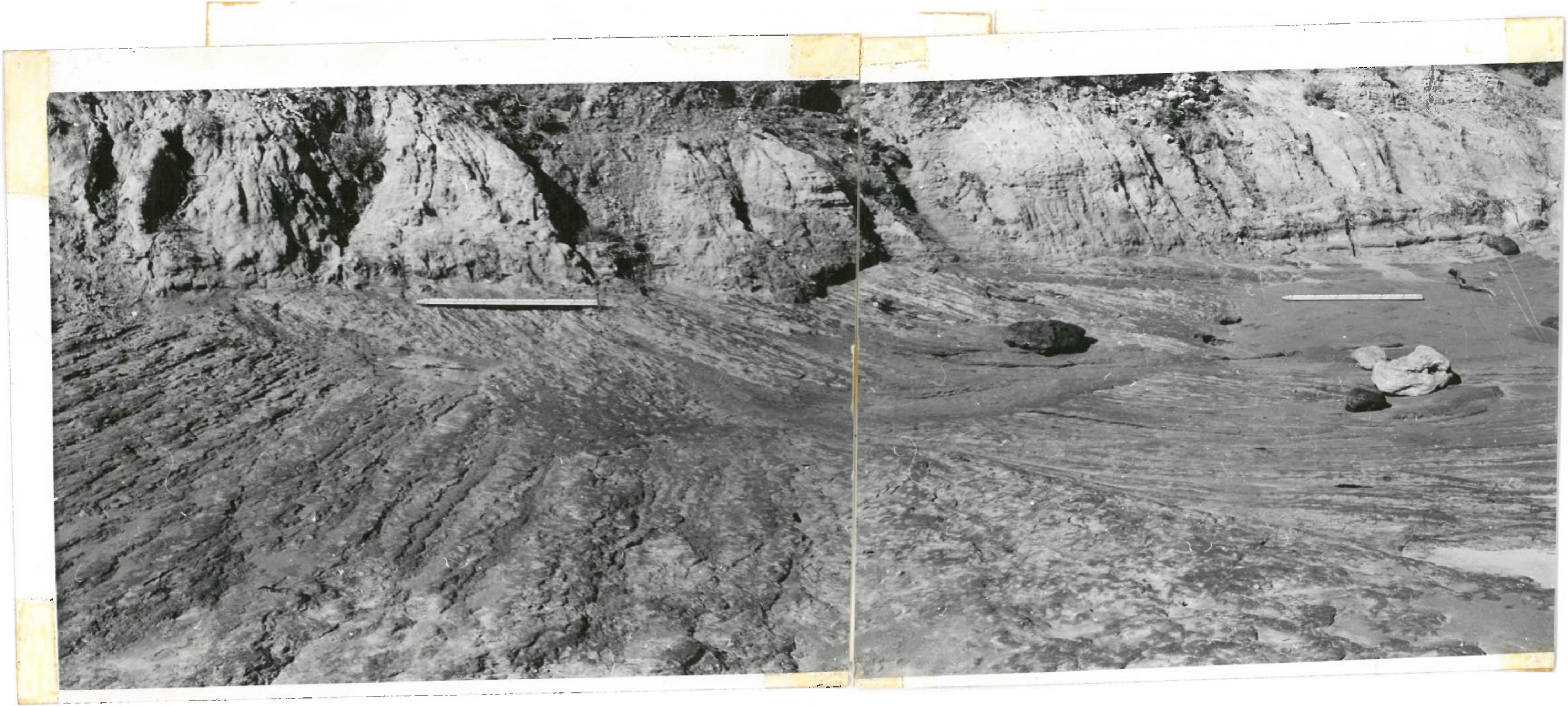
Fig 32

# WAVE-CUT PLATFORM MASLIN BAY



🟨 S Recent beach deposits

🟩 SOUTH MASLIN SANDS



Scour & fill structure, Maslin Bay wave-cut platform (continued over)

Scour & fill structure, Maslin Bay wave-cut platform (continued from previous page)