STRATIGRAPHY AND GEOLOGY OF THE WILLUNGA BASIN

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ABSTRACT

An almost complete sedimentary record of Cainozoic sediments from Eocene to Recent is known in the Willunga Basin. The surface formations have been mapped and described, special attention being paid to the Stratigraphy of the area. The subsurface geology has been interpreted from bore logs, and attention is drawn to the conditions of sedimentation and changes in facies of the strata.

INTRODUCTION

1. Location.

The Willunga Basin which embraces part of the Hundred of Willunga together with part of the Hundred of Kuitpo is a roughly triangular area of about a hundred square miles extending westwards from the Willunga Scarp south of Kuitpo to the eastern shore of St. Vincent's Gulf. Its northern boundary consists of Pre-Cambrian metamorphosed sediments, the principal rock types including slates, limestones, quartzites and tillite. Cambrian sediments of the Willunga Scarp form the southern boundary, extending from the cliffs south-west of Mt. Terrible Gully to approximately half way between the townships of Willunga and Kangarilla where the contact with the Pre-Cambrian is exposed.

2. Previous work.

Previous geological investigations in this area have been confined mainly to the coastal strip south of Ochre Point. Early work on the Cainozoic sediments was carried out by Tate between 1879 and 1899; E.V. Clark (1899 and W. Howchin (1911, 1923). Faunal investigations have been made by Dennant, Chapman, Singleton, Parr and Crespin. The Cainozoic succession of Aldinga and Maslin Bays was mapped in 1951, and a succession established by M.A. Reynolds as part of the work for his Honours thesis. Inland, Eocene limestones were reported by Tate, and Howchin undertook general reconnaissance work. Dr. Glaessner has completed a reconnaissance of the area, and has collected material and made stratigraphic observations from most of the locations mentioned in this thesis. Sir Douglas Mawson has mapped the geological formations in association with establishing a sequence of the Tertiary succession, but has not yet published the results of his investigations. A survey of the area for hydrelogical purposes was completed by G.W. Cochrane of the South Australian Department of Mines, in 1950, and an attempt made to recognise the major stratigraphic divisions.

3. Nature and Scope of Investigations

The purpose of investigation of this area has been not only to map the surface geology, but both to correlate from available bore material the inland sediments of the Basin with the standard Cainozoic section prepared from coastal investigations by M.A. Reynolds in 1951, and to study the change in facies of the strata between the coastline and central portions of the Basin. This latter project has been made possible through the assistance of the Department of Mines, from whom samples of a bore WB-1 were supplied during the year, and also by Mr. D. Hardy of Tintara Winery, McLaren Vale, who also offered the material.

(1) Field Mapping.

Preliminary investigations in the field were made first in February of this year, but the field work was not completed until later in the year, the intervening period being spent on faunal investigations on the bores supplied. Considerable difficulty has been experienced in field mapping due to:-

(i) The low rolling topography and lack of exposures, these two factors reflecting the gently dipping attitude and lack of resistance to erosion of the Tertiary sediments.

(ii) The major portion of the area is under extensive cultivation.

(iii) All but the most juvenile of the water courses adjacent to the Willunga Scarp are shallow without rock exposures.

(iv) Most of the area not covered by alluvial clays is overlain by fine white dusty sands. These sands can be traced from west of McLaren Vale to the northern most limits of the Basin in the vicinity of Kangarilla.

(2) Sampling.

Specimens of all Tertiary rocks exposed in road and rail cuttings, quarries and creeks have been collected and numbered, together with numbering of the locations from which the samples were obtained. These location numbers, together with the nature of the outcrops, have been marked on the map, scale two inches to the mile, supplied. The samples are deposited in the Palaeontology coolection of the University. Investigations for microfossils suitable for correlation have been made on all suitable samples collected from these surface exposures.

The boundaries between surface sands and alluvium have been mapped and plotted with as reasonable degree of accuracy as the surface exposures will allow. Boundaries not clearly defined are shown with a broken line. Sections of all available bores and cuttings were prepared on a scale of one inch to fifty feet, and these have been used in subsurface correlation. The Willunga Bore WB-1 drilled at the corner adjacent sections 222-3 and 232-3 has been taken as the inland standard due to the importance of its position, its greater depth, and the more accurate and complete sampling at two to three feet intervals.

In foraminiferal investigation, samplings for washing were taken at ten foot intervals between the upper and lower limits of each unit and at proportionately closer intervals where any noticeable lithologic or faunal change necessitate more detailed investigation. Detailed study of the foraminifera has not been undertaken owing to lack of time, but separation of the different species into grid slides has been completed and generic identifications made on foraminifera from HB-420.

II Stratigraphy

1. Pre-Cambrian and Cambrian.

The northern limit of the Basin consists of Pre-Cambrian metamorphosed sediments of the Adelaide System. These are exposed from the coast at Ochre Point east to the Willunga Scarp, north of Kangarilla. They consist of steeply dipping and highly folded quartzites, slates, limestones and shales.

The southern limit of the Basin in the region of Willunga is of Cambrian sediments dipping steeply north-west with a strike of about 60°. These Cambrian slates, quartzites and limestones have been overturned and highly sheared, and are overlain unconformably by the Upper Tertiary sediments.

2. Tertiary Sediments

1. Formation: Bakers Gully Gravels.

Exposure.

This formation can be traced from the road cutting on the Clarendon-Yaroona highway where the unconformity between the gravels and Pre-Cambrian can be seen in a southwesterly direction bordering the Pre-Cambrian ridge south of the Onkaparinga River. The gravels are exposed in the Baker's Gully quarry, and from this point, can be traced in a minor arc over a mile or so distance on the south side of the unsurfaced road leading west from Baker's Gully. From this point they are overlain by fine Recent sands until a mile west of Blewitt's Springs and just south of the Baker's Gully - Seaview road where they are found in association with plant remains. A gravel bed in association with ferruginised sands and grits is found still further west of this point in a road cutting at Location 6, and on lithologic and stratigraphic grounds may be correlated with reasonable certainty with the Baker's Gully Gravels. In a shallow cutting adjacent to the Pre-Cambrian basement at Location 14, coarse cross-bedded sands overlain by weathered kunkar, are exposed to a depth of approximately five feet. Equivalents of this sand, and correspondingly of the Baker's Gully Formation, may be regarded as the North Maslin white and brown sands exposed in the sand quarry along the coast, about a mile south of Ochre Point (Reynolds).

Lithology

1. Baker's Gully.

The gravels consist predominantly of sub-angular to angular quartz pebbles, ranging in size from less than half an inch up to an inch or two inches in diameter, cemented in a fine sandy matrix which has undergone extensive ferruginisation resulting in a variegated reddish-brown lateritic gravel. Medium to coarse grained lenses showing the effects of current bedding and minor faulting are common, and usually are found in association with fine white silty clay bands.

2. Location 6: Road cutting two miles north of McLaren Vale. A lateritic grit sequence, consisting in ascending order, of:-

(1) Varigated yellowish-brown to dark brown ferruginised grit (Specimen A.265).

(2) Thin weathered pale brown calcareous sand (Specimen A.266).

(3) Coarse subangular quartz gravel bed, nine inches to a foot in thickness consisting of colourless to amber quartz pebbles up to half an inch in diameter in a fine sandy matrix, cemented by a limonitic cement. (Specimen A.267).

(4) Finer ferruginised grit bed, yellowish brown in colour, one foot nine inches thick.

(5) Sparkling white micaceous fine grained calcareous sand. (Specimen A.268).

(6) Brown ferruginised sandstone or grit.

3. Location 14: Two miles northwest of McLaren Vale in a road cutting on the Noarlunga-McLaren Vale Highway.
A medium to coarse grained cross bedded varigated pale yellowish-brown friable grit, consisting essentially of loosely consolidated colourless to amber quartz grains and subordinate muscovite in a fine sandy matrix.

4. Sand Quarry: South of Ochre Cove.
The red and brown sands grouped by Reynolds as the North Maslin Sands may be regarded as equivalents of the Baker's Gully Gravels on account of:-

(1) Their position, lowermost in the Tertiary succession unconformably overlying the Pre-Cambrian.

(2) They are of freshwater origin forming deltaic deposits adjacent to the quartzose Pre-Cambrian sediments.

(3) They are both characterised by the presence of fossil land plants.

(4) Lithological similarities may be drawn between the two formations with regards to:-

(a) The presence of fine cross bedded sand lenses in the Baker's Gully Formation similar to the North Maslin Sands.

(b) White silty clay lenses associated with fossil land plants are common in the lower regions of both the Gravels and North Maslin Sands.

The coarser grain size of the Baker's Gully deposits would be as expected in sediments adjacent to more elevated source rocks.

Contacts

The Baker's Gully Gravels overlie unconformably steeply dipping weathered purple and chocolate slates of the Adelaide System.

Chocolate slates are exposed in the base of the quarry at Baker's Gully, revealing a thickness of 25 to 30 feet of sand and gravels. No sharp contact with the Pre-Cambrian is elsewhere evident until in the sand quarry at Ochre Cove where the equivalents of this formation, the North Maslin Sands, are exposed unconformably with the pre-Tertiary basement.

South Maslin Sands

The lithological similarity inland, between the South Maslin Sands and the overlying, lower glauconitic sandy member of the Tortachilla Formation makes distinction between these beds difficult. Positive identification of this member can be made "from the southern parts of the sand quarry to the small shallow cave in the south-east corner of Maslin Bay" (Reynolds) and in a shallow cliff section at L.11 half a mile due east of Tortachilla Trig station.

Lithology

The sands consist of well rounded quartz and limonite pebbles together with small green clay pellets, quartzite pebbles etc., set in a loosely consolidated calcareous cement. The sands vary considerably both in grain size and colour, but are generally coarse in texture with a greenish to purplish-brown colour. Cross bedding is generally characteristic of the sands in the coastal exposures, but inland where the outcrop is limited and weathering effects are more pronounced, such features are difficult to discern. Glauconite has not been proved from the sands, but in view of the high percentage of limenitic pebbles, and the common greenish to blue colour the presence of glauconite seems substantiated.

Contacts

South of the Sand Quarry this member overlies unconforably the North Maslin Sands. East of Tortachilla Trig the base of this member is not exposed but its upper limit is given by the fossiliferous Glauconitic and Polyzoal Tortachilla Limestone Members.

3. Formation: Tortachilla Limestones.

1. Polyzoal Limestone Member.

The only exposure of this member known inland from the coast is at L.11, in the shallow cliff section east of Tortachilla Trig where the top of the South Maslin Sand is marked by a thin polyzoal horizon immediately below the base of the Glauconitic Limestone member.

Lithology.

A medium grained polyzoal sand, purplish-brown in colour containing coarse limonite and quartz pebbles.

2. Glauconitic Limestone Member.

As indicated previously, difficulty has been met in distinguishing this member from the South Maslin Sands, in the cuttings north of McLaren Vale where the change in facies has produced a corresponding change in the lithology of this member.

Exposure.

In addition to coastal exposures described by Reynolds (1951), outcrops of this member are known from (1) L.11, east of Tortachilla Trig, where the fossiliferous hard glauconitic limestone forms the predominant ridge of the minor cliff section,

(2) L.7; fossiliferous greenish coloured glauconitic sand.

(3) L.1; " " " " "

Lithology.

1. L.11. - east of Tortachilla Trig.

A hard calcareous highly fossiliferous glauconitic limestone characterised by the presence of small pockets of fr. glauconitic material in the upper parts of the bed. Limonitic pebbles and coarse, angular, amber coloured quartz grains are distributed throughout the calcareous cement, which has in part both within and without the fossil casts undergone recrystallisation. The echinoid *Australanthus longianus* Gregory was collected and identified from the [illegible] Tortachilla Limestone 16 inches above the base.

Contacts.

This member which is known here to a thickness of four feet is terminated below by the Polyzoal Limestone and above by a two feet thick Transitional glauconitic marly bed.

2. Sandy Equivalents of the glauconitic limestone.

Lithology.

Though generally uniform, slight variations in lithology are noticeable in samples taken from the different outcrops. Typically, however, the member consists of a pale greenish-brown medium to coarse grained glauconitic sand consisting of grains of quartz and limonite in a loosely consolidated calcareous cement. In addition, clay pellets, quartz pebbles and organic fragments, the last named much altered by weathering are common. In the base of the cutting at L.7 the sand has undergone extreme leaching and oxidation, resulting in the base of the exposure becoming dominantly iron-rich with a characteristic dark-brownish-green colour. In this firmly consolidated region, polished limonite pebbles and replaced fossil casts are very common. The fact that the leached and oxidised portions of the formation become progressively limonite-rich, substantitates the view that the sand is glauconitic.

Structure.

Altitudes at which this formation is exposed range from 400 feet at L.11, a difference in height of 300 feet over a distance of nearly $5\frac{1}{2}$ miles. This gives a southwesterly, approximate dip of $\frac{1}{2}^{\circ}$.

Contacts.

At Location 7 the fossiliferous glauconitic sand is overlain by fossiliferous Blanche Point Marls. The base of the formation is not exposed, but it seems most probable that the sands have been formed following reworking of the underlying South Maslin Sands.

North of McLarem Vale at L.1, this glauconitic sand forms one of the lower beds of the first road cutting. It is limited below by mottled reddish-brown to yellow ochre-rich silty clays containing medium sized sand grains in a fine ochrous matrix. Overlying the glauconitic sand are unfossiliferous white sands which are in turn overlain by the fossiliferous Blanche Point Marls. The exact position of the unfossiliferous sands in the stratigraphic column is difficult to determine but they may represent a non-marine phase represented in the coastal succession by the Tortachilla Limestones or lower Blanche Point Marls, and as such have been included under this heading. The glauconitic member (Specimen A.255) measures 10 inches to a foot in thickness.

Overlying this member are in order:-

	Lithology	Sample	Thickness
(1)	Fine grained white sands containing the calcified remnants of former root structures.	A.254	6½ feet.
(2)	Medium to coarse grained unfossiliferous quartz sand.	A.253	6½ feet.
(3)	Friable greyish to white silty sands containing laminated pebbles of Pre-Cambrian shale and medium sized quartz grains. A thin yellow ochre band with clear and amber quartz grains follows the bedding two feet above the base of this member.	A.252	5½ feet.
(4)	Yellowish-brown weathered limonite band marking the contact with the overlying "Turritella" beds.		9 inches

Ferruginised sandstone similar to A.255 overlain by kunkar is exposed in the base of the first rail cutting L.8 south of McLaren Vale. Pliocene above.

2nd rail cutting L9 has unfossiliferous sands w Pliocene ferrug sands & gravel (8') above.

4. Formation: Blanche Point Marls.

Exposure.

Three members are distinguished by Reynolds as making up the Blanche Point Marls. These together are exposed from Uncle Tom's Cabin to just south of Chinaman's Gully. Distinction between two of the members can be made in the road cutting L.11 east of Tortachilla Trig but elsewhere inland positive demarkation is difficult and all exposures have been grouped only as the Blanche Point Marls. They are exposed inland along a line trending northeast roughly parallel to the Pre-Cambrian basement, and over a distance of eight miles at:-

(1) The cliff section and road cutting east of Tortachilla Trip L.11 (1) and (2).

(2) North of McLaren Vale - L.1 and L.17.

(3) In the McLaren Vale Quarry and rail cutting - L.3.

(4) South of Seaview at L.7 (above the South Maslin Sands) and at L.12.

(5) South of "Amery" - L.16.

(6) Two miles east of Seaview at L.23.

Member 4a: Transitional Marls.

1. Location 11.

Lithology.

A greyish soft fossiliferous marly bed containing grains of glauconite and sand which impart a characteristic speckled appearance. In the upper regions the bed becomes pale-brownish yellow in colour, the proportion of silica increasing especially in the replaced fossil casts.

Contacts and Thickness.

The member is terminated below by the Glauconitic Limestone Member. Upwards it passes imperceptably into the Banded Marls.

A thickness of approximately 6 feet could be determined.

Member 4b: Banded Marls.

Lithology and Thickness.

About 35 feet of alternating hard and soft grey fossiliferous marly bands rich in Turritella aldinge. The percentage of glauconite increases in the upper portions, and a shelly glauconitic bed four feet in thickness could be distinguished below the upper 6 feet of harder marls containing nodules of grey chert and the replaced siliceous casts of Turritella aldingae (Specimen A.281).

Contacts.

The upper member, the Soft Marls is not represented, the Banded Marls being overlain unconformably by an orange-brown pebbly sandstone formation at least twenty feet thick of? Pleistocene age.

Other Locations.

The close similarity from both lithological and faunal viewpoints indicates that other outcrops of marls inland belong to the Banded Marl member of this formation. The marls maintain the characteristic glauconitic speckled appearance and Turritella dominates the fauna preserved in the rock. The outcrop cf. Locationl north of McLaren Vale provides the first exception and indication of a change in facies. Here the marls, while still rich in Turritella have become dominantly sandy with a high percentage of fine mica. Fragments from this location to which have been added Hydrochloric acid show no signs of effervescence, but this may be due to extreme leaching of the sediments. The fossil structures are well preserved, both casts and moulds of primipally Turritella being known.

Contacts and Structure.

North of McLaren Vale at L.7, the weathered marls overlie directly the glauconitic South Maslin sands. In all cases they are surface exposures, overlain only by Recent sands and alluvium. Generally leaching of the upper portions has produced a thick surface layer of kunkar.

Dip.

An estimation of the angle and direction of dip based on Lahee's three point method has been made from altitudes at which the Blanche Point Marls are exposed unconformably with the underlying Tortachilla Formation at L.7, L.1 and in the bore HB-420. This gives, as accurately as determinations will allow, a dip of 1° in a direction 218°.

5. <u>Formation: Chinaman's Gully Beds.</u>

Exposure.

In the coastal section these have been determined from 300 yards north of Chinaman's Gully south as far as Aldinga Creek, the best exposures being known in Chinaman's Gully and two small creeks to the north (Reynolds 1951).

No inland exposures of this formation are known. They may be regarded as equivalents of the upper lignitic beds known in bores from the area.

6. <u>Formation: Port Willunga Beds.</u>

Exposure.

Along the coast, the northernmost limit of these beds is obscured by Recent terrestrial and aeolian deposits, but has been calculated by Reynolds, from the apparent dip of $1\frac{1}{2}^{\circ}$ (120 feet/mile; 200°T) to be 280 to 290 yards north of Chinaman's Gully. The beds pass below beach sands a thousand yards south of Port Willunga, and do not reappear until a hundred yards south of Sellick's Beach where they form resistant beach cliffs about 15 feet high, which have been eroded away in the region of Mt. Terrible Gully. Southwest of this point, the sediments form the steeply dipping southern limb of a syncline, unconformably overlying Cambrian shales and limestones.

Lithology.

A yellowish-brown shelly limestone of varying hardness made up of the triturated fragments of Bryozoa, Echinoids, Pelecypods, Foraminifera and other marine fossils. In the Port Willunga section the lithology varies considerably, and different members have been distinguished on lithological grounds. "The formation as a lithological unit could be classed as an arenaceous polyzoal limestone with argillaceous bands" (Reynolds 1951).

The limestone which exhibits pronounced cross-bedding forms a low cliff about 15 feet in height. Folding has formed a shallow dipping anticlinal structure which extends for about half a mile soutwhards along the coast, one limb pitching gently to the north, the other to the south. The southern limb disappears below thick alluvial boulder beds of ? Pleistocene to Recent age, which vary in thickness from 150 to 200 feet. Though the cliff limestone has been extensively eroded by the sea, a wave-cut platform of the same material extends as the floor of the bay as far south as Mt. Terrible Gully. The limestone is not again exposed above sea-level until in the zone of the Willunga Scarp about 500 yards southwest of Waterfall Creek, where it is found dipping steeply to the northwest and lying unconformably above the buff and purple coloured Cambrian slates and limestones. The dip which ranges from 60° to 80° forms a curve in the form of a monoclinal fold which flattens out gradually in the sediments further to the north. The contact between the Tertiary and the Cambrian is marked by a basal boulder of derived Cambrian slates together with a black powdery Manganese deposit which predates fossiliferous marine Tertiary sedimentation. At the base of the high cliffs, the harder siliceous strata which have resisted erosion from the sea, form together with isolated stacks continuous ridges from which a strike of 57° to 60° with a dip of 70° can be measured. Fossiliferous pink limestone weins with fragments of Cambrian slates are formed from the lower part of the Port Willunga beds, and dissect the Cambrian sediments along irregular fractures.

The thickness of this formation measured by Reynolds in the vicinity of Port Willunga is 111½ feet.

7. Formation: Pliocene Limestones and Sands.

Exposure.

Pliocene sediments have their maximum development along the coastline from north of Ochre Cove to south of Snapper Point where they have a thickness of approximately 36 feet. South of Sellick's Beach, fossiliferous Pliocene sediments were discovered by

Dr. Glaessner unconformably above the folded lower Miocene limestones.

Lithology.

Three divisions of the white and yellow sands and arenaceous limestones are considered by Reynolds as making up the Pliocene sedimentary record.

1. In the sand quarry, and extending 120 yards south of Tortachilla Trig, are basal white and yellow sandstones overlain by banded white and yellow sands with an upper limonitic band.

The thickness of this member is 10½ feet.

2. South from the Trig. Point to the north side of Blanche Point are "... yellow sands (Sample A.200) 9 feet thick overlain by a green clayey band (A.199c) grading into a dark greyish green to brown clay (A.199b) 4½ feet thick and the section is capped by white sandy limestone (A.199a) 5½ feet thick" (Reynolds 1951).

3. A series of calcareous sandstone and arenaceous limestone bands from Blanche Point south to Snapper Point, varying in thickness from 18 to 20 feet, make up the third member.

South of Sellick's Beach, Pliocene sediments have a maximum thickness of 10 to 12 feet. The shallow Miocene anticline is overlain unconformably by a group of sediments consisting in ascending order of:-

(1) A four inch pebble bed marking the unconformity.

(2) Six to eight feet of well weathered white limestone with numerous quartz grains and containing the casts of fossil gastropods and lamellebranchs.

(3) A thin greenish-brown sandy bed between 18 inches and 2 feet in thickness, becoming argillaceous in its upper extremities.

Contacts and Structure.

This formation overlies with angular unconformity the pre-Pliocene sediments, and is overlain by Pleistocene to Recent sands, clays and quartz boulder beds. In the vicinity of Mt. Terrible Gully the Pliocene sediments along with part of the Port Willunga Beds have been completely eroded away, and are overlain by boulder clays (Fanglomerate) of ? Pleistocene to Recent age. Elsewhere unfossiliferous mottled clays form an extensive capping. The Pliocene beds south of Sellick's Beach show a gentle northerly dip unconformable with the Miocene anticline. This indicates that the period of folding of the Pre-Pliocene sediments subsequent to deposition of the Port Willunga Beds, but predating Pliocene sedimentation, would have been in late Miocene times.

? Pleistocene to Recent Deposits.

Several lithologically distinctive groups of sediments may be recognised. They include:-

1. Pleistocene mottled clays confined mainly to the coastal and southwest sections of the Basin.
2. Unfossiliferous variegated white and red ferruginised sands.
3. Coarse quartz pebble conglomerates in places heavily ferruginised, confined largely to the more elevated portions of the Basin.
4. Thick quartz boulder beds in the neighbourhood of the Willunga Scarp.
5. Recent alluvial sand and stream deposits.

1. From north of Ochre Point to south of Snapper Point Pleistocene beds consist predominantly of red and green mottled sandy clays overlying gravels and boulder beds. These have a maximum thickness along the coast of 59 feet of which the red beds form 39 feet. (Reynolds 1951). Variation in thickness of these beds is noticeable between Blanche Point and Snapper Point. The coast section in the vicinity of Sellick's Beach shows a maximum thickness of about 50 feet of mottled reddish and greyish-green clays. The mottled beds are exposed inland in road cuttings and creeks, two miles west of Willunga township. Extensive cultivation of the area prevents any sharp demarkation between these mottled clays and surface alluvium, and an approximate boundary only can be fixed. In the road cutting north of Aldinga township, variegated yellow and white sandstone reaching a thickness of at least five feet is exposed in the base of the cutting (Specimen A.294). This sand is overlain by thick mottled red and green clays. Further east of this cutting mottled clays overlain by Recent kunkar are exposed to a depth of three feet

in a shallow road cutting (Specimen A.293).

2. The most extensive ? Pleistocene sediments are the loosely consolidated unfossiliferous red and yellow sands which form a thick capping over most of the area. They are met with in all of the known bores and show a maximum thickness in a water bore sunk at the Willunga Post Office where they reach a thickness of at least 300 feet. Generally surface exposures are consolidated sandstones, heavily ferruginised with a characteristic reddish to yellow-brown colour. Consolidated sandstones of this type are known from several localities:-

(1) A mile east of McLaren Vale in a shallow road cutting (L5) are variegated yelllwish-brown consolidated sands.

(2) A mile and a half east of McLaren Flat, ferruginised reddish-brown sands are exposed as the walls of a deep creek, revealing a thickness of over 25 feet (Specimen A.287; L.15). These sandstones are overlain by thick alluvial river conglomerate, the coarse well rounded pebbles consisting of Pre-Cambrian quartzite and slate. These alluvial beds which show pronounced current-bedding may be regarded as of Recent age. North of this exposure similar sandstone and boulder beds are exposed at L.10 (Specimen A.275).

(3) South of McLaren Vale, consolidated sands of this type are known from the third rail cutting; in a shallow creek bed west of Willunga and in the first road cutting north of Aldinga.

3. The more elevated portions of the basin are commonly capped by heavily ferruginised quartz conglomerates. The pebbles which are of "milky" quartz, range in size up to an inch or so in diamter and are cemented by a dark reddish-brown iron cement in a finer sandy matrix. Rocks of this type are extensively developed along the Pre-Cambrian ridge south of the River Onkaparinga and are known at an altitude of 400 feet as hill cappings north of McLaren Vale at L.4 (Specimen A.261) and south of "Amery". Between L.7 and the Pre-Cambrian, a few isolated surface exposures of rounded quartz pebble beds have been found by Dr. Glaessner but in these the ferruginous cement is lacking. Distinction can be made between

these Pleistocene deposits and the Baker's Gully Gravels on the basis of the difference in angularity of the quartz pebbles between the two formations. The Pleistocene deposits generally show more complete rounding of the pebble constituents than do the lower Eocene gravels.

4. Adjacent to the Willunga Scarp in the vicinity of Sellick's Beach is a thick series of coarse conglomerates consisting of well rounded quartzite limestone and slate boulders, deposited in an alluvial fan. These sediments which have been deposited as outwash from the Willunga Scarp are known to over a 100 feet in thickness, unconformably above the marine Tertiary sediments. Their heterogeneous nature together with the deltaic type of deposit and their close proximity to the elevated Cambrian rocks suggests they may be regarded as a Fanglomerate.

5. <u>Fine Dusty Quartz Sands.</u>

An extensive cover above the Tertiary sediments is provided by fine unfossiliferous quartz sands which are known over the greater part of the Basin north-east of McLaren Vale. The sands consist of a heterogeneous mixture of angular to sub-angular quartz grains which vary from clear and colourless to pale amber shades. The sands form a series of three roughly parallel ridges, up to 700 feet in height south-west of the Baker's Gully Quarry. In addition, however, they are known as alluvial surface deposits, forming sandy clays which are under extensive cultivation over the greater part of the area south of McLaren Vale.

The genesis of these sands is difficult to determine, but in view of the marked angularity of the grains, it seems possible that they may have been derived by aeolian transportation from sandy glacial deposits close to the Basin.

III Subsurface Geology.

Subsurface interpretations are based on evidence from bore logs recorded from this area together with samples obtained from WB-1 and HB-420. The locations of these two bores are:-

Bore WB-1 Corner adjacent to sections 222-3 and 232-3 Hundred of Willunga.

Bore HB-420 Northwest corner of section 506; Hundred of Willunga.

Lithology.

The outstanding feature of sediments from these bores is the lack of similarity lithologically between the bore samples and their equivalents exposed in the cliff section along the coast. In both WB-1 and HB-420 silty sands predominate, and distinction cannot be made between the different members of the coastal formations as lithological grounds. The lithologics of the two bores are set out in tabular form below:-

Bore WB-1.

Thickness (feet)	Description of Strata.	Depth (feet)
20	Impure calcareous brownish-grey clays.	20'
14	Dark brownish-yellow ochre-rich medium to fine grained sands.	34'
16	Pale greyish to buff coloured impure silty sands	50'
6	Light grey to white quartz sand.	56'
5	Light grey quartz sand	61
3	Dark orange-red ochre-rich impure sands.	64
46	Dark yellow unfossiliferous ochre-rich sands.	110
2	Medium to coarse grained quartz gravel bed with finer ochre brown sandy matrix.	112
1	Ochre brown impure silty sands, with medium to coarse grained angular quartz pebbles.	114
1	Hard calcareous travertine.	115
42	Pale yellowish-brown dusty sand with medium to coarse grained quartz pebbles.	157
3	Hard light brown siliceous shelly limestone containing the casts of fossil lamellibranchs algae etc. The matrix is characterised by the presence of medium to small sized limonite and quartz grains set in the recrystallised calcareous cement.	160
8	Yellowish-brown medium grained impure quartz sands.	168
4	Fossiliferous limonitic hard limestone, containing fossil brachiopods, lamellibranchs (Spondylus; Pectin) and characterised by the high proportion of coarse polished limonite pebbles.	172

Bore WB-1 (continued).

Thickness (feet)	Description of Strata.	Depth (feet)
78	Yellowish-brown medium grained sands with polished limonite pebbles becoming slightly greyish at the base.	250
78	Medium grained grey bryozoal silty sand with a hard fossiliferous siliceous band at 290 feet.	328
47	Greyish-green fossiliferous silty sands with shell fragments of echinoids, lamellibranchs and bryozoa.	375
38	Dark grey to black coarse silty lignitic sands	413
3	Lignitic clay	416
22	Fine dark grey to black carbonaceous silts with black lignitic fragments distributed throughout.	438
24	Dark grey micaceous silty sands with small lignitic pockets and coarse angular quartz grains.	462
18	Dark grey silts with subordinate fine sand grains.	592
	Dark grey glauconitic silty sand.	610
8	Light greenish-grey silt with small limonite and quartz grains in the finer matrix.	618
62 549	Grey to black coarse silty lignitic sands with larger rounded quartz pebbles.	680
	Bore reference HB-420	
3	Impure dark brown sandy clay	3
9	Fine white siltstone	12
24	Unfossiliferous yellowish-brown impure silty sands	36
4	Coarse grained impure yellowish-brown sand	40
4	Finer yellow silty sands	44
16	Grey sandy clays	60
2	Hard siliceous fossiliferous "Turritella" marl containing small grains of quartz and glauconite in the siliceous matrix.	62
90	Grey silty sands with fossiliferous bands of softer light grey "Turritella" marl.	152
14	Dark brown impure lignitic clays with pockets of black lignitic material distributed throughout.	166
19	Light grey gritty sands; unfossiliferous.	185
25	Unfossiliferous yellow gritty sands.	210
5	Unfossiliferous yellow sands.	215

Bore reference HB-420

Thickness (feet)	Description of Strata.	Depth (feet)
9	Coarse light grey gravelly bed, the pebbles well rounded and up to an inch in diameter.	224
29	Unfossiliferous light grey gritty sands.	253
10	Unfossiliferous grey to yellow silty sands.	253
50	Unfossiliferous yellow silty sands.	317
7	Light greenish grey fossiliferous glauconitic sandstone from which Hantkenina was determined, and containing coarser rounded limonite and quartz pebbles.	324
96	Hard siliceous Pre-Cambrian quartzites and siliceous slates.	420

Though the members named from the coastal section cannot be distinguished in the bores, the equivalents of the coastal formations can be differentiated on palaeontological evidence. Hantkenina has been determined from the lower glauconitic sands in both WB-1 (610-618 feet) and HB-420 (317-324 feet). These glauconitic sands of the bores may be regarded as upper Eocene in age, and correppond to the Transitional Member of the Blanche Point Marls. The overlying fossiliferous sands of WB-1 correspond to the remaining members of this formation. The combined thickness of sediments, which is 101½ feet in the coastal exposures, is represented by at least 130 feet of sands in WB-1 and by 90 feet of sands and marls in HB-420. Formation 5 of Reynolds, the Chinaman's Gully beds, is represented inland as the upper lignitic series of carbonaceous sands and clays which have a thickness of fifty feet in WB-1 as compared with a maximum of 5½ feet on the coast. There is thus evidenced an inland thickening of the formations exposed in the coastal section. Formation 6, the Port Willunga Beds, are distinguished in WB-1 at a depth of 375 feet with the appearance of a foraminiferal fauna which has been identified by Dr. Glaessner. These beds which have a maximum thickness of 111½ feet along the coast are represented by 260 feet of Bryozoal sands in the bore WB-1. Post Miocene erosion has removed Pliocene sediments inland, but the Pleistocene-Recent sands and clays thicken from 59 feet on the coast to over 300 feet in the region of Willunga. These greatly increased thicknesses are indicative of a deepening of the basin inland and towards the south.

Structure.

The sediments have a general south westerly dip of 1° to 2° that has been interrupted towards the south by minor folding. Attention has been drawn to the steeply dipping Port Willunga Beds unconformably above the Cambrian, and of the minor anticline north of Mt. Terrible Gully. Subsurface sections on a scale of two inches to the mile ($\frac{V}{H}=\frac{2}{1}$) have been prepared to illustrate the disposition of the sediments.

IV Facies Changes.

Moore (1949) defines sedimentary facies as "any areally restricted part of a designated stratigraphic unit which exhibits characters significantly different from those of other parts of the unit".

Regional variation in sedimentary conditions resulting in a change in lithological aspect, are typical of all Tertiary sediments in the Willunga Basin. Changes in facies are controlled by two sets of sedimentary variables (Lowman, 1949) reflecting reflecting environmental and diagenetic effects. Variations in the environments of depotiion in the Willunga Basin are indicated not only from a change in character of the sediments, but also in the cyclical alternation of marine and non-marine conditions accomplished during a series of transgressions and regressions of the sea. The Blanche Point Marls, coastal exposures of which typify sedimentation in a shallow water marine environment, are replaced inland by contemporaneous fossiliferous sandy beds, where the less stable conditions, deeper waters, and higher rates of sedimentation, inhinits the formation of the calcareous beds. The change from marls to sand is a progressive one, and the intermediate silty fine grained sandy facies is exposed north of McLaren Vale in L.1. The division of the calcareous sediments into lithologically distinctive members on the basis of variation in lithological composition, is not possible in the sandy beds, where little variation except in the case of slight colour changes takes place. In addition to the changing marine environments, as typified by the development of the sandy equivalents of the Blanche Point Marls and the Port Willunga Beds, variations in terrestrial facies are indicated from the bores, where the lignitic counterparts of the freshwater sands develop under the influence of more pronounced swampy conditions. In view of the exposure of lithologically similar outcrops of Blanche Point Marl in a line trending northeast from Location 11 to Location 23, and the change in lithological aspect only a short distance southeast of this line it would seem that the boundary of facies change for this formation lies between the exposures of L.1 and L.17.

In the bore 5310 at the McLaren Vale Hospital marls containing Turritella have been reported above the Tortachilla limestones at a depth of feet. In WB-1 the marls are replaced by fossiliferous sandy equivalents so that the facies boundary between marls and sands must follow an irregular line, possibly determined by the structure of the basement, roughly parallel to the northern outline of the Basin. Complications have, however, been introduced, in that a non-marine facies of part of the Blanche Point Marls is exposed in the sequence of unfossiliferous sands below the Turritella beds of locaion 1, north of McLaren Vale. This development corresponds with the formation of the upper lignitic series below the Blanche Point Marls which are represented by alternating sandy and marly bands in HB-420.

A change in facies is also exemplified in the Tortachilla Formation. The fossiliferous glauconitic and polyzoal limestone members of the coast are replaced inland by glauconitic pebbly sands and in part by the unfossiliferous sands below the Blanche Point Marls which are represented by alternating sandy and marly bands in HB-420.

A change in facies is also exemplified in the Tortachilla Formation. Tehf ossiliferous glauconitic and polyzoal limestone members of the coast are replaced inland by glauconitic pebbly sands and in part by the unfossiliferous sands below the Blanche Point equivalents, which are exposed in the cuttings L.1,,L.7. and L.8. Preceding the marine transgression of this region which led to the development of the fossiliferous Blanche Point Marls, lacustrine conditions prevailed, and unfossiliferous quartz sands, from which calcareous root-structures have been derived, were laid down.

In the case of the Lower Miocene sediments, facies change has been controlled by the increasing depth fo the Basin east of the coastline. This variation in marine environment from shallow waters favourable for development of the Port Willunga Beds, has resulted in the accumulation of a thick series of grey bryozoal sands inland, as shown from WB-1. It seems, therefore, that the main factor controlling the changes in facies of the Tertiary sediments has been the structure of the Basin which, in association with the degree of its mobility, has determined the environments of sedimentation.

V Tectonics and Sedimentation.

The formation of the Willunga Basin is accounted for by a southerly tiling of the Pre-Cambrian sediments following folding and faulting in pre-Tertiary times. The lithologic associations encountered, suggest conditions varying from those of the stable shelf in the north, to those of a mildly unstable shelf in the south. This is evidenced by the increasingly silty nature of the sediments towards the deepening parts of the Basin. Transgressive and regressive phases in marine sedimentation are evidenced by the alternation of marine and swampy lacustrine conditions which have favoured developement of the upper and lower lignitic series. The Baker's Gully Gravels and their equivalents the South Maslin Sands are deposits of deltaic origin derived from adjacent Pre-Cambrian quartzose sediments. The coarser grain size of the Baker's Gully Beds is in keeping with a derivation from the more elevated source rocks. At the time of deposition of these sediments, shallow water lacustrine conditions prevailed and this is evidenced by the presence of silty clay bands from which fossil plant remains have been described, and pronounced cross-lamination in the sands. It seems probable that the lower lignitic series as encountered in WB-1 corresponds to the deposition of these sands and gravels. Towards the upper Eocene these lacustrine conditions were replaced by a marine transgression which led to the development of the Tortachilla Limestone. The slow rate of sedimentation under quiescent conditions was favourable for the formation of the glauconitic sands from which Hantkenina has been found. The appearance of rare pelagic foraminifera in this bed suggest that the basin was locally connected to the open seas. Krumbein and Sloss (1951, p.144) state: "... Glauconite apparently forms under conditions of slow sedimentation in partially restricted environments (Galliher 1935)... Relatively little is known regarding the exact significance of glauconite, although it is considered a sound criterion of marine origin of the enclosing sediment".

Marine conditions prevailed in the more southerly deeper portions of the basin. After the close of the Eocene, but to the north, sedimentation is represented by unfossiliferous quartz sands and gravels of freshwater origin. In view of the restricted development of these sediments north of McLaren Vale where the combined thickness of the strata between the lower glauconitic sands and the Blanche Point Marls as exposed in the cutting at L.1 is only twenty feet, and the relatively rapid change in altitude from 400 feet at L.1 to 200 feet a quarter of a mile south at McLaren Vale, some hypothesis seems necessary to account for the thinning out of the sedimentary sequence. Two views may be considered:-

1. A Pre-Cambrian ridge, possibly the result of folding may have divided the basin into two partially separated depressions.

2. Possibly there is a more extreme tilting of the Basin south of McLaren Vale, which downwarping would be associated with the known folding and faulting of the Basement.

In the southern portions, the upper lignitic sequence as shown in WB-1 lies above the silty Turritella sands, whereas evidence in the north from HB-420 shows the lignitic series below the Turritella marls. Slight subsidence of the northern portion, following the swampy conditions necessary for the formation of the lignite, would afford favourable conditions for development of the Blanche Point Marls which in HB-420 are lithologically similar to those of the coastal section. Contemporaneously with subsidence and the formation of these marls in the north, the southern portion was slightly elevated and shallow lacustrine conditions replaced the marine regression enabling development of the upper lignitic series. Marine transgression in the lower Miocene was possibly associated with settling along the old fault line, and affected only the southern portions of the basin where Bryozoal sands and fragmental fossiliferous limestones were developed. At the close of the Miocene, movements along the fault accompanied by thrusting from the south culminated in a folding of the Tertiary into a series of gentle anticlines and synclines with the fold axes trending to the north-east. Dips of up to 80° have been measured in the Miocence limestone, unconformably above the Camrbian slates and quartzites south-west of Mt. Terrible Gully. A period of erosion followed, predating the marine Pliocene deposition.

Since the close of Pliocene times no submergence below sea-level has taken place, though continued downwarping of the basin was maintained subsequent to post Pliocence erosion which removed much of the Tertiary sediments. A thick series of unfossiliferous ochre-rich sands, mottled clays and boulder beds, has been devloped over the whole of the Basin since the beginning of the Pleistocene. The most recent deposits excluding alluvial wash, are thick unconsolidated white quartz sands covering the major portion of the area north-east of McLaren Vale. The origin of these sands is doubtful and two theories are advanced:-

1. They may be derived from the underlying Pleistocene sands following reworking and aeolian transportation under arid conditions.

2. Their close lithological similarity with the Permian sands of glacial origin (south of the region of Meadows) suggests a possible derivation under aeolian conditions from these deposits. The sands are not confined only to the Willunga Basin but are known also as a thin capping over much of the surrounding pre-Cambrian.

List of Sample Nos. and Locations: Willunga Basin.

A.250	Turritella sandy beds; 1st cutting north of McLaren Vale.	L.1.
A.251	Unfossiliferous sands.	L.1.
A.252	" ochrous limonitic sand.	L.1.
A.253	" " " coarse sand.	L.1.
A.254	Fine white powdery sand.	L.1.
A.255	Coarse fossiliferous glauconitic sand with limonite pebbles.	L.1.
A.256	Impure sandy clay.	L.1.
A.257	Red and yellow ochrous silts.	L.1.
A.258	Sandy clay.	L.1.
A.260	Turritella "marl" above upper limonite band.	L.1.
A.259	Turritella marl.	L.2.
A.259b.	Turritella marl weathered to chalk.	L.3.
A.261.	Lateritic gravels.	L.4.
A.262	Kunkar.	
A.263	Fine dusty surface sands east of L.1.	
A.264	Unfossiliferous yellow-brown sand.	L.5.
A.265	Coarse brown sand.	L.6.
A.266	? Kunkar or calcareous sand.	L.6.
A.267	Coarse sub-angular gravel.	L.6.
A.268	White micaceous calcareous sandstone.	L.6.
A.269	Fossiliferous glauconitic sand.	L.7.
A.270=A.288	Brownish-yellow laminated silts.	L.7.
A.289	Glauconitic ferruginised sand.	L.7.
A.271	Ferruginised sandstone similar to A.255.	L.8.

A.272	Laminated quartz sands.	L.9.
A.274	Kunkar capping - 1st cutting south of railway line, Aldinga road.	
A.275	Reddish-grey sandstone.	L.10.
A.276	Glauconitic sand south of Sand Quarry on coast.	
A.277	Fossiliferous Glauconitic Limestone.	L.11.
A.278	Yellow soft marl.	L.11.
A.279	Soft marly bed.	L.11.
A.280	Maslin sands.	L.11.
A.281	Hard "Turritella" Marl.	L.11.
A.282	Orange-brown pebbly sandstone.	L.11.
A.283	Quartzite.	L.12.
A.284	Marls above glauconitic sands.	L.7.
A.285	Medium grained quartz sand.	L.14.
A.286	Calcareous sand.	L.14.
A.287	Reddish-brown unfossiliferous sands.	L.15.
A.288	Banded silts below glauconitic sand.	L.7.
A.289	Turritella-rich marls.	L.16
A.290	Turritella marl.	L.17.
A.291-A.292	Sands from Post Office Bore, Willunga.	L.18.
A.293	Mottled clays and kunkar.	L.20.
A.294	Variegated reddish-brown to yellow sandstone.	L.21.
A.295	Fragmental fossiliferous marine limestone south of Sellick's Beach.	L.22.
A.296	Baker's Gully Gravels.	L.23.
A.297	Pt. Willunga Limestone. South-west of L.22.	
A.298	Pink Limestone veins. " " " "	

VI Summary

The major problems in the Geology of the Willunga Basin have been outlined following an introduction that includes an account of the Location of the area, previous work in the Basin, and the Scope and Nature of Investigations made by the writer.

A general account of the outcropping Tertiary to Recent Formations is discussed under the headings Exposure, Lithology, Contacts and Structure, and classification of the sediments is based on the Standard Succession of Aldinga and Maslin Bays prepared by Reynolds in 1951.

Attention has been drawn to the Sub-surface Geology, and the Conditions of Sedimentation and Changes in Facies of the sediments. A geological map to show the distribution of the Tertiary and Recent Formations has been prepared in association with sub-surface sections. Diagrams of the bores on a scale of 1" to 50 feet have been prepared and used in correlation, and a sub-surface contour map of the base of the Pleistocene has been drawn to show the disposition of the sediments following late Miocene movement and Pliocene erosion.

Acknowledgements.

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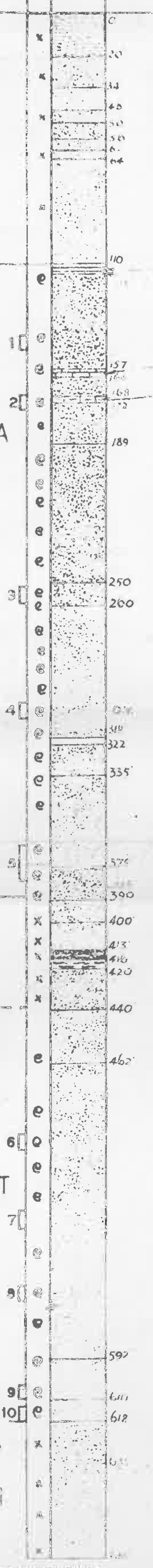
BORE WB-1, HUNDRED OF WILLUNGA.

LOCATION - Road adjacent Sec 222·3, 232·3

160 FT ASL

SCALE 1 inch = 50 feet

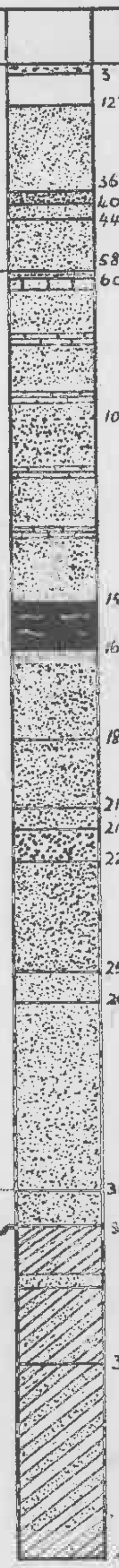


AGE	FORMATION	LITHOLOGIC CHARACTER
RECENT		Impure brownish [illegible] clays
PLEISTOCENE — PLIOCENE		Yellow sands.
		Light yellow sand
		Pale greyish buff coloured sand.
		Light grey - white sands
		Greyish sands
		Orange red sands
		Dark yellow unfossiliferous ochre rich sand
LOWER MIOCENE	SANDY FACIES OF PORT WILLUNGA BEDS	Brown quartz gravel bed.
		Light brown yellow sand with small quartz pebbles
		Hard calcareous travertine
		Yellow ochre rich sand
		Arenaceous limestone
		Yellow ochre sand
		Hard shelly calcareous band with abundant limonite pebbles.
		yellow sands.
		Yellow brown sandstone, changing to a
		Buff coloured sandstone
		Light grey medium grained Bryozool sand.
		Grey silty fossiliferous sandstone with abundant Bryozoa.
		Grey sands and silts
		Greyish-green silty sandstone
		Grey fossiliferous glauconitic sand.
OLIGOCENE	CHINAMANS GULLY BEDS	Dark grey impure silt.
		Grey impure silty sands
		Lignite
		Black lignitic clay with medium sand grains
		Fine dark grey silty sands.
	SANDY FACIES OF BLANCHE POINT MARLS	Dark grey fine silty sands
		Dark grey silts with fine sand grains
		Dark grey fine silt
UPPER EOCENE	HANTKENINA BED	Buff coloured to grey silt, glauconitic sand
	LIGNITIC FACIES OF NORTH MASLIN SANDS	Dark grey coarse [illegible] sand
		Black lignitic sands containing medium sand quartz grains

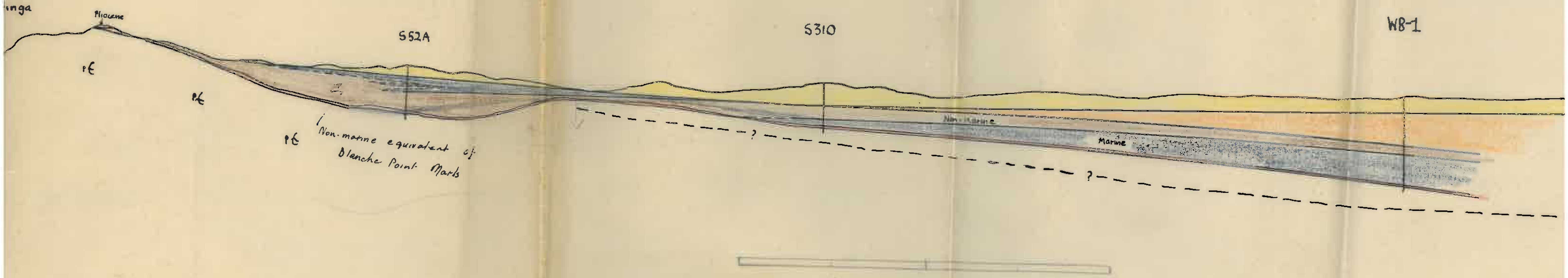
© FOSSILIFEROUS
× UNFOSSILIFEROUS

BORE HB 420. HUNDRED OF WILLUNGA.

LOCATION: Section 506. ALTITUDE 400 feet. SCALE: 1 inch = 50 feet.



AGE	FORMATION		LITHOLOGIC CHARACTER
RECENT ?PLEISTOCENE		3	Brown sandy clay.
		12'	
			White siltstone.
		36	yellow sand.
		40'	Coarse yellow sand.
		44'	yellow sand.
		58'	Grey sandy clay
OLIGOCENE	BLANCHE POINT MARLS	60	
			Grey silty sand with fossiliferous bands of 'Turritella' marl.
		100'	
			Soft sandstone with fossiliferous marly bands, the sandstone is glauconitic & fossiliferous
	LIGNITIC AND SANDY EQUIVALENTS OF BLANCHE POINT MARLS	152'	Lignitic clay.
		166	
			Light grey sand and grit.
		185'	
			Fine unfossiliferous yellow sand
		210	yellow gritty sand.
		215'	Coarse quartz gravel bed.
		224'	
			Light grey gritty sand.
		253	Grey to yellow silty sands; unfossiliferous.
		265	
			yellow silty sands; unfossiliferous.
EOCENE	HANTKENINA BED	317'	Light greenish fossiliferous glauconitic sandstone with small limonite grains.
PRE-CAMBRIAN		324'	Hard Blue Quartzite or Siliceous Slate.
		365	
			Slate & Quartzite.
		420'	



Horizontal Scale 2" = 1 mile

Vertical Scale $\frac{V}{H} = \frac{4}{1}$

IW