Rept. Bk. No. 60/55
G.S. No. 3107
D.M. 1807/63

DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY

NON METALLICS SECTION

Report on

AUGER BORING OF HACKHAM CLAY DEPOSIT

Part Sections 7 and 17, Hundred Noarlunga

(Jarvis Industries Ltd.)

by

J. G. Olliver
Geologist

Follow up - Crumsie J.N (1966) Report on Hackham Clay Deposit
R.B no. 61/174
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16th March, 1965

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Part Sections 7 and 17, Hundred Noarlunga

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ABSTRACT

Near horizontal Upper Eocene sediments, comprising Blanche Point Marls, Tortachilla Limestone and South Maslin Sands, have been test bored at Hackham in the Noarlunga Basin in the search for a bentonite-type clay deposit.

Reserves of 400,000 cubic yards have been proved which contain more than 50% montmorillonite in the clay fraction. The testing of other outcrops of the Upper Eocene sediments in the Noarlunga and Willunga basins is recommended. At present, the bulk of requirements for bentonite in Australia are met by imports from the U.S.A.

INTRODUCTION

Following a request from Jarvis Industries Ltd., the railway cutting and adjoining property in Sections 7 and 17, Hundred Noarlunga, County Adelaide, at Hackham, 18 miles south of Adelaide, were inspected on 18th November, 1963.

The company is seeking a deposit of bentonite-type clay suitable for use as a drilling mud. Bentonite is defined as a rock composed predominantly of the clay mineral montmorillonite and which has formed by the alteration of volcanic tuff or ash.

The accompanying plan and cross sections (Plan No. 64-267) are based on a stadia theodolite survey by R.E. Adams (Surveyor) on the 6th and 12th December, 1963.

Ten Gemco machine auger holes were bored between 29th January and 5th February, 1964.

The results of microscopic examination of selected borehole samples by J.M. Lindsay (Geologist - Palaeontology Section) are summarised in Appendix I. Complete geological logs of the boreholes, including microscopic descriptions by J.M. Lindsay are detailed in Appendix II.

Samples from the railway cutting and from boreholes were submitted to Australian Mineral Development Laboratories for sieve analyses and identification of clay minerals, the results of which are tabulated in Appendices III and IV respectively.

BENTONITE IN AUSTRALIA

The increase in oil drilling activity and the sustained demand in the foundry industry has produced a continual rise in the consumption of bentonite and bentonitic clay in Australia. This increased demand has been met by a record level of imports and an expanding domestic production, which reached a record high in 1963. The bulk of the imports come from Wyoming (U.S.A.) which is the world's main source.

Australian production supplied 11.5%, 7.8% and 12.5% of the total apparent domestic consumption in 1961, 1962 and 1963 respectively. The tonnages of imports and production of bentonite in Australia for the period 1959-1963 are tabulated below.

Production of Bentonite and Bentonitic Clay in Australia (tons)

	1959	1960	1961	1962	1963
Queensland	96	173	307	299	333
N.S.W.	56	17	-	-	-
W.A.	133	382	587	485	1,197
Total	285	572	894	784	1,530
Value ex-mine	£1,770	£4,000	£5,000	£6,000	£7,000

Imports of Bentonite (tons)

	1959	1960	1961	1962	1963
U.S.A.	6,291	7,163	6,858	9,145	10,426
N.Z.	23	33	11	-	-
Others	16	74	26	60	339
Total	6,330	7,270	6,895	9,205	10,765
Value f.o.b.	£93,113	£127,506	£119,619	£178,661	£246,195

Note: Imports of "treated" bentonites with specific trade names are not included in the above table.

REGIONAL GEOLOGY

The area investigated is situated near the southeast margin of the Noarlunga basin, a tectonic valley which is bounded on the southeast by the Clarendon-Ochre Cove fault. Tertiary and younger sediments fill the basin and shelve out to the northwest. Proterozoic bedrock, comprising slates, tillites and quartzites of the Adelaide System, outcrops on the upthrown (southeast) side of the fault and around the northwest rim of the basin (see Locality Plan).

The stratigraphic sequence of the near horizontal post-Proterozoic sediments within the Noarlunga basin is as follows:-

Recent - Alluvial clays of the plains with sands and gravels.

Alluvial flood plains associated with low gradient streams.

White siliceous and calcareous back shore beach dunes of the modern coast.

Pleistocene - Mottled brown, red and white clays.

Pliocene - Freshwater gravels and sandstones frequently lateritised.

Oligocene-Miocene- Port Willunga Beds - Bryozoal sands and limestones.

Eocene - Blanche Point Marls - Marls, sands and clays with Turritella.

Tortachilla Limestone - Richly fossiliferous glauconitic limestones and clays.

South Maslin Sands - Dark green to purplish blue glauconitic sand with rounded grains of limonite.

North Maslin Sands - vari coloured quartz sands.

The Port Willunga Beds and the underlying sediments are exposed in the coastal cliffs and occasionally in creek banks or road cuttings (See Locality Plan).

In the railway cutting at Hackham, two thin beds of clay within the Blanche Point Marls proved to contain montmorillonite. A programme of auger boring was devised to test the extent of the deposit in the adjacent property.

RESULTS OF BORING

The results obtained by boring ten Gemco auger holes are summarised below and represented graphically on the accompanying cross sections, Plan No. 64-267.

Bore No.	Loam & kunkar (feet)	Alluvium (feet)	Blanche Point Marls (feet)	Tortachilla Limestone (feet)	South Maslin Sands (feet)
1	0 - 6	-	6 - 48	-	-
2	0 - 9	-	9 - 36	-	-
3	0 - 6	-	6 - 42	42 - 54	-
4	0 - 6	-	6 - 44	44 - 48	-
5	0 - 3	-	3 - 13	13 - 27	27 - 54
6	0 - 6	-	6 - 15	15 - 24	24 - 45
7	0 - 6	-	6 - 15	15 - 27	27 - 42
8	0 - 6	-	6 - 20	20 - 30	-
9	0 - 3	3 - 24	-	-	-
10	0 - 3	3 - 30	-	-	-

The lithology and fossil assemblages of each stratigraphic unit are described by J.M. Lindsay in Appendix I.

The surface is covered by brown sandy loam approximately 1 foot thick but up to 3 feet on the lower (South-eastern) portion of the property. The Blanche Point Marls are kunkarised near the surface to a maximum depth of 9 feet in borehole No. 2. The maximum thickness of these marls was penetrated in borehole No. 1 (48 feet).

The thickness of the underlying Tortachilla Limestone varies from 9 feet in borehole No. 6 to 14 feet in Borehole No. 5. The thickest section of South Maslin Sands was intersected

in Borehole No. 5 from 27 feet to 54 feet.

The following section is exposed in the railway cutting:

Thickness of bed (feet)	Description
1	Brown loam.
1-4	Kunkar grading down into soft marl.
1-2	Gravel
0-1	Irregular pockets of soft clay
3-8	Marls
1-2	Poorly outcropping clay (upper layer).
2-3	Marl
1-2	Poorly outcropping clay (lower layer).

The sediments dip gently to the southwest (see cross sections Plan No. 64-267).

The two clay layers exposed in the railway cutting are composed predominantly of montmorillonite. Montmorillonite also constitutes more than 50% of the clay fraction from both the Blanche Point Marls and the Tortachilla Limestone (see Appendix IV).

From the size gradings (Appendix III) an average of 67% of the Blanche Point Marls passes the 300 mesh screen as does 69% of the Tortachilla Limestone. All samples tested have a relatively small proportion of material passing 100 mesh and retained on 300 mesh screen.

RESERVES

Boring has proved 400,000 cubic yards of clay within the area tested, as outlined on cross sections A-A' to D-D'. These reserves are composed of -

270,000 cubic yards of Blanche Point Marls

and 130,000 cubic yards of Tortachilla Limestone

The clay extends beyond the area bored north of cross section A-A'.

CONCLUSIONS

Boring has intersected a sequence of Upper Eocene (Tertiary) marine sediments in the Noarlunga basin near the Clarendon Ochre Cove fault at Hackham.

Blanche Point Marls, kunkarised at the surface, overlie Tortachilla Limestone and South Maslin Sands.

The strata dip to the southwest at a shallow angle.

The potentially economic clay deposit comprises the Blanche Point Marls and the Tortachilla Limestone.

The clay fraction of these sediments contains more than 50% montmorillonite.

Proved reserves of montmorillonitic clay are estimated at 400,000 cubic yards.

The clay extends north of the area tested.

Laboratory testing is being undertaken to assess potential uses for the clay.

A ready market exists in Australia for bentonite-type clays.

It is recommended that outcrops of Blanche Point Marls and Tortachilla Limestone in the Noarlunga and Willunga basins be investigated for potential deposits of montmorillonite.

J. G. Olliver
Geologist
NON-METALLICS SECTION

JGO:AGK
16/3/65

APPENDIX I

REPORT ON

PALAEONTOLOGICAL EXAMINATION OF AUGER SAMPLES FROM HACKHAM, PT.SEC. 17, HD. NOARLUNGA, CO. ADELAIDE.

by

J. M. Lindsay
Geologist,
Palaeontological Section.

APPENDIX I

PALAEONTOLOGICAL EXAMINATION OF AUGER SAMPLES FROM HACKHAM, PART SECTION 17, HUNDRED OF NOARLUNGA, COUNTY ADELAIDE.

by

J. M. Lindsay

SUMMARY

40 auger samples were examined from 8 bores at Hackham, 18 miles south of Adelaide, in the Noarlunga Basin. An upper Eocene sequence of South Maslin Sands - Tortachilla Limestone - Blanche Point Marls is recognized on the basis of distinct lithologies and foraminiferal faunas, closely comparable with the type section in the Willunga Basin. ?Quaternary alluvium occurs as valley-fill.

INTRODUCTION

In search for montmorillonitic clay beds, ten scout holes were drilled at Hackham 18 miles south of Adelaide between 29.1.64 and 5.2.64 with a Department of Mines Gemco auger machine. Fifteen samples from bores 1, 3, 5, 6 and 8, were submitted for palaeontological examination to determine formation and stratigraphic position. As the investigation proceeded twenty-five additional samples from bores 4, 5, 7, 8 and 10, were examined and one hundred sludge samples were logged. Tertiary formations encountered in the bores are the Blanche Point Marls and Blanche Point Transitional Marls, Tortachilla Limestone and South Maslin Sands.

FORMATIONS ENCOUNTERED

a. <u>?Quaternary alluvium</u>.

At least 30 feet of brown poorly-sorted pebbly, gritty, clayey quartz sand, probably fluviatile and alluvial were cut in Bore 10, sited low in the present valley. This material, which is apparently unfossiliferous, is in its upper part kunkarized, as indeed are the Blanche Point Marls where they are within about 10 ft. of the present sand surface.

b. <u>Blanche Point Marls</u> (Upper Eocene)

This is the youngest of the Tertiary formations encountered in the bores. Including the Blanche Point Transitional Marls,

a maximum thickness of at least 48 feet is cut in Bore 1. The Blanche Point Marls in this area are typically cream, light brown or light grey, speckled with green glauconite, more or less sandy, siliceous (spicular chert or flint) marls or mudstones becoming increasingly fossiliferous downwards. Entry into Transitional Marls Member is marked by a change to a khaki colour, more glauconite and limonite, light pink brown and green calcite recrystallization, larger and more common mollusc fragments, and an abundant and varied fauna including such foraminifera as Gyroidina sp., Carpentaria sp., Maslinella chapmani, Asterigerina adelaidensis and Cheiloguembelina rugosa. The thickness of this Transitional Marls Member is about 10 ft.

c. Tortachilla Limestone (Upper Eocene)

This is a distinctively green and brown (overall khaki brown) glauconitic and limonitic, sandy and clayey, somewhat siliceous (cherty) abundantly fossiliferous shelly limestone, marl and calcarenite, about 10 ft. thick in this area. Glauconite impregnated calcitic fragments and honey-brown limonite-stained sub-rounded and polished quartz sand, are typically common. Most of the abundant originally-glauconitic ovoids and aggregates have been more or less oxidized to limonite. The limestones matrix is variously light greenish-grey, light pink, light brown and cream A prolific foraminiferal fauna includes a very rare but distinctive Pseudopolymorphina sp. which seems to be restricted to the Tortachilla Limestone. Other species although better developed and more abundant in the Tortachilla Limestone, persist into the Blanche Point Transitional Marls.

d. South Maslin Sands (Upper to Middle Eocene)

Under the Tortachilla Limestone occur dark brown slightly glauconitic very limonitic calcareous silty and clayey quartz sand referred to the South Maslin sands. Limonite (oxidized glauconite) ovoids and aggregates are abundant, the quartz grains are generally stained or coated with limonite, and the rare to frequent bryozoal echinoid mollusc and foraminiferal fossils are often limonitized. Cibicides umbonifer dominates the

foraminiferal fauna. Bore 5 penetrates the South Maslin Sands most deeply, and here, under about 22 ft. of the above lithology occurs at least 5 ft. of a light grey (streaked and mottled with limonitic-brown) micaceous sandy and silty clay. Cibicides umbonifer occurs frequently, some at least within this matrix on them. An amphibian tooth was also recovered. This interval is regarded as a clayey phase of the South Maslin Sands. No formation older than the Upper Eocene South Maslin Sands was encountered in any of the bores examined.

J. M. LINDSAY,
GEOLOGIST,
PALAEONTOLOGY.

17.3.64

APPENDIX II

GEOLOGICAL LOGS OF GEMCO BOREHOLES

LOG OF GEMCO BOREHOLE NO. 1

PROJECT: Jarvis Industries Ltd.

SECTION: 17 **HUNDRED:** Noarlunga **COUNTY:** Adelaide

R.L.: 391 feet **DEPTH:** 48 feet **DRILLER:** R.Cortolezzis

LOGGED BY: J.G. Olliver **DATE:** 3.2.64

Depth(feet) From	To	Description
0	3	Minor loam over kunkar.
3	6	Kunkar grading down into brown limey and sandy clay.
6	9	Cream to pale brown and green calcareous and fossiliferous clay with minor sand and grit. Microscopic Cream to very light brown glauconitic cherty and sandy marl with common sponge spicules, spicular moulds, and light brey or brown translucent chalcedonic spicular flints. Mollusc moulds and casts bryozoal fragments and very rare non-diagnostic foraminifera are also present. Light olive-green glauconite ovoids and aggregates are abundant. The sample is assigned to the Blanche Point Marls in view of its lithology and spiculiferous nature.
9	15	As So far 6 to 9 feet, slightly more sandy. Microscopic - 9 to 12 feet Cream to white, speckled green, very similar to the previous interval. Very rare foraminifera, rare echinoid spines, bryozoal fragments and mollusc moulds and casts, abundant sponge spicules. Blanche Point Marls.
15	18	Pale green slightly calcareous clay with minor sand and grit fragments.
18	27	Light green marl (calcareous clay) with abundant white pellets up to ¼ inch.
27	48	Khaki marl with black glauconite specks and white pellets. Microscopic - 45 to 48 feet. Light greenish khaki-coloured glauconitic sandy cherty marl with abundant sponge spicules, common mollusc, echinoid and bryozoal fragments, and abundant foraminifera. Very light pink calcitic recrystallization of the carbonate fossils is common. The glauconite is a darker olive-green. Foraminifera include: large Lenticulina sp.(R)*, Cibicides umbonifer (A), Cibicides near pseudoconvexus (R), Cibicides cf. vortex (F), Globigerina linaperta (VR), Cheiloguembelina rugosa (F), Pullenia quinqueloba (C), Cassidulina subglobosa(F) Rosalina sp. (R), and many other small species. The sample is from the Blanche Point Transitional Marls. Boring difficult - hole stopped at 48 feet.

* (VR) = very rare, (R) = rare, (F) = frequent, (C) = common, (A) = abundant.

LOG OF GEMCO BOREHOLE NO. 2

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L.: 388 feet DEPTH: 36 feet DRILLER: R. Cortolezzis

LOGGED BY: J. G. Olliver DATE: 3.2.1964

Depth(feet) From	To	Description
0	3	Loam over kunkar.
3	9	Light brown kunkar.
9	15	Pale green clayey sand with black glauconite specks and fragments of light brown limestone.
15	24	As for 9 to 15 feet but more clayey.
24	36	Khaki clay with black glauconite specks and white pellets.
		Boring difficult - hole stopped at 36 feet.

LOG OF GEMCO BOREHOLE NO. 3

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L.: 386 feet DEPTH: 54 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G. Olliver DATE: 30.1.1964

Depth(feet) From	To	Description
0	6	Minor loam over kunkar.
6	9	Pale green clayey and calcareous sand with fragments of pale brown limestone and black glauconite specks. Microscopic - 6 to 9 feet Green-speckled, cream to light grey, glauconitic sandy cherty marl and mudstone with many fossil casts and moulds, mostly of mollusca. Sponge spicules and chalcedonic spicular flints are common. Foraminifera are rare. The sample is mostly Blanche Point Marls. However there are frequent fragments of light green, light pink and light brown glauconitic slightly limonitic sandy and shelly limestone with polished honey-brown limonite-stained quartz grains. Frequent moderately large pelecypod fragments occur in this matrix as do light pink recrystallized bryozoal fragments and frequent glauconitic-impregnated fragments, particularly of echinoids. Limonite ovoids and aggregates occur frequently. A foraminiferal fauna distinctively coloured a very light green (glauconitic impregnation) includes Pseudo-polymorphina sp. (VR), Asterigerina adelaidensis (VR), a moderately large Lenticulina sp. (VR), Gyroidina sp. (VR), Cibicides pseudoconvexus (R), Cibicides umbonifer (C), Rosalina sp. (VT), "Eponides repandus" (F) and Dorothia sp. (R). The above lithology and fauna is typical of the Tortachilla Limestone. Since the sample representing 9-12ft. is also mostly Blanche Point Marls with only a very small amount of Tortachilla Limestone, the Tortachillan contribution in the sample 6-9ft. is regarded as either reworked material (remanie fossils) or contamination during drilling or sampling.
9	21	As for 6 to 9 feet but with more limestone fragments (up to 1 inch). Microscopic 9 to 12 feet This is mostly very light grey, speckled green, glauconitic sandy cherty marl and slightly calcareous cherty fossiliferous mudstone of the Blanche Point Marls. Glauconite ovoids and aggregates are abundant. Loose? Sponge spicules in light-coloured matrix are common in washed material. Foraminifera are rare and include Cibicides umbonifer. A small amount of glauconitic shelly limestone, similar to that in the 6-9ft. sample, is likewise regarded as Tortachilla Limestone introduced by reworking or contamination.
21	36	Khaki clay with fragments of calcareous mudstone.
36	42	Khaki clay with small white pellets.

Log of Gemco Borehole No. 3 (continued)

Depth (feet) From	To	Description
42	54	Khaki calcareous clay with fragments of glauconitic limestone.

Microscopic - 42 to 45 feet
Khaki green and brown, glauconitic, ferruginous, sandy and clayey, slightly cherty, shelly limestone and marl, typical of the Tortachilla Limestone, with abundant mollusc fragments (some large), bryozoa, echinoids, and foraminifera, rare ostracods and frequent sponge spicules. There is much glauconite impregnation especially of porous echinoid fragments. Honey-brown, limonite-stained, polished quartz grains are common. Most glauconite ovoids and aggregates have been more or less limonitized (oxidized). A distinctive and prolific foraminiferal assemblage generally tinted by glauconite or limonite includes Maslinella chapmani (VR), Asterigerina adelaidensis (R), large Lenticulina sp. (R), Pseudopolymorphina sp. (VR), and several other species of Polymorphinidae, Cibicides pseudoconvexus (F), Cibicides umbonifer (A), Cibicides spp. (C), Rosalina sp. (F), Gyroidina sp. (F), "Eponides repandus" (F), Eponides sp. (C), Anomalina sp. (F), Globigerina linaperta (R), Globigerina spp. (C), Cheiloguembelina rugosa (F), Cassidulina spp. (F), Pullenia quinqueloba (R), species of Angulogerina, Uvigerina, and Trifarina; Carpenteria sp. (F), Lagena hexagona (F), Dorothia sp. (R), Textularia sp. (R), Fissurina sp. (F), and Dentalina soluta (R).

51 to 54 feet
Tortachilla limestone, very similar to 42-45 feet.

LOG OF GEMCO BOREHOLE NO. 4

PROJECT: Jarvis Industries Ltd.

SECTION: 17 DEPTH: 48 feet COUNTY: Adelaide

R.L.: 382 feet HUNDRED: Noarlunga DRILLER: R. Cortelezzis

LOGGED BY: J.G. Olliver DATE: 30.1.1964

Depth (feet) From	To	Description
0	3	Loam over kunkar.
3	6	Kunkar over light brown calcareous clay.
6	9	Pale greenish-yellow sandy and calcareous clay. Microscopic - 6 to 9 feet Light grey and cream, slightly greenish, with minor light brown ferruginous patches, somewhat kunkarized, glauconitic spicular cherty marl and cherty mudstone. Light green glauconite ovoids are quite abundant. Light grey chalcedonic spicule-rich flints are common in washed material. A small amount of angular to rounded clear quartz sand is present. Foraminifera are very rare. The sample is from the Blanche Point Marls.
9	12	As for 6 to 9 feet but less sandy.
12	18	Khaki clay with glauconite specks, white limestone fragments and minor fossil casts. Microscopic - 12 to 15 feet Light grey, light brown, light olive-green (overall light khaki), glauconitic spicular cherty marl and mudstone with more sand than 6-9ft. Glauconite ovoids and aggregates are more abundant; loose sponge spicules are abundant in addition to spicular flints. Frequent mollusc casts and moulds include Turritella sp. Foraminifera are very rare. Blanche Point Marls.
18	27	Green calcareous clay and claystone with glauconite specks and rounded brown grains. Microscopic - 18 to 21 feet. Rather similar to 12-15ft. Blanche Point Marls. Dark olive-green glauconite is abundant, as are fragments of spicular chert. Mollusc casts and moulds are common in glauconite and chert. Quartz sand is only minor. Foraminifera are very rare. Microscopic - 24 to 27 feet. Light grey, light brown, speckled olive-green (overall unwashed colour in greenish light khaki) sandy, glauconitic cherty marl with abundant loose sponge spicules and light grey chalcedonic spicular glauconitic flints. Foraminifera are common, dominated by Cibicides umbonifer (C), and Cassidulina subglobosa (F). A moderately large Lenticulina Sp. occurs very rarely. Lagena hexagona (R), and rare Polymorphinidae and Nodosarinae are present. Blanche Point Marls.

Depth(feet) From	To	Description
27	39	Khaki sandy flauconitic and calcareous clay, with minor white pellets. Microscopic 30 to 33 feet Speckled greenish light khaki sandy glauconitic cherty marl rather similar to 24-27ft. Mollusc fragments (mostly pelecypods) are common, generally like the foraminifera, in very light pink recrystallized calcite. Foraminifera are common and include Gyroidina sp. (R), Cibicides umbonifer (C), Cibicides sp. (F) and Rosalina sp. (R). Probably Blanche Point Transitional Marls. Microscopic 36 to 39 feet Speckled brownish-khaki limonitic and glauconitic sandy cherty marl, with a more abundant and varied fauna of mollusca (fragments abundant), sponges (spicules common), echinoids (fragments frequent), bryozoa (fragments rare) and foraminifera (abundant). Frequent light pink, light brown and light green calcite fragments contribute to a more calcareous lithology. Foraminifera include Maslinella chapmani (VR), Carpentaria sp. (VR), "Eponides repandus"(R), large Lenticulina sp.(R), Sigmorphina sp. (VR), and Cibicides sp. in addition to previously listed forms which are also more abundant. Blanche Point Transitional Marls.
39	48	Khaki to dark green calcareous clay with glauconite pellets and fragments of limestone. Microscopic - 42 to 45 feet Predominantly a brownish-khaki limonitic and glauconitic sandy cherty marl, still with many fragments of light grey glauconitic chert. Entry into the Tortachilla Limestone (at, say, 44ft.) is marked by the appearance of frequent fragments of green-brown, glauconite-impregnated, limonitic fossiliferous sandy limestone with large mollusc fragments, bryozoa and glauconite-impregnated echinoid fragments. Asterigerina adelaidensis (VR), Cibicides near pseudoconvexus (VR), Pseudopolymorphina sp. (VR), and Guttulina sp. (VR) are present. Microscopic - 45 to 48 feet Darker greenish-khaki (grey-green and brown when washed) glauconitic limonitic abundantly fossiliferous sandy clayey and shelly limestone, with abundant limonitized glauconite ovoids and many fragments of light green, light pink, light brown or cream limestone. A Tortachillan fauna similar to that recorded from Bore 3, 42-45ft. confirms Tortachilla Limestone. Boring difficult - hole stopped at 48 feet.

LOG OF GEMCO BORE-HOLE NO.5

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L.: 365 ft. DEPTH: 54 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G. Olliver DATE: 4.2.1964.

Depth(feet) From	To	Description
0	3	Loam over kunkar.
3	6	Red-brown gritty clay with pockets of white calcareous material.
6	12	Light brown calcareous clay with red-brown patches.
		Microscopic - 9 to 12 feet. The washed sample is very light brown to grey with speckling of ferruginous brown and glauconitic green (unwashed: brownish-cream). A sandy glauconitic and ferruginous somewhat kunkarized marl, in which blue-green glauconite and limonitized glauconite both occur frequently, and light green calcitic fragments are abundant as are fine to coarse subrounded quartz grains. Bryozoal fragments are rare, echinoid and mollusc fragments very rare. Rare and small foraminifera include Cheiloguembelina rugosa (VR), Triferina bradyi (R), Bolivina sp. (VR), Cibicides cf. vortex (R), Cibicides sp. (VR), Rosalina sp. (VR), Cassidulina sp. (VR), Astrononion sp. (VR) and Lagena sp. (VR). A fragment of a light green larger polymorphinid, small spinose spheroids, and siliceous ovoids and discs are also present. The interval is assigned to the Blanche Point Transitional Marls.
12	15	Light brown to khaki clayey limestone.
		Microscopic - 12 to 15 feet Speckled light brown and greenish-grey glauconitic limonitic sandy cherty fossiliferous limestone, somewhat kunkarized. The limestone which is in part hard, recrystallized, and siliceous, varies in colour from white, cream and pink, to very light green and brown. Honey-brown limonite-stained polished quartz grains are common, as are limonitized ovoids and aggregates. Large mollusc fragments are frequent, but generally the common bryozoal, echinoid and mollusc fragments are broken small. Glauconite-impregnated fragments, especially of echinoids, are present as are limonitized bryozoal fragments. Foraminifera are quite rare, recrystallized, and coloured light green, brown or pink. Cibicides umbonifer is the most common; others include Maslinella chapmani (VR), Asterigerina adelaidensis (VR), large Lenticulina sp. (VR), Gyroidina sp. (VR), Cibicides near Pseudoconvexus (VR), "Eponides repandus" (VR), Carpentaria sp. (R), Dentalina soluta (VR), Fissurina sp. (VR), Guttulina sp., (VR), and several other species of Polymorphinidae. One fragment may be Pseudopolymorphina sp. Lithology and fauna suggest Tortachilla Limestone, at least for part of the interval.
15	27	Pale green calcareous sandy clay with white pellets becoming wet below 24 feet.

Depth(feet) From	To	Description
15	27 contd.	Microscopic - 15 to 27 feet Greenish-brown and grey (unwashed colour a light khaki-brown) more ferruginous glauconitic sandy and clayey cherty limestone and marl, with a Tortachillian fauna and abundantly fossiliferous. Mostly Tortachilla Limestone.
27	48	Yellow brown sandy clay with minor grit and gravel. Microscopic - 27 to 48 feet. Darker brown glauconitic very limonitic calcareous clay, silt and sand, with abundant limonitized ovoids, limonite stained or coated quartz, and rare to frequent mostly limonitized bryozoal and echinoid fragments. Foraminifera are rare and mostly small, dominated by Cibicides umbonifer. Cibicides pseudoconvexus, Cibicides sp., Rosalina sp., and a few Polymorphinidae, are all very rare. "Eponides repandus" is rare. The interval is assigned to the South Maslin Sands.
48	54	Off white, with irregular brown mottling, clay, micaceous and containing minor sand. Microscopic - 48 to 54 feet. As above passing down to light grey (streaked and mottled with limonitic-brown) micaceous sandy and silty clay. Frequent Cibicides umbonifer occurs, some at least in this matrix. An amphibian tooth and a few other foraminifera were also recovered. The sample is probably from the South Maslin Sands.
		Samples below 48 feet cemented to auger flights - Hole stopped at 54 feet.

LOG OF GEMCO BOREHOLE NO. 6

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L.: 364 feet DEPH: 45 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G. Olliver DATE: 6.2.1964

Depth(feet) From	To	Description
0	6	Brown sandy loam over white kunkar.
6	30	Brown calcareous sandy clay with rounded quartz grit.
		Microscopic - 6 to 30 feet This is a composite sample which seems anomalous in some respects, since Bore 6 is sited between Bore 5 and Bore 7 on much the same level, and should be comparable. The unwashed sludge is brown, slightly ferruginous, calcareous gritty quartz sand and clay with abundant buff to cream sandy kunkar fragments and frequent fragments of white, light greenish-grey and light brown glauconitic spicular chert and cherty marl. The washed material is mostly quartz sand, some of it iron-stained. The glauconitic slightly limonitic chert fragments are fossiliferous, with gastropod and pelecypod moulds and casts. This lithology is typical of the Blanche Point Marls. Very rare glauconite-limonite green and brown fragments are reminiscent of Tortachilla Limestone lithology. Polished limonite ovoids and aggregates are frequent. Glauconite-impregnated echinoid fragments occur rarely. Echinoid spines, bryozoal fragments, foraminifera and ostracods are very rare, generally in recrystallized brown calcite. Foraminifera include Cibicides vertex (VR), Gyroidina sp.,(VR), Cibicides umbonifer (VR) and Cassidulina subglobosa (VR). Loose sponge spicules and spicular grey flints are rare. Small spinose spheres are frequent, siliceous milky ovoids are very rare. Black, Glossy carbonaceous fragments are rare. In all there is evidence for predominant Blanche Point Marls, with some contribution from Tortachilla Limestone and ?South Maslin Sands.
30	45	Similar to 6 to 30 feet but samples wet and rounded quartz gravel up to ½ inch.
		Microscopic - 30 - 45 feet The unwashed sludge is very similar to that of 6-30ft. being brown clayey and sandy with many light-coloured fragments of cherty more or less calcareous lithology, and both glauconite and limonitic. The washed sample is largely gritty quartz sand with abundant fragments of white, cream and light brown sandy glauconitic chert and cherty limestone. Mollusc casts and moulds are frequent. Sponge spicules are frequent. Rare foraminifera include Pollenia quinqueloba (VR), Cassidulina subglobosa (VR), Pyrgo sp. (VR), Cibicides umbonifer (VR) Cibicides sp (VR), and Globigerina spp. (VR). Small spinose spheres, and siliceous ovoids are rare. This sample again seems largely Blanche Point Marls, but like 6-30ft. is composite, anomalous, and perhaps contaminated or reworked.
		Water at 43 feet - Hole stopped at 45 feet.

LOG OF GEMCO BOREHOLE NO. 7

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L.: 366 feet DEPTH: 42 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G. Olliver DATE: 6.2.64

Depth(feet) From	To	Description
0	3	Red-brown sandy and clayey loam.
3	6	Light brown clay under minor kunkar.
6	12	Light brown sandy calcareous clay.
		Microscopic - 6 to 9 feet Light brown sandy kunkarized glauconitic slightly limonitic cherty marl. Common light grey glauconitic spicular chert fragments, with mollusc casts and moulds, and sometimes with dendritic black (?manganese-dioxide) staining. Foraminifera are very rare. Kunkarized Blanche Point Marls.
12	15	As for 6 to 12 feet
		Microscopic - 12 to 15 feet Light brown sandy kunkarized cherty marl rather similar to 6-9ft. but more fossiliferous. Echinoid and bryozoal fragments, and foraminifera are frequent Rare loose mollusc fragments are present, some fairly large. Ostracods are very rare. Glauconite-impregnated light grey-green echinoid and other calcitic fragments occur rarely, as do fragments of bright green and brown glauconitic limonitic sandy and cherty shelly limestone. Foraminifera include Cibicides umbonifer (F), Cibicides pseudoconvexus (VR), moderately large Lenticulina sp. (VR), Gyroidina sp.(R), Guttulina sp. (VR), Cassidulina subglobosa(R), "Eponides repandus"(VR), Globigerina spp.(F), Trifarina bradyi (F), Angulogerina spp. (VR), Angulogerina spp. (VR), Urigerina spp. (VR), Lagena hexagona (F), Lagena spp. (F), Dentalina soluta (VR) and Dorothia sp. (VR). Small spinose spheroids and siliceous ovoids are rare. The lithology and fauna shows entry into the Blanche Point Transitional Marls.
12	15	As for 6 to 12 feet
		Microscopic - 12 to 15 feet Light brown sandy kunkarized cherty marl rather similar to 6-9ft. but more fossiliferous. Echinoid and bryozoal fragments, and foraminifera are frequent. Rare loose mollusc fragments are present, some fairly large. Ostracods are very rare. Glauconite-impregnated light grey-green echinoid and other calcitic fragments occur rarely, as do fragments of bright green and brown glauconitic limonitic sandy and cherty shelly limestone. Foraminifera include Cibicides umbonifer (F), Cibicides pseudoconvexus (VR), moderately large Lenticulina sp. (VR), Gyroidina sp. (R), Guttulina sp. (VR), Cassidulina subglobosa (R), "Eponides repandus" (VR), Globigerina spp. (F), Trifarina bradyi (F), Angulogerina spp.(VR), Angulogerina spp. (VR), Urigerina spp. (VR), Lagena hexagona (F), Lagena spp. (F), Dentalina soluta (VR)

Log of Gemco Borehole No. 7 contd.

Depth(feet) From	To	Description
12	15 contd.	and Dorothia sp. (VR). Small spinose spheroids and siliceous ovoids are rare. The lithology and fauna shows entry into the Blanche Point Transitional Marls
15	24	Khaki sandy and glauconitic calcareous clay with fragments of limestone. Microscopic - 18 to 21 feet Khaki-coloured (grey-green and brown speckled when washed) limonitic glauconitic sandy cherty and clayey limestone, abundantly fossiliferous and shelly, with abundant fragments of light green, light brown and cream cherty limestone. The lithology and fauna is typical of the Tortachilla Limestone as previously described. Pseudopolymorphina sp occurs very rarely.
24	42	Yellow-brown to brown clay, sandy in parts and with minor greenish streaks. Microscopic - 24 to 27 feet. Khaki-brown (when washed - brown, light grey, green) moderately glauconitic more limonitic and sandier than 18-21ft. The fauna is less abundant but still predominantly Tortachillan. Most of the interval is Tortachilla Limestone but South Maslin Sands may be may be entered. Microscopic - 30 to 33 feet Dark brown very limonitic slightly glauconitic calcareous silty and clayey quartz sand, of the South Maslin Sands, with abundant limonite ovoids, aggregates, coatings and stainings. Bryozoal, echinoid and mollusc fragments are frequent and often limonitized. Cibicides umbonifer is common. One specimen each of Pseudopolymorphina sp., Asterigerina adelaidensis and Maslinella Chapmany may be Tortachillan contaminants. Microscopic - 36 to 39 feet Very similar to 30 - 33 feet. Much limonitization. South Maslin Sands. Microscopic - 39 to 42 feet Very similar to 30 - 33 feet. South Maslin Sands. Water at 40 feet - Hole stopped at 42 feet.

LOG OF GEMCO BOREHOLE NO. 8

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L. 359 feet DEPTH: 30 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G. Olliver DATE: 6.2.64

Depth(feet) From	To	Description
0	3	Loam over kunkar
3	6	Kunkar with greenish chert fragments.
6	15	Light brown calcareous clay, slightly sandy becoming greenish below 9 feet.

Microscopic - 6 to 9 feet
Cream, partly kunkarized glauconitic sandy shelly cherty marl. Loose sponge spicules are frequent, as are spicular chert fragments. Pelecypod fragments are common, echinoid fragments (occasionally glauconite,impregnated) are frequent, and bryozoal fragments rare. Ostracods are rare. Foraminifera are common and include Cibicides umbonifer (C), Rosalina sp.(R), Cassidulina subglobosa (R), Lagena hexagona (VR), and a medium-sized Lenticulina sp. Blanche Point Marls.

Microscopic - 12 to 15 feet
Cream, slightly green and light brown partly kunkarized glauconitic cherty sandy and shelly marl with frequent chalcedonic spicular flints which are greenish-grey and sometimes glauconitic. Mollusc fragments are common, sometimes large; echinoid fragments and loose sponge spicules are common, bryozoal fragments rare, and foraminifera common and more varied than 6-9ft. Ostracods are frequent. Limonite ovoids, aggregates, quartz-stainings etc. occur frequently. Foraminifera include Asterigerina adelaidensis (VR), moderately large Lenticulina sp. (VR), Rosalina sp. (R), Cibicides cf. vortex (R), Cibicides umbonifer (A), Cibicides spp. (C), Cassidulina subglobosa (F), at least eight species of Polymorphimidae, all very rare. Pyrgo sp. (VR), small Urigerininae (R), Bolovina spp. (R), Lagenidae (R), and Dentalina sp. (R). Small milky siliceous ovoids are rare. Blanche Point Transitional Marls.

15	30	Khaki calcareous clay with glauconite sand and limestone fragments.

Microscopic - 18 to 21 feet
Green-grey, dark olive-green and brown glauconitic limonitic sandy shelly and cherty marl tending in part to light brown, green and cream abundantly fossiliferous limestone. A full benthonic Tortachillan foraminiferal fauna is present, similar to that described earlier. The sample thus involved Blanche Point Transitional Marls passing down into Tortachilla Limestone.

Microscopic - 24 to 27 feet
Khaki (green, grey, brown) abundantly fossiliferous glauconitic limonitic sandy cherty shelly impure limestone of the Tortachilla Limestone.

LOG OF GEMCO BOREHOLE NO. 8 contd.

Depth(feet) From	To	Description
15	30 contd.	Microscopic - 27 to 30 feet Khaki brown (speckled brown and greenish-grey) notably limonitic, glauconitic sandy impure limestone or calcarenite with an abundant Tertachillan fauna as above. On long-lasting reaction with dilute hydrochloric acid considerable brown ferruginous clay is released and much siliceous spicular meshwork is revealed, together with frequent green-grey chert fragments. Tertachilla Limestone. At 30 ft. Very similar to the above in every way. Tertachilla Limestone. Water at 30 feet.

LOG OF GEMCO BOREHOLE NO. 9

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L. 352 feet DEPTH: 24 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G.Olliver DATE: 6.2.64

Depth(feet) From	To	Description
0	3	Brown sandy loam.
3	9	Mottled brown and grey clay, sandy with minor grit. - Samples damp.
9	24	Brown mottled sandy and gritty (rounded quartz grains) clay. - Samples wet.
		Water at 23 feet. Hole stopped at 24 feet.

LOG OF GEMCO BOREHOLE NO. 10

PROJECT: Jarvis Industries Ltd.

SECTION: 17 HUNDRED: Noarlunga COUNTY: Adelaide

R.L.: 349 feet DEPTH: 30 feet DRILLER: R. Cortolezzis

LOGGED BY: J.G. Olliver DATE: 6.2.64

Depth(feet) From	To	Description
0	3	Dark brown sandy loam.
3	6	Mottled brown, grey and red clay with rounded quartz sand and grit.
6	30	Dark brown slightly sandy clay with rounded quartz grains up to ½ inch. More sandy with depth.

Microscopic - 6 to 9 feet
Kunkarized brown gritty silty and clayey ferruginous quartz sand. Washed material is almost entirely a poorly sorted limonite-stained gritty quartz sand with frequent more or less rounded fragments of brown phyllitic siltstone. Common in the washed sample are light brown to brown-grey sandy kunkar fragments which dissolve in dilute hydrochloric acid to leave brown clay, quartz silt and sand. Apparently unfossiliferous.

12 - 15ft.
Very similar to above. Apparently unfossiliferous.

18 - 21ft.
As above with common subangular to rounded lithic fragments of brown, red-brown and grey phyllitic siltstone. Apparently unfossiliferous.

24 - 27ft.
As for 18-21ft. Abundant lithic fragments in gritty sand. Apparently unfossiliferous.

Microscopic - at 30 feet
Washed material is brown pebbly gritty sand, apparently unfossiliferous, with abundant fragments of phyllitic siltstone as above.

Water at 25 feet - Hole stopped at 30 feet.

APPENDIX III

RESULTS OF SIEVE ANALYSES

Weight Percent

Mesh B.S.S.	Borehole No. 1 6'-27' A1665/64	Borehole No. 1 27'-48' A1666/64	Borehole No. 2 9'-15' A1667/64	Borehole No. 2 15'-24' A1668/64	Borehole No. 2 24'-36' A1669/64
+ 100	21.5	20.1	37.6	29.0	14.6
+ 200	7.0	8.3	11.5	8.5	7.9
+ 300	4.7	3.6	4.8	4.9	4.1
- 300	66.8	68.0	46.1	57.6	73.4
	100.0	100.0	100.0	100.0	100.0

Mesh B.S.S.	Borehole No. 3 6'-21' A1670/64	Borehole No. 3 21'-42' A1671/64	Borehole No. 3 42'-54' A1672/64	Borehole No. 4. 6'-18' A1673/64	Borehole No. 4. 18'-27' A1674/64	Borehole No. 4. 27'-44' A1675/64	Borehole No. 4. 44'-48' A1676/64
+ 100	30.9	12.2	21.5	25.3	21.9	9.5	18.5
+ 200	10.0	7.3	7.9	8.4	7.0	5.7	6.5
+ 300	5.4	4.1	4.2	4.4	4.2	4.7	3.8
- 300	53.7	76.4	66.4	61.9	66.9	80.3	71.2
	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Mesh B.S.S.	Borehole No. 5 9'-15' A1679/64	Borehole No. 5 15'-27' A1680/64	Borehole No. 6 6'-45' A1681/64
+ 100	21.2	23.2	21.4
+ 200	10.1	9.5	22.0
+ 300	3.1	3.4	4.1
- 300	65.6	63.9	52.5
	100.0	100.0	100.0

Mesh B.S.S.	Borehole No. 7 6'-15' A1677/64	Borehole No. 7 15'-24' A1678/64	Borehole No. 8 6'-15' A1682/64	Borehole No. 8 15'-30' A1683/64
+ 100	14.2	10.3	21.5	17.9
+ 200	17.0	7.7	12.8	8.3
+ 300	1.7	4.5	6.6	4.1
- 300	67.1	77.5	59.1	69.7
	100.0	100.0	100.0	100.0

APPENDIX IV

MINERALOGICAL EXAMINATION OF HACKHAM CLAY

Investigation and Report by

N. A. Trueman
J. R. Worden
B.H.J. Waters
(A.M.D.L.)

Bore 1 - bulk sample (A 14/64)

The sample consists of calcite, clay and minor quartz. Illite or glauconite is the dominant clay mineral constituent.. Montmorillonite is present but is less abundant than the hydrous mica. The differentiation between illite and glauconite in this sample is not possible, but the colour is suggestive of glauconite.

Upper clay layer from railway cutting P16/64
Lower " " " " " P17/64

The samples were examined by X-ray diffraction. Both P16/64 and P17/64 are identical and consist of montmorillonite and accessory quartz.

The samples were separated by sedimentation and only the minus 2 micron fraction examined.

		Sample No.	
Bore 4	6-18 feet	A1673/64	Montmorillonite dominant(a), kaolin and illite sub-dominant, zeolite accessory(b).
	18-27 feet	A1674/64	Montmorillonite dominant, illite and zeolite sub-dominant, kaolin accessory.
	27-44 feet	A1675/64	Montmorillonite dominant, illite and zeolite sub-dominant.
	44-48 feet	A1676/64	Montmorillonite and illite co-dominant, kaolin and zeolite accessory.
Bore 7	6-15 feet	A1677/64	Montmorillonite dominant, illite, kaolin and zeolite sub-dominant.
	15-24 feet	A1678/64	Montmorillonite dominant, illite and zeolite sub-dominant.

(a) The abundance of the constituents is estimated from x-ray diffraction and related to standards. However, owing to variations in crystallinity of the clay minerals the estimates are only semi-quantitative. The terminology is as follows.

Dominant: greater than 50 per cent.

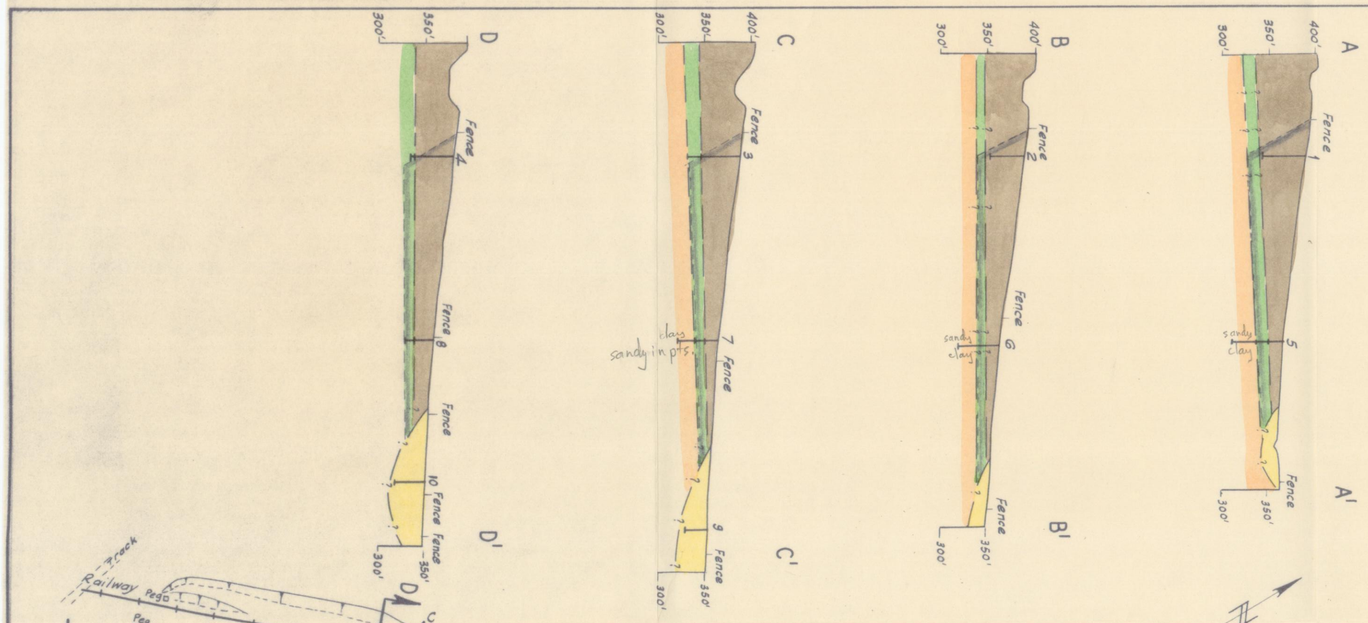
Co-dominant: two components constituting more than 60 per cent.

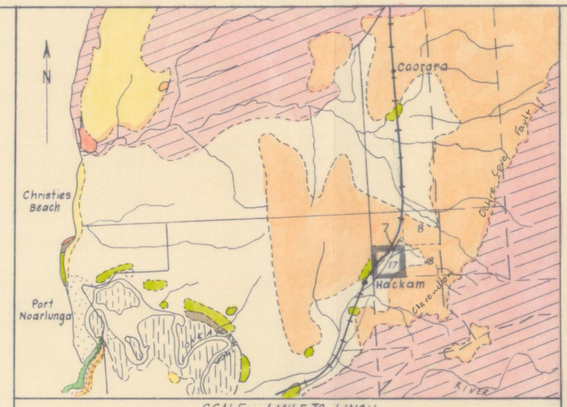
Sub-dominant: 20-50 per cent

Accessory: less than 20 per cent.

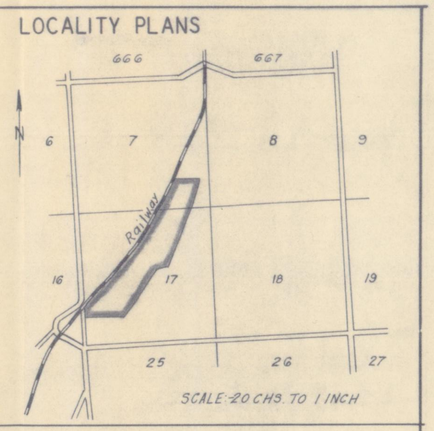
(b) The zeolite could not be identified positively. Only one diffraction line is visible (8.9 A units) and in all cases is of low intensity. The mineral assemblage and diffraction data suggest that it is possibly heulandite. However D.T.A. failed to detect any heulandite and no other zeolite was identified.

jb:1





SCALE:- 1 MILE TO 1 INCH

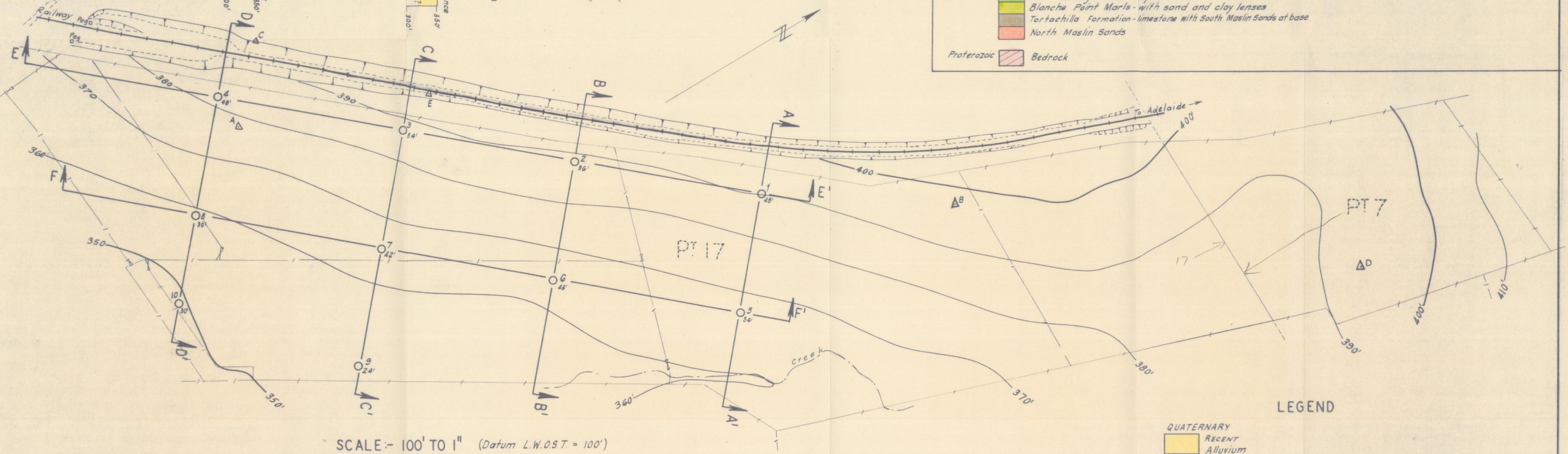


Quaternary
Recent
- Alluvial clays with sands and gravels
- Alluvial flood plains
- Dune sands

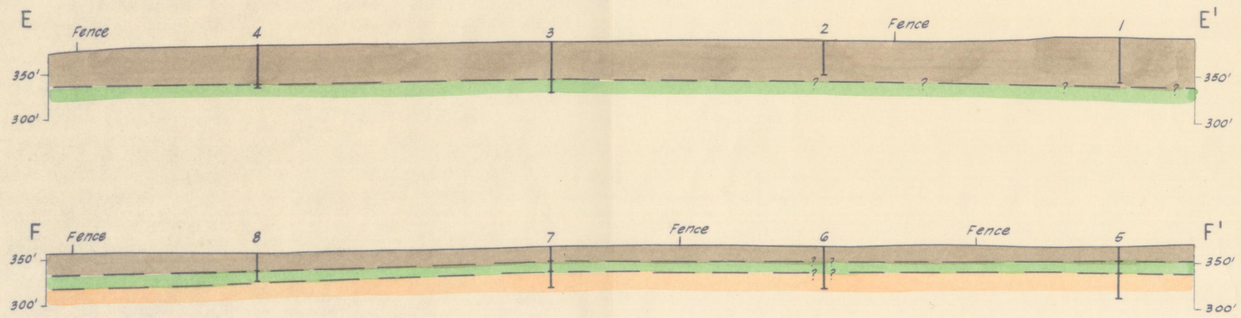
Pleistocene
- Mottled clays

Tertiary
- Freshwater gravels, sands and clays
- Port Willunga Beds - Bryozoal sands and limestones
- Blanche Point Marls - with sand and clay lenses
- Tortachilla Formation - limestone with South Maslin Sands at base
- North Maslin Sands

Proterozoic
- Bedrock



SCALE:- 100' TO 1" (Datum L.W.O.S.T. = 100')



LEGEND

QUATERNARY
- RECENT Alluvium
- TERTIARY Blanche Point Marls and Transition Marls, Kunkarised at the top and covered by a veneer of loam.
- Tortachilla Limestone
- South Maslin Sands

Geological Boundaries
- Approximate
- Inferred

Volumes calculated from areas outlined.

3 No 54' Depth. Gemco borehole

To accompany report by J.G. Olliver

S.A. DEPT. OF MINES

CLAY DEPOSIT
PT. SECS. 7 & 17 HD. NOARLUNGA
GEOLOGICAL PLAN AND SECTIONS

Req. No.
D.M.
Compiled from

Associated Drawing	No.	No.	Amendment	Exd.	Date

Approved	Passed	Stadia Survey R.E. Adams S.F.B. 273	Scale: As shown
		Drn. J.G.O.	64-267 Ha 9
		Tcd. A.O.W.	
Director of Mines		Ckd.	
		Exd.	Date 10-4-64

300—4.63 1403