71/37.

DEPARTMENT OF MINES
SOUTH AUSTRALIA

GEOLOGICAL SURVEY
PETROLEUM EXPLORATION DIVISION

MT. WILLOUGHBY NO.1

WELL COMPLETION REPORT

by

R.C.N. THORNTON
GEOLOGIST
PETROLEUM SECTION

Rept.Bk.No. 71/37

5th April, 1971

DEPARTMENT OF MINES
SOUTH AUSTRALIA

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G.S. No. 4617
D.M. No. 612/70

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with Appendix F by B.E. MILTON, Senior Geophysicist, Seismic Geophysics Section and Appendix G by B. McGOWRAN AND W.K. HARRIS, Palaeontology Section.

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DEPARTMENT OF MINES
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MT. WILLOUGHBY NO. 1

Well Completion Report

ABSTRACT

Mt. Willoughby No. 1 was drilled in the northern part of the Arckaringa Basin as a continuation of the S.A. Department of Mines stratigraphic study of this area.

The well was drilled on the western plateau of a positive gravity high on the Wintinna 1 mile sheet in an attempt to identify the high speed seismic refractor, with a velocity of 21,000 feet per second which was known to occur in the area at a depth of approximately 2,000 feet. The drill intersected a very hard, dense dolomite sequence, tentatively dated as Devonian, at 2046 feet. The physical properties, particularly a specific gravity of 2.77 gm./cc., leave no doubt that this is the high speed refractor.

52.8 feet of the ? Devonian dolomite (Unit 3?) were drilled, T.D. being at 2098.8 feet. It contains very interesting microcrystalline silica and dolomite concretions and/or pebbles of unknown origin, together with algal stromatolites.

An unconformity separates Unit 3 from the overlying L. Permian glacigene Unit 2 sediments, which are 1086 feet thick. Unit 1 is absent and 305 feet of L. Permian Mount Toondina Beds overlie Unit 2. It is believed that the lower part of the Mount Toondina Beds sedimentation occurred during the time that Unit 1 was being deposited in the more southerly parts of the basin.

655 feet of normal Mesozoic western Great Artesian Basin sediments were intersected.

INTRODUCTION AND REASONS FOR DRILLING

Mt. Willoughby No. 1 was drilled in the northern part of the Arckaringa Basin as a continuation of the subsurface stratigraphic study of the area that is being carried out by the Geological Survey of the South Australian Department of Mines. The well was located approximately 80 miles west of Oodnadatta on the Wintinna 1 mile sheet, in the out of lease "Corridor Area" between P.E.L. 5/6 and P.E.L. 10/11 (fig. 1). Access to the site was provided by a track graded in from the Stuart Highway. The well was spudded in on 5th November, 1970 and the drilling time to Total Depth was 18 days.

One of the lesser known features on the Wintinna 1 mile sheet was a positive gravity high discovered during a helicopter gravity survey in 1969 (Hall and Townsend, 1969). Comparison between the Bouger gravity map and the depth to magnetic basement map shows that this strong positive gravity anomaly coincides with a depth to magnetic basement in excess of 6,000 feet. In the southern part of the Arckaringa Basin, areas of sediment fill such as the Phillipson and Wallira troughs are directly related to gravity lows, the highs being associated with basement ridges, for example the Coober Pedy ridge. Another difference is that, whereas the high speed refractor underlying Permian sediments in the southern troughs has a velocity of 18,500 feet per second reconnaissance seismic work in 1969 and more detailed work

in 1970 (Milton, 1970 and 1971) showed the high speed refractor over this gravity high to have a velocity of 21,000 feet per second and to occur at a depth of about 2,000 feet. Stratigraphic drilling during 1969 in the western part of the Arckaringa Basin (Townsend, 1970) indicated that the origin of the 18,500 feet per second refractor was crystalline basement, and a possible dense carbonate origin was therefore suggested for the 21,000 feet per second material to explain the anomalous gravity values.

Lambina No. 1 was drilled in March, 1970, on the northern flank of the gravity high in an attempt to intersect the high speed refractor. This was unsuccessful, however, due to the inability of the rig to drill through a hard horizon at 1450 feet. Further seismic work was therefore carried out during the 1970 field season (Milton 1971) to obtain a clearer picture of the subsurface structure, and the site of Mt. Willoughby No. 1 was chosen from this work, locating it on a western plateau of the feature.

WELL HISTORY

General Data

Well Name and Number:

South Australian Mines Department Mt. Willoughby No. 1

Location:

Latitude: 27°39'46"S

Longitude: 134°16'39"E

The well is located approximately 80 miles west of Oodnadatta at a position which is 10 miles east of the Stuart Highway.

Access:

An access track was graded into the campsite along the S.A. Department of Mines JC (1970) seismic line, starting from the Stuart Highway at a point three miles north of Wintinna Homestead.

Map References:

1:250,000 sheet : WINTINNA

1" = 1 mile " : Wintinna

Details of Petroleum Tenement:

The well was drilled in an "out of lease" area, known as the "corridor area", between P.E.L.'s 10 and 11 and P.E.L.'s 5 and 6.

Elevation:

Rotary Table : 792.25 feet A.S.L.

Ground Level : 789 feet A.S.L.

Total Depth: 2098.8 feet

Date Drilling Commenced: 5th November, 1970

Date Drilling Completed: 23rd November, 1970

Drilling Time to Total Depth: 18 days

Date Well Completed: 26th November, 1970

Date Rig Released: 26th November, 1970

Status: Abandoned in a condition suitable for development as a water well, with one plug set as follows:

Interval	Sacks of Cement
650-700 feet	5

Drilling Data

Name and Address of Drilling Contractor:

S.A. Department of Mines Mechanical & Drilling Branch, Dalgleish Street, Thebarton, S.A. 5031.

Drilling Rig:

Make:	Failing 1500
Type:	Rotary Drill
Rated Capacity:	1500 feet with 2 3/8" drill pipe
Motor:	Cummings Diesel
H.P. Rating:	185 B.H.P. at 1800 R.P.M.

Mast:

Make:	Failing 1500
Type:	Open Front
Rated Capacity:	24,00 lbs.

Pumps (2):

Make:	Gardner - Denver

Type: FGFXG

Size: 5" x 6"

Motor: Cummings Diesel

H.P. Rating: 42.5 B.H.P.

Hole Size: 9¼" to 145 feet

4½" to 2022 feet

4¼" to 2087 feet

3.907" to 2098.8 feet

Casing and Cementing Details:

Size	Weight	Grade	Depth
5"	10lb/ft.	Steward & Lloyd Water Bore	144.5 ft.

Note: Cemented casing from surface to 144.5 feet, using 16 sacks of cement in 100 gallons of water.

Bit Record:

No. of bits used	Size	Type	Make
1	9¼"	Finger	Hughes
1	6¾"	W4	Williams
1	4½"	V1	Varel
2	4½"	V2	Varel
2	4½"	VH2	Varel
5	4½"	V3	Varel
1	4½"	K7	Williams
2	4¼"	V1	Varel
3	3.907"	Diamond Core	Mindrill

Drilling Mud Materials:

Bentonite	10 bags
Dextrid	26 bags
Quick - Trol	20 lbs
Caustic	196 lbs
C.M.C.	120 lbs
Myrtan	5 bags
Bran	2 bags
Cement	18 bags

The mud used was of a water based bentonite kind. Severe loss of circulation occurred at 44 feet and 75 feet and bran was added to help cure the problem.

Water Supply:

Water for the camp site was obtained from Hawks Nest Well on the Stuart Highway, 25 miles from the site to the north. Drilling water was obtained from Junction Well, also on the Stuart Highway, 3 miles south of Hawks Nest Well.

Perforation Record:

No perforations were carried out.

Formation Sampling

Coring:

Six cores were cut, using Mindrill stationary inner tube barrels (Nos. 1-3: 10 feet; Nos. 4-6: 20 feet) and Mindrill face discharge bits.

Core No.	Depth (ft.) From	To	Length Cored (ft.)	Recovery ft.	%	Core size (inches)
1	203.5	213	9.5	9.5	100	2 1/8
2	853	863.5	10.5	0.5	5	2 1/8
3	1080	1087	7	4.8	68.4	2 1/8
4	2022	2042.27	20.27	20.27	100	2 1/8
5	2061.25	2074.5	13.25	13.25	100	2 1/8
6	2087	2098.8	11.8	11.8	100	2 1/8
	Totals:		72.32	60.12	83.1	

Ditch Cuttings:

One sample was collected and preserved for every 10 feet interval drilled from surface to Total Depth. Washed samples were examined under a binocular microscope to determine % of cuttings and under ultra violet light to detect any hydrocarbon fluorescence.

Sidewall Sampling: None

Both the ditch cuttings and the cores are stored at the S.A. Department of Mines Core Laboratory, Thebarton.

Logging and Surveys

All logging was carried out using the S.A. Department of Mines Failing Logmaster unit (3000 feet model).

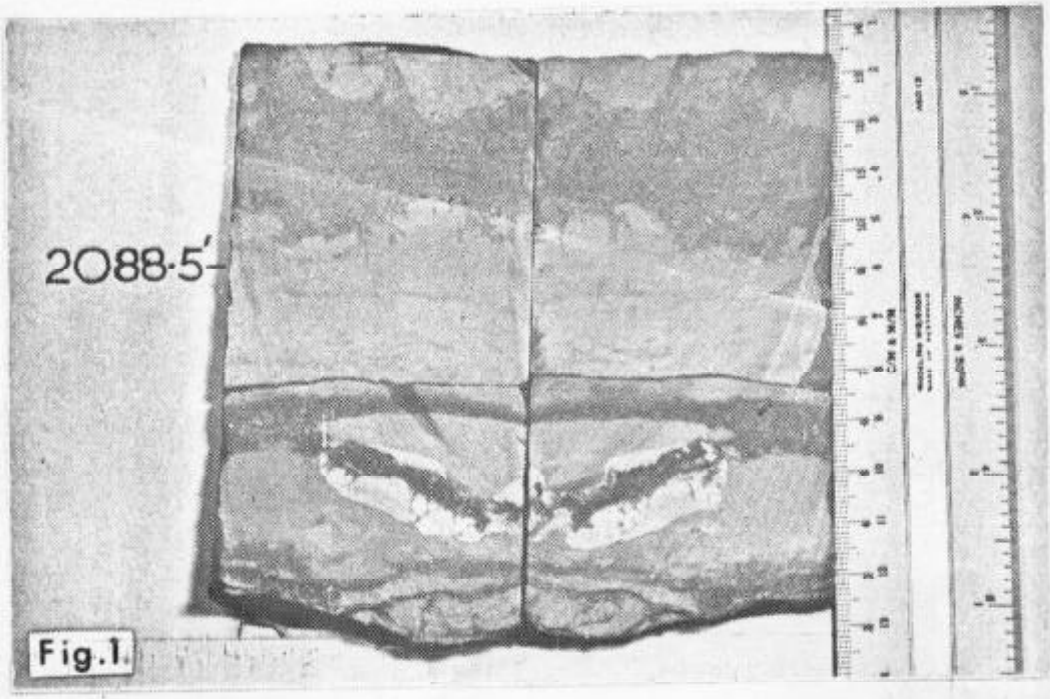

Fig.1.

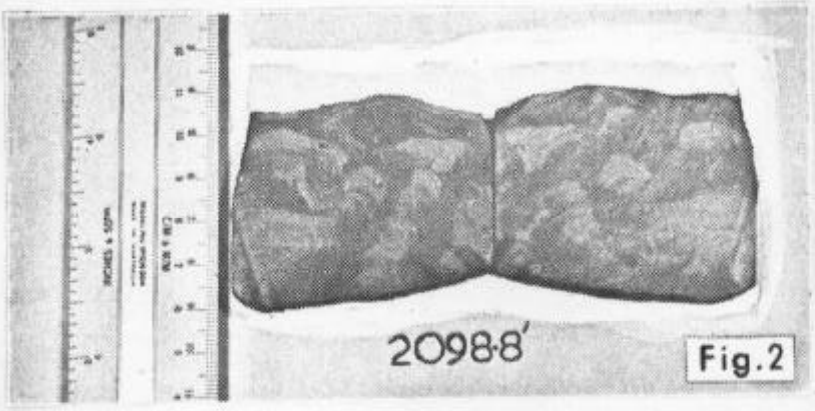

Fig.2

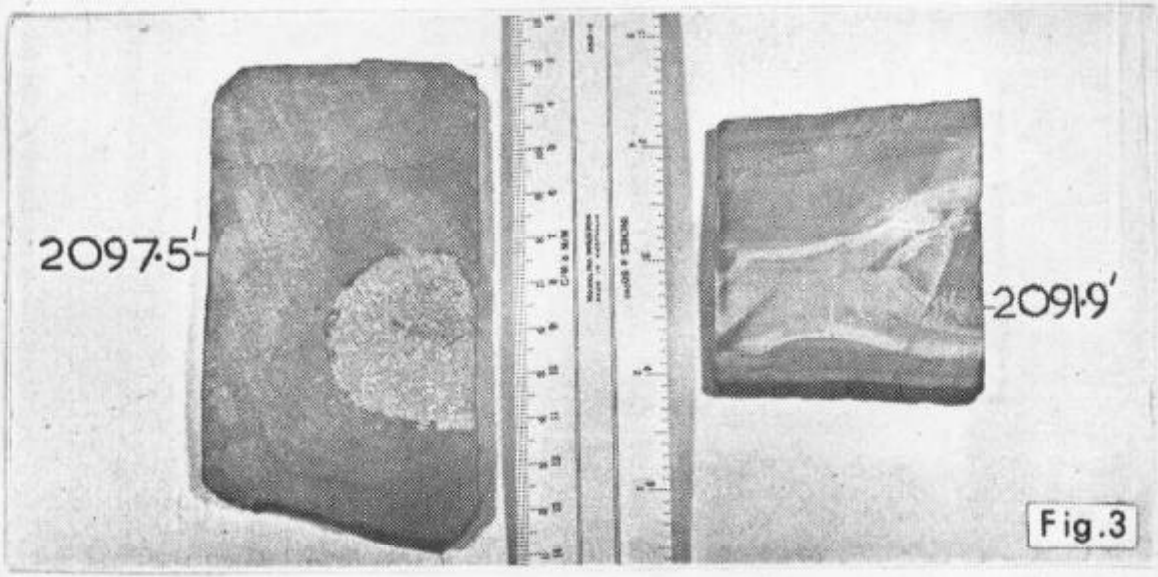

Fig.3

PLATE 1

Electrical and other Logging:

Log	Depth (ft.) From	To	Scale
Gamma Ray	0	2100	2" = 100'
Neutron - Neutron	0	2110	2" = 100'
Spontaneous Potential (S.P.)	145	2111	2" = 100'
Resistivity: (1) Point Resistivity (P.R.)	145	2111	2" = 100'
(2) 16" normal	145	2111	2" = 100'
(3) 64" normal	145	2111	2" = 100'
(4) 6' lateral	145	2111	2" = 100'
Temperature	0	2103	2" = 100'

N.B. The depths in the above table are those from the logger. All logging was carried out to T.D. and the discrepancy between the logger's and driller's calculation of T.D. is due to a 0.5% error in the logging unit.

Penetration Rate:

The penetration rate for every foot drilled, including coring, was recorded by the driller and a graphic representation is included on the composite log (Enclosure 1).

Velocity Survey:

A velocity survey using a "down the hole" geophone and near surface explosive charges was carried out. For a complete report on this survey see Appendix F.

Deviation Surveys: None

Formation Testing

None.

GEOLOGY

General

The sequence of sediments intersected at Mt. Willoughby No. 1 comprises three different depositional basins, namely the Upper Jurassic to Lower Cretaceous western Great Artesian Basin and the Upper Palaeozoic Arckaringa Basin. The hole bottomed in a dolomite sequence of possible Devonian age, which may have to be related to the Officer Basin.

Wopfner (1970) deals very fully with the Permian geology and palaeogeography of the Arckaringa Basin, and a synopsis of his paper was included in the well completion report for Lambina No. 1. (Thornton, 1970), together with a short general description of the Artesian Basin sediments.

Figure 2 shows a structure contour plan of the base of the Permian in the Arckaringa Basin.

Stratigraphic Table

Age	Lithological Unit	Formation Tops Subsurface Depth ft.	Formation Tops Subsurface Depth metres	Formation Tops Subsea Elevation ft.	Formation Tops Subsea Elevation metres	Thickness ft.	Thickness metres
Lower Cretaceous	Bulldog Shale	0	0	+792	+241.4	330	100.6
	Cadna-Owie Fm.	330	100.6	+462	+140.8	144	43.9
Upper Jurassic	Algebuckina Sst.	474	144.5	+318	+96.9	181	55.2
	Unconformity						
Lower Permian	Mt. Toondina Beds	655	199.6	+137	+41.8	305	93.0
	Unit 2	960	292.6	-168	-51.2	1086	331.0
	Unconformity						
Devonian?	Unit 3	2046	623.6	-1254	-382.2	52.8	16.1
	T.D.	2098.8	639.7	-1306.8	-398.3		

N.B. The formation boundaries have been taken from the gamma-ray log, and because of the error in the logging unit (see Logging and Surveys) there may be a depth error of ± 5ft. on these boundaries. It was also necessary to adjust the neutron log slightly on the composite log (Enclosure 1) to conform with the gamma-ray log.

Stratigraphy

N.B. For a more complete description of the formation lithologies see Appendix A.

Bulldog Shale (Aptian to Albian) Depth Interval : 0-330 feet.

The Bulldog Shale is normally a blue-black shale with thin siltstones. However, deep weathering of the silcrete profile has completely altered the colour of the top 87 feet and clays heavily predominate over shales throughout the section. The top 20 feet intersected contains indurated claystone and slumped blocks of silcrete from the silcrete profile. An olive green, glauconitic and silty greensand horizon occurs between 165-195 feet.

Cadna-Owie Formation (Neucomian to Aptian) Depth Interval: 330-474 feet.

The top of the Cadna-Owie Formation is marked by a very hard, pale green sandstone, but underlying this is a soft sand comprising unconsolidated quartz grains set in a white to pale pink clay matrix.

The quartz grains are colourless to pale translucent blue. They are poorly sorted, but a majority are coarse to very coarse grained, and quartz pebbles are common. Most grains are subangular, with a few being rounded. A little pyrite occurs, as do minor bands of black shale.

Algebuckina Sandstone (Upper Jurassic) Depth Interval: 474-655 feet.

The Algebuckina Sandstone consists of unconsolidated, very poorly sorted, fine to very coarse, colourless quartz grains set in a very soft pinkish-creamy white clay matrix. A few thin bands of pyrite occur. The top of the formation is marked by a clay rich unit.

Mount Toondina Beds (Artinskian) Depth Interval: 655-906 feet.

The Mount Toondina Beds consist of a rather homogeneous sequence of pale grey, clay rich silty sands that are calcareous below 850 feet. Pyrite bands are common. There is a distinct change in both the gamma-ray and neutron logs at 790 feet due possibly to variations within the clay matrix. The quartz grains are generally colourless, well rounded and have a high sphericity. There is a gradual decrease downwards in grain size through the formation from medium to fine grained. Below 790 feet a few hard bands occur where the clay rich sands have been cemented with calcite.

Unit 2 (Lower Permian) Depth Interval: 960-2046 feet.

Unit 2 is made up of a monotonous sequence of calcareous sandy clays which are hard when dry, but extremely soft when wet. The amount of calcite within the clay varies, but in some cases probably exceeds that of the clay, in which case a more correct terminology would be sandy argillaceous limestone. The clays have a green-grey colour above 1720 feet and are chocolate brown below. The amount of clastics within the clays varies considerably, as is shown well on the gamma-ray/neutron logs (Enclosure 1) from which five subunits can be picked, with their tops at 960 feet, 1154 feet, 1279 feet, 1524 feet, and 1720 feet. The clastics consist primarily of colourless quartz grains that are mainly fine to medium grained, well rounded and frosted. Hard bands of clayey sandstone, cemented with calcite, occur throughout the sequence, but particularly between 1279-1524 feet and 1720-1748 feet. Pyrite is a common accessory (except below 1748 feet) and pebbles, especially of dolomite,

are abundant near the base of the sequence.

Unit 3? (Devonian?) Depth Interval: 2046-2098.8 feet.

Unit 3 consists of pale grey, hard, dense, massive, predominantly pure dolomite. Most of it is recrystallised micrite, with, mainly in the upper part of the section, interbeds of recrystallised calcareous to quartzitic sand. Thin shale bands and many stylolites, occur, as do large "concretions", made up of intergrown microcrystalline quartz, chalcedony and dolomite. Algal stromatolites exist at the base of the sequence drilled.

RESULTS AND DISCUSSION OF THE GEOLOGICAL SEQUENCE

Results

The primary objective of the drilling project, to identify the high speed seismic refractor in the area, was successfully achieved on the intersection of a dense, hard dolomite sequence at a depth of 2046ft. A well velocity survey carried out in the well (Appendix F) showed this material to have an interval velocity of 18,000ft. per sec. Assuming that the interval velocity of a formation is nine tenths the refraction velocity, this value compares very favourably with an observed high speed refraction velocity of 21,000ft. per sec. for the area (Milton, 1970 and 1971). There can, therefore, be no doubt that the high speed refractor originates from this dolomite sequence.

Palaeozoic

(a) Unit 3?

Palynological study of core samples from Unit 3 yielded no fossils, and the age must therefore be in doubt. However, the dolomite sequence at Cootanoorina No. 1 was tentatively dated by Harris and McGowran (1967) as Middle to Upper Devonian. A comparison of these two dolomite sequences shows that they both consist mainly of hard, massive, dense, fine grained, pale grey dolomite. However, in both sequences there are distinct sections of thinly interbedded fine grained carbonate (magnesite at Cootanoorina, dolomite at Mt. Willoughby) with coarser, graded bedded detrital material (although the amount of detrital quartz is greater at Cootanoorina). In each case the laminae have been disturbed by current and load structures. Also, both contain a similar suite of accessory minerals, namely, feldspar, muscovite, biotite, tourmaline

and opaques. Partly filled vugs occur in each sequence, providing appreciable secondary porosity in the case of Cootanoorina, while one section at Mt. Willoughby contains fairly extensive small sub-horizontal tunnels. However, large microcrystalline quartz concretions occur in Mt. Willoughby No. 1, but not in the section drilled at Cootanoorina No. 1. Nevertheless, considering the identification of ?Devonian sediments in Munyarai No. 1 (Continental Oil Co., 1969), 135 miles west of Mt. Willoughby No. 1, it seems reasonable at this time to consider the three sequences to be part of the same formation (Wopfner, pers. comm.). A Devonian age is therefore tentatively placed on the sequence intersected at Mt. Willoughby No. 1.

One major difference between the dolomite sequences encountered at Cootanoorina No. 1 and Mt. Willoughby No. 1 is that anhydrite is present in the former but not in the latter. However, the presence of magnesite with the anhydrite is thought to satisfactorily compensate in that, under slightly different environmental conditions (possibly higher salinity) a greater proportion of the magnesium ions available could have been taken out of the interstitial water to form magnesite. This would decrease the Mg/Ca ratio and allow for the crystallisation of anhydrite.

This hypothesis in no way contradicts Allchurch and Wopfner's statement that the dolomite at Cootanoorina No. 1 was formed in an evaporitic environment, due to the action of hypersaline brines. Hypersaline brines are formed either by "capillary concentration" or by "refluxion" (Chilingar et al., 1967, p.267). By inference, Allchurch and Wopfner suggested that the dolomites were formed by the latter process, whereby evaporation increases the concentration and density of the water in a restricted lagoon or intermontane basin. However, it is considered that "capillary

concentration", which is the process where interstitial waters in the sediments transpire upwards through porous sea-marginal sediments and evaporate at the sediment-air interface, more satisfactorily explains some of the facts.

The algal stromatolites identified from the base of Core No. 6 (2087-2098.8ft.) at Mt. Willoughby No. 1 are suspected to be of the SH-V type (from the classification of Logan et al. 1964). Logan et al. maintain that stromatolites are shallow water features and that this type of stromatolite in particular is a powerful environmental indicator of exposed intertidal conditions. However, Playford and Cockbain (1969) claim to have discovered Devonian stromatolites that grew at depths as great as 45 metres below sea level, although this is strongly disputed by Logan. If Playford and Cockbain are correct, the stromatolites from Mt. Willoughby No. 1 may not be intertidal. However, since they were discussing algae from a reef complex it is considered that their evidence is probably not relevant to the Mt. Willoughby No. 1 dolomite sequence, and therefore an intertidal environment is hypothesised.

"Capillary concentration", which leads to dolomite formation in supratidal or intertidal environments on broad shallow shelves. (Chilingar et al. 1967), is therefore thought to have been active during part of the period of dolomite formation. This method leads to interfingering with the dolomite of gypsum and/or anhydrite (landward) and marine carbonates (seaward). With respect to the Cootanoorina and Mt. Willoughby wells, the presence or absence of evaporite minerals and the differing amounts of clastics in the sediments could be related to the respective proximity to the shoreline.

However, it would seem difficult to explain the presence of load structures, graded bedding and layering within the dolomite by this method. Therefore it is considered most probable that both processes were involved, depending on the water depth at any one time, with capillary concentration occurring along the shore line and refluxion in the deeper parts of the basin.

The presence of large ovoid concretions in the dolomite at Mt. Willoughby No. 1, however, still needs explaining. Made up of microcrystalline dolomite microcrystalline quartz and chalcedony, they are up to 6 x 4 cms. across and may have been derived from chert nodules (Plate 1). However, some of them look as if they may be large pebbles. One in particular (at 2091.0ft., see Appendix D) has a core of pure dolomite, which is completely rimmed by pure quartz, and has a sharp boundary with the enclosing dolomicrite. This sediment shows bedding planes curved around the pebble. Other concretions however must have developed within the sediment, especially the irregularly shaped one at 2088.7ft., which probably grey within the dolomicrite and was subsequently disrupted by dolomitic sand (Plates 1 & 2). This sand must have been either deposited as dolomite or else been recrystallised. There is a third type, which may have been introduced as a pebble but must then have undergone some recrystallisation. The concretion at 2091.9ft., shows this, where thin quartz bands seem to cut both the concretion and the sediment. If the quartz used to be part of a pebble, similar to that at 2091.0ft., then it has undergone diagenetic remobilisation. Further diagenetic stages that occurred in the dolomite were the development of fine calcite bands and the growth of large euhedral dolomite grains, the latter sometimes at the expense of quartz.

The crystallisation/recrystallisation processes that have occurred in the dolomite are, therefore, complex. In summary, it is considered that while the majority of the dolomite was formed syngenetically, at least some must have been formed in a final diagenetic phase.

Comparison of the Mt. Willoughby and Cootanoorina dolomites shows important differences in both the specific gravities and refraction velocities, although in the case of Cootanoorina No.1 the refraction velocity is probably too low because it was extrapolated from that observed over the Mt. Toondina piercement structure, four miles to the north. These values are 2.77 gm./cc. and 21,000 ft./sec. respectively for Mt. Willoughby No. 1 and 2.69 gm./cc. and ? 17,500 ft./sec. for Cootanoorina No. 1.

There are two basic types of rocks underlying the Permian Boorthanna Trough. The southern and central portion of the Trough contains Permian sediments overlying crystalline basement, whilst in the northern part the Permian sequence overlies dolomites. Notwithstanding the differences noted in the previous paragraph, the identification of a similar dolomite sequence at Mt. Willoughby No. 1 to that at Cootanoorina No. 1 strongly supports the continuation of a pre-Permain, dolomite filled, trough in an arc northwestwards and then southwestwards around the north of the central platform area. Recent seismic work in the area between Mt. Willoughby and Cootanoorina wells (Pexa, 1970) seems to agree with this idea in that the dolomite reflector ("D" seismic horizon) is shown to be continuous between them. The Wintinna Gravity High northwest of the central platform area may be a part of the same trough, although drilling will be necessary to prove this theory, and it seems likely that the ?Devonian dolomites in the Officer Basin are also related (Wopfner pers.comm.).

(b) Discussion of Permian Formation Boundaries

In describing the sequence of Cootanoorina No. 1., Allchurch and Wopfner (1967) set up the informal division of the Permian into three units, namely Mt. Toondina Beds, Unit 1 and Unit 2, to a large degree on the basis of electric and radioactive logs. Since then, correlation with the Cootanoorina No. 1 logs has played a major part in the picking of formation boundaries for wells subsequently drilled in the Arckaringa Basin. However, the logs from Mt. Willoughby No. 1 have proved to be not nearly so satisfactory for defining the boundaries as in the wells drilled in the southern part of the basin; for example there is no large change in resistivity at the base of the Mt. Toondina Beds, as identified on other criteria (Appendix G). On the other hand, the palynological and lithological evidence outlined in Appendix G has proved invaluable in determining the bases of the Algebuckina Sandstone and the Mt. Toondina Beds.

(c) Unit 2

The thickness of Unit 2 at Mt. Willoughby No. 1 (1086ft.) is greater than has been intersected by the drill before. The palynological bio-stratigraphic Stage 3/Stage 2 boundary occurs at the top of Unit 2 (Appendix G, McGowran and Harris, 1971), whereas it occurs in Cootanoorina No. 1 about 400ft. below the top of Unit 1. This indicates that the Mt. Toondina Beds sedimentation commenced earlier in the northern part of the basin than at Cootanoorina No. 1, at the time when Unit 1 sediments were still being deposited. In other words, the base of the Mt. Toondina Beds is allochronous (McGowran, 1969, Harris and McGowran, 1971).

The dominant lithology throughout Unit 2 is a calcareous clay or argillaceous limestone with varying amounts of quartz and lithic grains interspersed through it, forming a diamictite sequence. Lithic grains include those derived from gneiss, schist, feldspathic sandstone and limestone. Within this sequence are pebbles of various lithologies. Those identified in Core No. 3 are of red siltstone and limestone. However, the pebbles within the basal part of the sequence consist solely of dolomite that has been derived from Unit 3. This is a clear indication of uplift of the dolomite sequence prior to, and erosion of nearby uplifted dolomites during, the depositional phase of Unit 2, and supports palaeontological evidence for an unconformity between Unit 3 and Unit 2 at Cootanoorina No. 1 (Harris and McGowran, 1967).

Although Unit 2 contains a number of minor subunits (as described in Stratigraphy) there is only one major lithological change through the section, at 1720ft. Both logs and lithology indicate a radical difference above and below this point. The upper section is made up of mainly pale grey clays with up to 15% clastic grains in it, while the lower section, below a very hard calcareous sandstone horizon, consists predominantly of chocolate brown clays with 35% clastics. X-ray analysis of the -2 micron fraction has not satisfactorily shown any difference between the two clay types. However a rather more aerobic environment for the lower portion might explain the difference in colour, with ferric iron being enclosed in the clays, rather than ferrous.

Interspresed within the diamictite sequence are bands of calcareous and argillaceous sandstone. The general depositional environment for the sequence is therefore considered to be one in which mudflows have transported glacial debris down the basin slope

(Wopfner, 1970), with the occasional deposition of cleaner sand bands, possibly by turbidity flow. Turbidity flow is not contradicted by the observation that, although sorting within the sandstones is poor overall, individual beds show fairly good sorting. The huge volume of calcite within the matrix must have been precipitated from sea water. Pyrite is common, especially as a cement within the cleaner sandstones, and its presence points to an anaerobic depositional environment if it is not all diagenetic. It is rare below 1745 ft. (the chocolate clay subunit).

A certain amount of diagenetic recrystallisation has, however, occurred. For example, in Core No. 3 minor amounts of recrystallised calcite were observed. Also, it is considered that the dolomite matrix in Core No. 4, at the base of Unit 2, was derived from remobilised Unit 3 dolomite.

(d) Unit 1

Unit 1, as defined by Allchurch and Wopfner (1967) is a predominantly shale sequence. Microfloras recovered from Core No. 3 (1080-1087ft.) in Mt. Willoughby No. 1 are referable to palynological Stage 2, which is found typically in Unit 2 and the lower part of Unit 1. However, both the radioactive logs and the observed lithology of the section between the base of the Mt. Toondina Beds and Core No. 3 indicate a far more arenaceous sequence than observed for Unit 1 at Cootanoorina No. 1. Unit 1 is therefore considered to be absent from the sequence intersected at Mt. Willoughby No. 1 for this reason and those stated in the previous section. It is believed that the quiet water marine environment envisaged for Unit 1 formation never developed in this part of the basin.

(e) Mount Toondina Beds

The fairly well sorted clayey sands and sandstones encountered do nothing to contradict the terrestrial origin for the Mt. Toondina Beds suggested by Wopfner (1970). In fact palynobiofacies evidence (Appendix G) demonstrates the change in environment at the onset of Mount Toondina Beds sedimentation. The predominantly fine grained, well polished nature and high sphericity of the quartz grains seems to point to a quiet water (lacustrine?) deposition environment, fed by fluviatile sands. Micas, both brown and white, are common, and were seen to delineate small scale cross-beds in Core No. 2. Pyrite bands are also very common throughout the sequence. However, periodical influxes of coarser material occurred, as exemplified by the large pebble of highly pyritic sandstone in Core No. 2.

A distinct change in the gamma-ray and neutron logs occurs at 790 ft. This may be due to variations within, and/or the amount of, the clay matrix, which is calcareous through most of the portion below this depth, but not above it. The overall clastic grain size is smaller in the lower section, and so a rather lower energy environment is suggested.

The top of Mt. Toondina Beds in the Arckaringa Basin to the south is marked by coal beds. The lack of coal at Mt. Willoughby can be explained by either a lack of deposition or an erosional hiatus. The latter alternative is preferred since erosion occurred throughout much of the western Great Artesian Basin prior to deposition of the Mesozoic sediments (Harris pers. comm.).

Mesozoic

Both the Algebuckina Sandstone and the Cadna-Owie Formation consist of a clay rich, unconsolidated, coarse quartz sand, much of which is of granule size. Minor bands of pyrite occur within the sands, and the depositional environment for the two is thought to be terrestrial, probably fluviatile.

Black, slightly silty shale occurs near the top of the Cadna-Owie Formation. This may indicate the start of the marine transgression that preceded the deposition of the marine Bulldog Shale.

The Bulldog Shale is primarily a blue-black, slightly silty claystone. However, an interesting glauconitic, greensand horizon occurs at 165-195ft. Although unlikely, it was thought possible that this was the Coorikiana Member of the Oodnadatta Formation, which elsewhere overlies the Bulldog Formation. However, palynological work (Appendix G, McGowran and Harris, 1971) carried out on Core No. 1 just below this horizon, has shown that the core comes from low in the Bulldog Shale. This shows that the glauconitic horizon cannot be the Coorikiana Member.

LAMBINA NO. 1 RECONSIDERED

The lithology and gamma-ray/neutron logs are similar in Mt. Willoughby No. 1 and Lambina No. 1 (10 miles to the north), especially in the Mesozoic section. In particular, the dolomitic sandstone horizon at the top of the Cadna-Owie Formation, and the gamma-ray boundary between Cadna-Owie and Algebuckina, are virtually identical.

However, in the light of stratigraphic and palaeontological studies of the section in Mt. Willoughby No. 1, it was felt (see Appendix G) that the Permian stratigraphy of Lambina No. 1, previously interpreted in the well completion report by Thornton (1970), needed reconsideration. In that report the base of the Mt. Toondina Beds was placed at a depth of 1425ft. The sequence from 1050ft. - T.D. in Lambina No. 1 is similar to that encountered at Mt. Willoughby No. 1 below 960ft. Core No. 3 (1444-1457 ft.) at Lambina No. 1, especially is, in part, similar to Core No. 3 (1080-1087ft.) at Mt. Willoughby No. 1.

McGowran and Harris (Appendix G) carried out a study of the Lambina No. 1 cuttings over the interval 900-1000ft., the interval having been selected by comparing the well logs with the interpreted profiles in Mt. Willoughby No. 1. Their results do not contradict lithological and well log evidence that the Mount Toondina Beds and Unit 1 or Unit 2 interfinger at the contact. The contact is at either 936ft. or 990ft., marked, in each case, by large increases downwards of the gamma-ray count. A repetition is therefore suggested with Unit 1/2 sediments from 936-955ft., Mt. Toondina Beds from 955-990ft. and Unit 1/2 below 990ft. (see fig.3).

If the above interpretation is correct, it is strong evidence to show that the two formations are not disconformable, at least in this portion of the basin, and this evidence is pertinent to the suggestion that the base of the Mount Toondina Beds is significantly allochronous, as has already been discussed.

However, it would seem virtually impossible for glacigene Unit 2 to interfinger with warm, terrestrial Mount Toondina Beds without invoking a topography for the landmass of the magnitude of the New Zealand Alps, for which there is no evidence (Wopfner, pers. comm.). It is therefore considered that a near shore facies of marine to marginal marine Unit 1 must be present at Lambina No. 1 (although not at Mt. Willoughby No. 1). This unit has not been picked from the cuttings, but an investigation of the gamma-ray/neutron logs suggests that the Unit2/Unit 1 boundary could be at either 1120ft. or 1180ft., probably the latter.

Depth-Temperature curves for Mt. Willoughby No. 1 and Lambina No. 1 are shown on fig. 4. The temperature differences between the two curves may be due to the fact that different logging units were used.

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APPENDIX A

RECONSTRUCTED LITHOLOGIES

RECONSTRUCTED LITHOLOGIES

Bulldog Shale (Aptian to Albian)

Depth Interval: 0 - 330 feet Thickness: 330 feet

0 - 20 ft: INDURATED CLAYSTONE, white, yellow, pale grey, usually hard and sometimes iron (red) stained. There are very minor occurrences of dendritic manganese on the claystone.
SILCRETE blocks, white, yellow, very hard. Some consist of fine grained silcrete conglomerate.

20 - 87ft: CLAYSTONE, yellow, pale grey, soft, usually silty (the amount of silt ranges from 0 - 50%, usually 10 - 20%). Silt grains are colourless. Contains brown-red, hard haematite fragments.

87 - 165ft: CLAYSTONE, blue-black, fairly soft, usually silty (the amount of silt ranges from 0 - 35%, usually 15 - 20%), very slightly micromicaceous. Occasional very thin stringers of colourless siltstone occur in the claystone.

165 - 195ft: GREENSAND, glauconitic, silty to very fine grained, clay rich, micaceous. Glauconite grains are olive-green, quartz colourless, clay blue-black, but the dominant colour is green. Glauconite is up to 50%, quartz 20%, clay 30% but usually rather less glauconite and more clay, i.e., gradational from greensand to claystone. Grain size of glauconite is about 0.05 mm. White mica constitutes about 1.5% of the rock, which is slightly harder than the claystone above.

195 - 330ft: CLAYSTONE, blue-black, fairly soft, generally not very silty, but with occasional lenses of siltstone in it. Slightly glauconitic. PYRITE is a fairly common accessory. Near the base a few hard bars of very fine to fine grained SANDSTONE occur, cemented in a pale green calcareous clayey matrix. The base of the succession is marked by a soft, green, slightly silty clay.

Cadna-Owie Formation (Neocomian to Aptian)

Depth Interval: 330 - 474ft. Thickness: 144ft.

330 - 354ft: SANDSTONE, consisting of quartz grains set in a pale green, clayey, dolomitic matrix. Very hard. The grains are colourless and vary in grain size from very fine to very coarse grained; mainly subangular to subrounded, with the coarser fraction tending to be well rounded. A few pebbles exceed 2 mm. in diameter.

354 - 474ft: SAND comprising loose and unconsolidated quartz grains, colourless to translucent pale blue, predominantly coarse to very coarse grained; a few rounded, mainly subangular. Some pebbles exceed 10 mm. diameter, while quite a few bands of quartz occur with an average grain size greater than 2.5 mm. The unconsolidated quartz grains are either interbedded with or set in a white to pale pink clay matrix, which is soft when wet. The clay matrix itself contains about 50% quartz grains, fine to coarse grained, subangular to subrounded. It is possible that the clay matrix encloses all the quartz grains, but has been preferentially washed from the coarser fraction prior to examination. Sorting of the quartz grains within the clay matrix is poor overall, but probably individually well sorted bands occur of either fine or coarse grained material. The matrix contains a very little pyrite and a few lithic grains. Minor bands of black, slightly silty, fissile SHALE occur.

Algebuckina Sandstone (Upper Jurassic)

Depth Interval: 474 - 655 ft. Thickness: 181 ft.

474 - 495ft: CLAYEY SAND comprising unconsolidated quartz grains, predominantly fine grained, fairly well rounded, in a pinkish-white clay matrix which is soft when wet. The proportion of quartz to clay is about 50:50, with possibly slightly more clay.

495 - 655ft: SAND, made up of loose, unconsolidated quartz grains, colourless, milky white and yellow. The grains are very poorly sorted, fine to very coarse grained (many of them exceeding 2 mm. diam.) and are subangular to well rounded, predominantly subrounded. Sphericity is generally high. Some have a very high sphericity and are extremely well rounded. Most grains are fairly well polished, while some of them are made up of aggregates of fine to medium grained quartz. The quartz grains are set in a pinkish-creamy white clay matrix, which is very soft when wet. PYRITE occurs in a few thin bands. Usually the pyrite is a matrix cementing the quartz grains together, but it also occurs in balls cementing grains.

Mount Toodina Beds (Artinskian)

Depth Interval: 655 - 960ft. Thickness: 305ft.

655 - 790ft: CLAYEY SAND, comprising quartz grains set in a soft pale grey, clay matrix, which is sticky when wet. The ratio of quartz to clay is about 50:50. The quartz grains are mainly colourless, medium to very fine grained. There is a gradual decrease in grain size downwards from medium grained at 655 feet to very fine grained, at 790 feet, so at any one

point sorting is good. Most of the grains are well rounded, have a high sphericity and are polished. PYRITE is a very common accessory, occurring in bands cementing quartz grains together.

790 - 960ft: CLAYEY SAND, consisting of quartz grains set in a pale grey, soft clay which is generally calcareous (ranging from not calcareous to highly so) and micaceous, both brown (biotite?) and white (muscovite?). The ratio of quartz to clay is about 50:50, the quartz grains are colourless, generally very fine to fine grained, although sometimes medium grained and occasionally coarser. They are mostly well rounded and polished, with a high sphericity. A few CLAYEY CALCAREOUS SANDSTONE bands occur. They are made up of the same material as above, but the clay matrix has been cemented by calcite to form hard bands. The colour varies from slightly whiter than above to a pale greenish tinge. PYRITE is very common, forming hard bands.

Unit 2 (Lower Permian)

Depth Interval: 960 - 2046ft. Thickness: 1086ft.

960 - 1154ft: SANDY CLAY comprising 5 - 35% quartz grains set in a green-grey highly calcareous clay matrix, which is very soft when wet, hard when dry. A few bands in the bottom 50 feet are indurated, thus SANDY CLAYSTONE. The quartz grains are mainly colourless, generally poorly sorted, silt to medium grained, but mainly fine grained. They are usually well rounded and have a high sphericity. A few lithic and red quartz pebbles occur, together with very minor pyrite. A few CLAYEY SANDSTONE bands occur with up to 75% quartz grains, cemented by a hard, highly calcareous green-grey (slightly paler than above) clay matrix. The quartz grains are fine to coarse grained, mainly medium grained, generally well rounded, high sphericity, polished.

1154 - 1279ft: SANDY CLAY and CLAYSTONE as above except that there are usually 5% or less quartz grains which are silt to coarse grained, but dominantly very fine to fine grained and well rounded.

1279 - 1524ft: SANDY CLAY and CLAYSTONE as above, except that there are 15 - 25% colourless quartz grains, equally well rounded and poorly sorted as above, although mainly fine to medium grained. Some of the grains are polished while others are frosted.
Bands of hard CLAYEY to CALCAREOUS SANDSTONE occur, consisting of 60 - 70% quartz grains, colourless, fine to medium grained, well rounded. Some are polished, others frosted. There are a few bands of siltstone rather than sandstone. There is a gradation between

a matrix of calcareous clay to one of almost pure calcite (when the grain size of the quartz is slightly greater). The latter predominates. PYRITE is a very common accessory as cement in the calcareous sandstone. A few very thin bands of hard, green LIMESTONE occur.

1524 - 1720ft: SANDY CLAY as above, except that there are only 5 - 15% quartz grains, which are predominantly very fine to fine grained. At the base a few indurated claystone bands occur, as do colourless quartz pebbles, boulders, and pyrite.

1720 - 1748ft: CALCAREOUS to CLAYEY SANDSTONE, colourless to pale grey, very hard, consisting of quartz grains, dominantly colourless, a few red; well rounded, usually polished, some frosted. The sandstone is normally well sorted, occurring as bands of either very fine to fine grained or medium grained material. Either range of grain size can have as a matrix almost pure calcite (containing about 75 - 80% quartz) or else up to 40% calcareous clay. PYRITE occurs both as a cement in the sandstone and as bands of practically pure pyrite.

1748 - 2046ft: SANDY CLAY made up of 35% quartz grains set in a chocolate brown, highly calcareous clay, which is soft when wet. The quqrtz grains are mainly colourless, a few red. They are well rounded, with high sphericity; mostly frosted, some polished. The overall sorting is poor: very fine to coarse grained, but as a rule bands of either fine or coarse occur. Near the base much of the clay is indurated to form CLAYSTONE. Bands of SHALE occur, green-grey to dark grey to blue-green, fairly soft, calcareous micromicaceous, carbonaceous?, containing upwards of 5% quartz grains (usually less than 1%), which are rounded, silt-medium grained. The blue-green shale tends to be slightly harder and more fissile than the others.
Near the base, thin bands of LIMESTONE occur, that are dark grey, crystalline, very hard, containing a few well rounded, medium to coarse quartz grains. Throughout the section, PEBBLES of quartz, dolomite and lithics occur. The number increases with depth, especially in the case of dolomite pebbles, to the extent of sometimes making up 20 - 25% of the rock.

Unit 3? (Devonian?)

Depth Interval: 2046 - 2098.8ft. Thickness: 52.8ft.

2046 - 2098.8ft: DOLOMITE. At the top of the sequence it occurs in two horizontally interbedded phases, pale grey, fine to medium, crystalline dolomite and dark green-grey dolomicrite, forming thin laminae. SHALE and DOLOMITIC SANDSTONE occur in very minor amount. However, with depth, the dolomite becomes more uniform and consists

almost entirely of finely crystalline, anhedral granular dolomite. Large (2 X 4 cm.) "concretions" occur, made up of an intergrowth of microcrystalline quartz, chalcedony and dolomite. Algal stromatolites exist at the base of the sequence drilled.

APPENDIX B

DITCH SAMPLE DESCRIPTIONS

DEPTH	% CONSTITUENTS	DESCRIPTION
Surface-11ft.	40% Silcrete	White, yellow, very hard - some f.gr. silcrete conglomerate.
	60% Indurated Claystone	Pale grey, white-yellow, (partly silicified) sometimes stained red, other times speckled red, yellow, red and yellow: a few cuttings grey and speckled. Claystone usually hard, but some fairly soft.
	Trace	Quartz grains colourless very large, well rounded. Dendritic manganese (?) on the claystone.
11-20ft.	60% Claystone	Approximately 60% pale grey 40% yellow. Still indurated and partly silicified. Yellow due to iron staining and in many cases tends to be hardened by the Fe.A v. little red staining.
	10% Silcrete	A.A.
	30% Siltstone	Pale grey, some pale yellow clayey, tends not to be so hard as the claystone - Quartz grains mostly colourless in clay matrix. Some hardened yellow, Fe impregnated, bits.
20-30ft.	90% Claystone	Silty - yellow. Silt makes up 30-35% of the rock. Soft usually - slightly micromicaceous. Some hardly silty at all.
	5% Claystone	Silty pale greenish grey.

N.B. In both the claystones silt is colourless.

	5% Others	Pale grey claystone (not silty) harder than other claystone (indurated). Bright red haematite stained fragments. Silcrete chips.

DEPTH	% CONSTITUENTS	DESCRIPTION
30-40ft.	65% Claystone	Pale grey. Majority not silty, but a little is generally soft-medium hard, but some very soft, others hard.
	35% Claystone	Yellow. Majority silty A.A., others not silty; same range of hardness as pale grey claystone.
	Trace	Silcrete chips, red (haematite stained).
40-50ft.	90% Claystone	Pale grey, fairly soft. Majority not silty, but % silt varies from 0 to (in a few cases) 30%.
	10% Claystone	Yellow, slightly silty usually, medium soft.
	Trace	Hard brown haematite fragments.
N.B. Bad loss of circulation zone 44-47ft. Added bran to cure the problem.		
50-60ft.	75% Claystone	Pale grey, fairly soft; a very little is slightly silty.
	25% Claystone	Yellow, sometimes slightly silty, usually fairly soft, a little is hard.
	Trace	Purple claystone (Fe), hard brown haematite fragments; red haematite stained gibber conglomerate fragments (matrix red).
60-70ft.	85% Claystone	Yellow, usually slightly silty, fairly soft.
	10% Claystone	Pale grey, occassionally slightly silty, fairly soft.
	5% Claystone	Brown-red haematite stained claystone (sometimes silty), varies from hard to fairly soft.
70-80ft.	70% Claystone	Pale grey, silt ranges from 0% to >50%, i.e. clayey siltstone, but most are slightly silty; silt grains colourless.

DEPTH	% CONSTITUENTS	DESCRIPTION
	30% Claystone	Yellow, silt varies from 0% to about 20%.
	Trace	Red haematite fragments.
N.B. At 75ft: 6" Loss of circulation zone.		
80-90ft.	40% Claystone	Yellow, A.A.
	30% Claystone	Pale grey, A.A.
	30% Claystone	Blue-black to dark grey, silty, microcarbonaceous flecks in it. Fairly soft.
N.B. The change over to blue-black claystone is between 85-90ft. Yellow and pale gray are weathered products of blue-black claystone.		
90-100ft.	90% Claystone	Blue-black, silty, fine carb. flecks. Silt can be up to 30%, but mostly slightly silty; fairly soft.
	10% Claystone	Yellow and pale grey A.A. (probably cavings).
100-110ft.	95% Claystone	Blue-black mostly not silty (or only very slightly) but can range up to about 30%. Slightly carbonaceous. Fairly soft.
	5% Claystone	Yellow, A.A. (probably cavings).
110-120ft.	100% Claystone	Blue-black, silty, mostly 15-20%, some up to about 35%. Small flecks of carbonaceous material, up to about 5%. Very slightly micromicaceous. Fairly soft; occasional v. fine stringers of siltstone, colourless, in the claystone.
N.B. Carbonaceous flecks identified may in fact be glauconite.		
120-130ft.	100% Claystone	Blue-black, A.A.
130-140ft.	100% Claystone	A.A., except some is very silty (possibly up to 50%) and a few f.gr. quartz grains can be seen. Also more carbonaceous-micaceous. Flecks are slightly larger than above.

DEPTH	% CONSTITUENTS	DESCRIPTION
140-145ft.	100% Claystone	A.A.
N.B. Surface casing set to 145ft.		
145-150ft.	100% Claystone	A.A.
150-160ft.	100% Claystone	A.A.
160-170ft.	80% Greensand	Glauconitic, silty = v.f.gr. quartz, very clay rich; glauconite is olive green, quartz is colourless, clay is blue-black, but dominant colour is green. Micaceous. Glauconite up to about 50%, quartz 20%, clay 30%, but usually rather less glauconite and more clay; i.e. gradational from claystone to greensand. Mica (white) occurs in larger flecks in the greensand than the claystone. Glauconite grains about 0.05mm. Mica makes up about 1-2% of the rock. Slightly harder than claystone.
	20% Claystone	Blue-green-black, silty, micromicaceous, fairly soft, slightly glauconitic.
170-180ft.	100% Greensand	A.A.
180-190ft.	100% Greensand	A.A. except mica fraction in a few cases is up to 5%.
190-200ft.	95% Claystone	Blue-green-black, slightly silty, v. slightly micaceous and glauconitic. Fairly soft.
	5% Greensand	A.A.
200-210ft.	95% Claystone	A.A.
	5% Greensand	A.A.
CORE NO. 1: 203.5-213ft. 100% Recovery.		
210-220ft.	100% Claystone	A.A. except on the whole slightly more silty and very slightly more glauconitic.

DEPTH	% CONSTITUENTS	DESCRIPTION
220-230ft.	100% Claystone	A.A.; a few examples of quite highly silty lenses in the claystone.
	Trace	Pyrite in highly silty and somewhat glauconitic claystone.
230-240ft.	100% Claystone	A.A., except on the whole much softer. Also a few f.gr. quartz grains and larger glauconite grains.
240-250ft.	100% Claystone	A.A., on the whole only slightly silty; a little very soft, but most medium hard.
250-260ft.	100% Claystone	A.A.
260-270ft.	100% Claystone	A.A. Glauconite is very minor.
	Trace	Quartz grain, colourless, medium rounded, 3.5mm. across.
270-280ft.	100% Claystone	A.A. Minor small lenses of glauconitic, silty claystone, but mostly not very silty.
	Trace	Pyrite in claystone.
280-290ft.	100% Claystone	A.A. Practically all only slightly silty.
290-300ft.	90% Claystone	A.A.
	10% Sandstone	In a clayey calcareous or dolomitic (gives of CO_2 in warm Dil. HCl only), pale green matrix, v.f.-f.gr. quartz grains (colourless). Usually very hard, a few soft. Occurs as hard bars within the claystone. Ratio of quartz-matrix 60-40: 40-60.
300-310ft.	95% Claystone	A.A. But occurring in a green clay matrix, making the rock much softer. Matrix predominates; cuttings form balls of clay.

DEPTH	% CONSTITUENTS	DESCRIPTION
	5% Sandstone	A.A.
	Trace	Pyrite in claystone.
310-320ft.	75% Clay	Green, very slightly silty.
	25% Claystone	A.A.
320-330ft.	80% Clay	Green, very slightly silty and carbonaceous.
	20% Sandstone	In pale green clayey calc. dolomitic (?) matrix. Quartz grains vary from v.f.gr. to v.c.. V.f.gr. type gives a speckled appearance of white grains in the pale green matrix. The coarse to v. coarse type is colourless, subangular-subr. In all cases very hard, forming bands in the clay.
330-340ft.	90% Sandstone	A.A. Pale-green-brown, dolomitic clayey matrix (strong effervescence in hot dil HCl). Quartz grains colourless, subang-subr. The coarser fraction tends to be well-rounded. Very hard. Slightly micaceous.
	5% Quartz Grains	Colourless - translucent blue, very coarse - 2 mm. across on average; sub-rounded well polished.
	5% Claystone	A.A.
340-350ft.	85% Sandstone	A.A. except now about half consists of v.c.gr. quartz grains in dolomitic clayey matrix, some of them up to 2mm. in size. Mainly subang.-subr., even some of the coarse ones are subang.
	10% Quartz Grains	A.A. Many of them over 2mm.
	5% Claystone	A.A.
	Trace	Lithic pebble, green-brown, containing a few small quartz grains, very well rounded.

DEPTH	% CONSTITUENTS	DESCRIPTION
350-360ft.	85% Quartz Grains	Unconsolidated, colourless to milky to opaque yellow, very coarse, ranging from 0.2 to over 0.5cm., sub-angular to well rounded, not dependent on size; fairly well polished.
	10% Sandstone	A.A.
	5% Clayey Sand	Quartz grains, colourless, f.c.gr. subang-subr. in pale grey very soft. clay (approx. 50% quartz, 50% clay). Possibly all quartz grains in this matrix but it washes away very easily.
N.B. Difference between sandstone and clayey sand may just be hardness (i.e. presence of dolomitic cement).		
360-370ft.	40% Quartz Grains	A.A.
	40% Clayey Sand	A.A.
	10% Sandstone	A.A.
	10% Shale	Black, slightly silty, occurs in large flakes.
	Trace	Pyrite.
370-380ft.	45% Clayey Sand	A.A.
	40% Quartz Grains	A.A.
	10% Shale	A.A.
	5% Sandstone	A.A.
	Trace	Pyrite.
380-390ft.	80% Quartz Grains	A.A.
	10% Clayey Sand	A.A.
	5% Sandstone	A.A.
	5% Shale	A.A. except not silty.
390-400ft.	80% Quartz Grains	A.A., except mostly sub-angular, even the coarsest.
	15% Clayey Sand	A.A.

DEPTH	% CONSTITUENTS	DESCRIPTION
	5% (Sandstone (Shale (Lithic Pebbles	A.A. (probably cavings). A.A. Very well rounded 2mm., across brownish colour. Also some broken bits of pink quartz that look like pegmatite veins.
400-410ft.	90% Quartz Grains	A.A. Some up to 1cm. across and subang.
	10% Clayey Sand	A.A., but the clay looks pinkish-white.
	Trace	Sandstone A.A. (probably cavings)
410-420ft.	90% Quartz Grains	A.A., except extremely coarse, practically all over 0.25cm., a few pebbles over 1 cm. Only a few well rounded, generally subangular.
	10% Clayey Sand	A.A.
	Trace	Sandstone A.A. (probably cavings) pink quartz grains made up of fine quartz grains cemented together.
420-430ft.	85% Quartz Grains	A.A., one about 2.5cm. across.
	10% Clayey Sand	A.A. except that much of the quartz in the whitish clay matrix is f.-v.f.gr. although coarse gr. quartz is still included.
	5% Sandstone	A.A. (probably cavings)
430-440ft.	90% Quartz Grains	A.A., but not quite so coarse.
	10% Clayey Sand	Quartz varies from fine-coarse.
	Trace	Sandstone A.A. (probably cavings); Lithic pebbles, well rounded, brown colour.
440-450ft.	95% Quartz Grains	A.A.
	5% Clayey Sand	A.A.
450-460ft.	55% Clayey Sand	A.A. Grain size of quartz ranges from v.f.-c. but each "cutting" (which is very soft)

DEPTH	% CONSTITUENTS	DESCRIPTION
		usually contains either fine or coarse gr. quartz, so individually sorting is often quite good.
	40% Quartz Grains	A.A.
	5% Shale	Black, large flakes.
460-470ft.	100% Clayey Sand.	A.A. but quartz grains v.f.-f.gr. predominately, but a few larger grains, even up to v.c. On the whole fairly well rounded. Matrix is still very soft, pinkish-white colour. Proportion of quartz to clay is about 50:50, possibly slightly less quartz.
470-480ft.	100% Clayey Sand	A.A., except practically all the quartz is v.f.-f.gr. Only a very few c. grains.
	Trace	Mica (white) in the clay. Large black flakes of shale, slightly silty, medium hard.
480-490ft.	95% Clayey Sand	A.A., except sorting not quite so good; mostly v.f.-f.gr. quartz, but also quite a lot med.gr., as well as a few v.c.
	5% Shale	A.A.
490-500ft.	100% Clayey sand	A.A., except sorting v. poor. Grain size ranges from silt-v.c., with a lot of the coarser fraction. (Possibly due to bands of very coarse sand becoming mixed into the very soft clay during drilling). Much of the quartz is well over 2mm. and ranges up to pebbles of about 1cm. Mostly well polished, they range from subangular to rounded.
500-510ft.	80% Quartz Grains	Predominantly colourless, a few milky white. Mostly very coarse (many of them well over 2mm. diam.) some coarse, sphericity generally fairly high

DEPTH	% CONSTITUENTS	DESCRIPTION
		subang-well rounded, predominantly subrounded. A few very high sphericity and very well rounded. Some of the grains made up of aggregates of f.-m.gr. quartz. Fairly well polished.
	20% Clayey Sand	A.A., except practically all the grains are c. to v.c.
510-520ft.	95% Quartz Grains	A.A.
	5% Clayey Sand	A.A.
520-530ft.	85% Quartz Grains	A.A. except a few pale yellow grains, and quartz grains are slightly more rounded than above on the whole. No aggregate grains seen.
	15% Clayey Sand	A.A.- sorting v. poor grains f. - c.gr.
530-540ft.	50% Quartz Grains	A.A.
	50% Clayey Sand	A.A.
	Trace	Large, well rounded lithic pebble. Large fragment of pyrite.
5[illegible]-550ft.	100% Clayey Sand	Clay matrix, pinkish-creamy white in colour. Quartz grains very poorly sorted from silt-coarse gr., but predominantly silt-f.gr. Subang. to well rounded. A few pale yellow (f.gr.) grains. Ratio clay: quartz is about 50:50, possibly rather more clay.
	Trace	Pyrite chips.
550-560ft.	100% Clayey Sand	A.A., except better sorted. Silt-medium gr. size.
	Trace	Pyrite chips; coarse, well rounded quartz grains.

DEPTH	% CONSTITUENTS	DESCRIPTION
560-570ft.	100% Clayey Sand	A.A.
	Trace	A.A.
570-580ft.	80% Clayey Sand	A.A.
	10% Quartz Grains	A.A.
	10% Pyrite	Chips, usually cementing fine-medium gr. quartz grains together.
	Trace	Shale, black, large flakes (cavings?).
580-590ft.	50% Quartz Grains	A.A.
	40% Clayey Sand	A.A., except most of the quartz grains tend to be coarse to v.c., although still some fine grains.
	10% Shale	A.A. (cavings?).
590-600ft.	95% Clayey Sand	A.A. except v. poorly sorted. Quartz grains vary from silt to v.c. Predominantly medium-coarse.
	5% Pyrite	A.A.
	Trace	Shale A.A. (cavings?).

N.B. Proportion of clayey sand to quartz grains may partly be due to washing of the v. soft clay (naturally the coarsest fraction would separate out most easily).

600-610ft.	80% Clayey Sand	A.A.
	20% Quartz Grains	A.A.
610-620ft.	80% Clayey Sand	A.A.
	20% Quartz Grains	A.A.
	Trace	Pyrite chips
620-630ft.	80% Quartz Grains	A.A., predominantly v.c., but a few f.-m.gr. Mostly subround-round. Colourless white, pale yellow. Sphericity on the whole fairly high.

DEPTH	% CONSTITUENTS	DESCRIPTION
	20% Clayey Sand	A.A.
630-640ft.	50% Quartz Grains	A.A.
	50% Clayey Sand	A.A., except much coarser than above. Quartz grains vary from silt to v.c., mainly m.-c.gr., dominantly subang-subr., fairly well polished.
640-650ft.	80% Clayey Sand	A.A.
	15% Quartz Grains	A.A.
	5% Shale	Black, flaky (cavings?).
650-660ft.	100% Sandy Clay	Clay very soft, pale-grey-white, contains about 15% quartz grains, mainly colourless, generally fairly well rounded silt-m.gr. size.
	Trace	Small pyrite chips in the clay.

N.B. Clay in this sample seems to have a more sticky texture than above and is slightly more grey.

660-670ft.	95% Clayey Sand	Clay looks the same as at 650-660, but much more quartz. Approx. 60% quartz grains, mainly fine-med.gr., usually well rounded with fairly high sphericity and well polished.
	5% Pyrite	Occurring in balls (up to 2.5mm. in diam. and spherical) of med.gr. subangular to sub-rounded quartz grains cemented by pyrite.
670-680ft.	100% Clayey Sand	A.A.
	Trace	Pyrite in balls.
680-690ft.	100% Clayey Sand	A.A., except predominantly f.gr. Probably not quite so much quartz. Most of the grains well-rounded, high sphericity, well polished.

DEPTH	% CONSTITUENTS	DESCRIPTION
690-700ft.	100% Clayey Sand	A.A., except sorting not so good - mainly f.-m.gr., but also silt and quite a lot c-v.c. grains.
700-710ft.	100% Clayey Sand	A.A., except sorting again v.good - practically all f.-m.gr.
710-720ft.	100% Clayey Sand	A.A. ratio sand:clay is about 50:50.
720-730ft.	100% Clayey Sand	A.A.
730-740ft.	100% Clayey Sand	A.A. except a few c. grains.
740-750ft.	100% Clayey Sand	A.A.
	Trace	Pyrite.
750-760ft.	100% Clayey Sand	A.A. except well sorted, f.-m.gr.
	Trace	Small pyrite chips.
760-770ft.	100% Clayey Sand	A.A., now predominantly v.f.-f.gr.
	Trace	Small pyrite chips.
770-780ft.	100% Clayey Sand	A.A. except about 50:50 quartz: clay and grain size range is v.f.-m.gr. Clay is pale grey.
	Trace	Pyrite chips, both large and small.
780-790ft.	100% Clayey Sand	A.A.
	Trace	Pyrite chips, A.A.
790-800ft.	100% Clayey Sand	A.A., except sorting better, v.f.-f.gr. Quartz grains still dominantly well rounded, high sphericity and well polished.
800-810ft.	100% Clayey Sand	A.A., except finer grained - silt-f.gr.
	Trace	Small pyrite chips.

DEPTH	% CONSTITUENTS	DESCRIPTION
810-820ft.	100% Clayey Sand	A.A.
	Trace	Pyrite chips.
820-830ft.	100% Clayey Sand	A.A.
	Trace	Small-medium sized flakes of brown mica, presumably biotite, as grains in the clay, making up about 2% of the grains.
830-840ft.	100% Clayey Sand	A.A.
	Trace	Biotite A.A.
840-850ft.	100% Clayey Sand	A.A.
	Trace	Biotite A.A.; pyrite chips.
850-860ft.	60% Clayey Sand	A.A. except more clay than sand (about 60:40) so sandy clay. Also, the clay is slightly calcareous. contains biotite A.A.
	40% Clayey Sandstone	Very hard, like the clayey sand A.A., except that it has been cemented with calcite (possibly) Clay matrix tends to be whiter. Contains biotite A.A.
	Trace	Large black shale fragments slightly silty and carbonaceous (cavings?); pyrite chips. A few large, well-rounded quartz grains (colourless).
CORE NO. 2:	853-863.5ft. Recovered 0.5ft. (5%).	
860-870ft.	60% Sandy Clay	A.A., except v.calc. and sorting not so good, ranging from silt-m.gr. Also ratio clay: sand is again about 50: 50 (possibly a little more clay).
	40% Clayey Sandstone	A.A. Seems to have a greenish tinge overall. Only gives off a little CO_2 in cold dil. HCl, but effervesces strongly in hot (possibly due to clay blocking calcite, or else dolomitic).

N.B. There is a gradation in hardness between these two end members.

DEPTH	% CONSTITUENTS	DESCRIPTION
	Trace	Pyrite chips; shale A.A.; quartz grains A.A.
870-880ft.	100% Clayey Sand	A.A., except dominantly silt-v.f.gr. Clay:sand, approx. 50:50; clay is calcareous and contains approx. 2-3% small biotite flakes.
880-890ft.	100% Clayey Sand	A.A., mainly very soft, but some is slightly harder (due to cementing).
890-900ft.	100% Clayey Sand	A.A., except a few f.-m. grains in the dominantly v.f.gr. quartz and not so calcareous.
	Trace	Pyrite chips.
900-910ft.	100% Clayey Sand	A.A.
	Trace	Pyrite chips.
910-920ft.	100% Clayey Sand	A.A. except practically all silt-f.gr.
	Traces	V. small pyrite chips.
920-930ft.	100% Clayey Sand	A.A., except only v. slightly calcareous. The biotite (?) flakes often have a coppery lustre.
	Trace	Pyrite
930-940ft.	100% Clayey Sand	A.A.
	Trace	Pyrite.
940-950ft.	100% Clayey Sand	A.A. Slightly calcareous.
	Trace	Pyrite; white mica flakes (presumably muscovite) in the clay.
950-960ft.	100% Clayey Sand	A.A. except quite highly calcareous and there are a few white clay patches (also calc., bleached?). Still a little muscovite as well as the biotite.

DEPTH	% CONSTITUENTS	DESCRIPTION
	Trace	Pyrite; a few v. coarse, well rounded quartz grains.
960-970ft.	100% Clayey Sand	A.A. except very highly calcareous; sorting not nearly so good - up to c.-v.c.gr., although mostly f.-m.gr. (i.e. generally rather coarser overall). Very little biotite, and no muscovite.
	Trace	2-3% pyrite, much more abundant than above.
970-980ft.	100% Sandy Clay	A.A., except rather more clay than quartz. No white clay patches, but a little muscovite and biotite. Only slightly calcareous. Practically all very soft.
	Trace	Pyrite, but not nearly so much as above: < 1%.
980-990ft.	100% Sandy Clay	A.A., except now only 25-35% quartz grains. Sorting still poor: silt-m.gr. Only slightly calc. All very soft, still well-rounded and high sphericity generally.
990-1000ft.	100% Sandy Clay	A.A. except rather less than 25% quartz grains.
1000-1010ft.	100% Sandy Clay	A.A. except even less quartz grains. Sorting still very poor - a few v. well rounded m.gr. Fairly calc.
	Trace	Clayey sandstone. - i.e. consolidated clayey sand A.A., cemented with calcite. About 50:50 clay: sand, and hard. Dark grey shale fragments.
1010-1020ft.	100% Sandy Clay	A.A., except about 25-30% quartz grains, quite highly calcareous. Sorting poor-silt-m.gr., but dominantly f.gr.

DEPTH	% CONSTITUENTS	DESCRIPTION
1020-1030ft.	70% Sandy Clay	A.A., except about 35-40% quartz.
	30% Clayey Sandstone	A.A., Hard, slightly paler matrix than clay, highly calcareous, dominantly m.-c.gr., well rounded, high sphericity, colourless quartz grains.
	Trace	Shale fragments A.A. Pyrite chips.
1030-1040ft.	95% Sandy Clay	A.A. except ◁25% quartz.
	5% Clayey Sandstone	A.A.
1040-1050ft.	100% Sandy Clay	A.A. - about 25% quartz.
	Trace	V. coarse (about 2mm) well rounded, high sphericity, orange quartz pebbles.
1050-1060ft.	100% Sandy Clay	A.A. - distinct green-grey colour. All these clays, although v.soft when wet, are extremely hard when dry. However, only about 10% quartz grains, v.f.-m.gr. mostly f.-m.gr. Highly calcareous.
1060-1070ft.	100% Sandy Clay	A.A., except a few c.gr. and only fairly calcareous.
1070-1080ft.	100% Sandy Clay	A.A.
CORE NO. 3:	1080-1087ft. - Recovered 4.8ft. (68.4%).	
1080-1090ft.	75% Sandy Clay	A.A.
	20% Clayey Sandstone	A.A., predominantly f.-m.gr. quartz.
	5% Shale	Black fragments.
	Trace	Pyrite.
1090-1100ft.	80% Sandy Clay	A.A.
	10% Clayey Sandstone	A.A.
	10% Sandy Claystone	Like Sandy Clay except indurated and micaceous (white).

DEPTH	% CONSTITUENTS	DESCRIPTION
1100-1110ft.	90% Sandy Clay	A.A. except about 5% quartz grains; fairly calcareous.
	10% Sandy Claystone	A.A.
1110-1120ft.	50% Sandy Clay	A.A. except about 25% quartz grains and sorting not so good - f.-c.gr. mainly f.-m.gr.
	50% Clayey Sandstone	A.A. about 75% quartz grains set in highly calc. matrix, pale green-grey; sometimes white. F.-c.gr., mainly m.gr.; well polished, rounded, high sphericity.
	Trace	Shale fragments.
1120-1130ft.	75% Sandy Clay	A.A.
	25% Clayey Sandstone	A.A.
1130-1140ft.	100% Sandy Clay	A.A., except only about 10% quartz, mainly f.gr. slightly calcareous.
	Trace	Clayey Sandstone A.A.
1140-1150ft.	100% Sandy Clay	A.A., except <10% quartz. Dominantly f.gr., but a few well rounded v.c. grains including rose quartz. Fairly calcareous.
1150-1160ft.	90% Sandy Clay	A.A. <10% quartz, dominantly f.gr., a few m.gr. Fairly calcareous.
	5% Sandy Claystone	Like sandy clay, but harder.
	5% Shale	Mainly large black, slightly silty fragments (cavings?) Some small fragments.
1160-1170ft.	100% Sandy Clay	A.A., except only about 5% quartz grains, silt-m.gr. mainly v.f.-f.gr. Hardly calcareous at all.
	Trace	Shale A.A.

DEPTH	% CONSTITUENTS	DESCRIPTION
1170-1180ft.	100% Sandy Clay	A.A., except slightly calcareous.
	Trace	Shale A.A.
1180-1190ft.	100% Sandy Clay	A.A.
	Trace	Clayey Sandstone, highly calcareous. >50% quartz grains, mainly f.gr.
1190-1200ft.	100% Sandy Clay	A.A.
	Trace	Shale A.A.
1200-1210ft.	95% Sandy Clay	A.A.
	5% Shale	Fragments A.A.
	Trace	Sandy Claystone. About 15% f.-m.gr. quartz grains. Fairly calcareous with a little pyrite.
1210-1220ft.	100% Sandy Clay	A.A. except no more than 5% quartz grains, predominantly silt-f.gr. Very slightly calcareous.
	Trace	Shale A.A.
1220-1230ft.	90% Sandy Clay	A.A.
	10% Shale	A.A. (cavings?).
1230-1240ft.	100% Sandy Clay	A.A.
	Trace	Shale A.A.
1240-1250ft.	100% Sandy Clay	A.A.
	Trace	Shale A.A.
1250-1260ft.	100% Sandy Clay	A.A., green-grey, very sticky when wet, and hard when dry. <5% quartz grains, predominantly silt-f.gr., with a few c.gr. well-rounded, colourless. Clay is calcareous.
	Trace	Shale A.A.

DEPTH	% CONSTITUENTS	DESCRIPTION
1260-1270ft.	80% Sandy Clay	A.A.
	20% Sandy Claystone	Like sandy clay but harder and darker.
1270-1280ft.	95% Sandy Clay	A.A. except sorting not so good, quartz grain size ranges from silt-c.gr. Also up to 15% Quartz (varies from <5% to 15).
	5% Sandy Claystone	A.A.
[redacted]80-1290ft.	95% Sandy Clay	A.A. except in a few cases quartz makes up 25%. Overall, grain size ranges from silt-c.gr., dominantly v.f.-f.
	5% Sandy Claystone	A.A.
1290-1300ft.	100% Sandy Clay	A.A. except mostly quartz 15-25%, with quite a lot of 25%.
	Trace	Large shale fragments, A.A.
1300-1310ft.	100% Sandy Clay	A.A.
1310-1320ft.	100% Sandy Clay	A.A. except mostly about 10% quartz grains.
1320-1330ft.	100% Sandy Clay	A.A. except much of the clay has 25% quartz. Sorting is poor, silt-c.gr. (with a v. few v.c.gr.) Most of the grains are well rounded and polished, although some are frosted.
1330-1340ft.	100% Sandy Clay	A.A., except mostly only 5-10% quartz grains.
	Trace	Large shale fragments, A.A.
1340-1350ft.	100% Sandy Clay	A.A. only slightly calcareous. Many of the quartz grains are frosted.
1350-1360ft.	100% Sandy Clay	A.A. Fairly calcareous.
	Trace	Large shale fragments, A.A.

DEPTH	% CONSTITUENTS	DESCRIPTIONS
1360-1370ft.	100% Sandy Clay	A.A. Distinct green-grey colour. Generally <5% quartz grains.
1370-1380ft.	100% Sandy Clay	A.A. Quartz grains constitute 5-10%, many of them frosted, others well polished, all well rounded, silt-c.gr., mainly f.gr. Fairly calcareous.
	Trace	Large chips of pyrite.
1380-1390ft.	100% Sandy Clay	A.A., except quite highly calcareous. Quartz grains constitute up to 15% and are poorly sorted, even some v.c. grains.
	Trace	Green limestone chips; calcareous sandstone, made up of tightly packed med. grained quartz grains (mainly colourless, also pink, red) well polished and rounded set in a clear calcite cement.
1390-1400ft.	100% Sandy Clay	A.A.
	Trace	Calcareous sandstone, A.A.; Shale fragments, A.A.; pyrite chips.
1400-1410ft.	100% Sandy Clay	A.A., except quartz grains make up 15-25% mostly frosted, but well rounded, sphericity high, mostly colourless, mainly f.-m.gr. Clay is fairly highly calcareous.
	Trace	Pyrite.
1410-1420ft.	90% Sandy Clay	A.A., except 5-10% quartz grains.
	10% Sandy Claystone	Like sandy clay, except hard, dark grey and less obviously calcareous.

DEPTH	% CONSTITUENTS	DESCRIPTION
1420-1430ft.	100% Sandy Clay	A.A. except up to 25% quartz grains, silt-m.gr.
	Trace	Sandy claystone.
1430-1440ft.	85% Sandy Clay	A.A. except mostly quartz is 10-15%, a little up to 25%.
	13% Clayey Sandstone to Calcareous Sandstone	Gradational between quartz, f-m.gr. some frosted, some polished, well rounded, set in a calcareous clayey matrix (about 60-70% quartz) to quartz grains, generally slightly coarser, but otherwise the same, set in a practically pure calcite cement. Mostly calc. sandstone.
	2% Pyrite	Occurs in patches in the calcareous sandstone as cement. Also as chips of practically pure pyrite.
1440-1450ft.	95% Sandy Clay	A.A.
	5% Clayey-Calcareous Sandstone	A.A.
	Trace	Sandy claystone A.A.; very hard black igneous lithic pebble, containing flakes of biotite.
1450-1460ft.	90% Sandy Clay	A.A.
	10% Clayey-Calcareous Sandstone	A.A.
	Trace	Pyrite in the sandstone; sandy claystone.
1460-1470ft.	95% Sandy Clay	A.A., except a few more c. grains.
	5% Clayey-Calcareous Sandstone	A.A., except some of it is pale green clayey, calcareous siltstone.
	Trace	Pyrite, A.A.

DEPTH	% CONSTITUENTS	DESCRIPTION
1470-1480ft.	95% Sandy Clay	A.A.
	5% Clayey-Calcareous Sandstone	A.A.
1480-1490ft.	100% Sandy Clay	A.A. except only about 10-15% quartz grains.
	Trace	Clayey - Calcareous sandstone A.A.
1490-1500ft.	100% Sandy Clay	A.A.
	Trace	Clayey-Calcareous sandstone A.A.; pyrite A.A.
1500-1510ft.	100% Sandy Clay	A.A., usually 5-15% quartz grains, mainly f.m.gr. some polished, others frosted, mostly well rounded; matrix green-grey, highly calcareous.
	Trace	Clayey-calc. sandstone A.A.; pyrite A.A.; large shale fragments A.A.
1510-1520ft.	100% Sandy Clay	A.A.
1520-1530ft.	100% Sandy Clay	A.A.
1530-1540ft.	100% Sandy Clay	A.A. except only 5% quartz grains and most of these are f.-m. gr. Clay is highly calcareous.
	Trace	Sandy claystone A.A.; clayey sandstone A.A.
1540-1550ft.	100% Sandy Clay	A.A.
	Trace	Hard, green limestone.
1550-1560ft.	100% Sandy Clay	A.A.
1560-1570ft.	100% Sandy Clay	A.A. except some contains up to 10% quartz grains.
	Trace	Hard, green limestone chips.

DEPTH	% CONSTITUENTS	DESCRIPTION
1570-1580ft.	100% Sandy Clay	A.A. except quartz constitutes between 5-15% mainly f-m.gr., but ranges from silt-c.gr.
1580-1590ft.	100% Sandy Clay	A.A.
	Trace	Sandy claystone A.A., calcareous
1590-1600ft.	100% Sandy Clay	A.A., except mainly 5-10% quartz grains.
1600-1610ft.	100% Sandy Clay	A.A., except about 5% quartz grains, mainly v.f.-f.gr. some polished, others frosted; clay highly calcareous.
	Trace	Large chips of sandy claystone A.A.
1610-1620ft.	100% Sandy Clay	A.A.
	Trace	Sandy claystone A.A.
1620-1630ft.	100% Sandy Clay	A.A., except some up to 15% quartz grains, a few of which are m.-c.gr.
1630-1640ft.	100% Sandy Clay	A.A.
1640-1650ft.	100% Sandy Clay	A.A.
	Trace	Sandy claystone, A.A.
1650-1660ft.	95% Sandy Clay	A.A.
	5% (Calcareous-clayey Sandstone	A.A.
	(Sandy Claystone	A.A.
1660-1670ft.	100% Sandy Clay	A.A. except mostly 15% quartz grains, dominantly v.f.-f.gr., but quite a few m.-c.gr.
	Trace	A.A.
1670-1680ft.	100% Sandy Clay	A.A., except 5-10% quartz mainly v.f.-f.gr.
	Trace	Sandy Claystone, A.A.

DEPTH	% CONSTITUENTS	DESCRIPTION
1680-1690ft.	100% Sandy Clay	A.A.
	Trace	Sandy claystone A.A. & calcareous sandstone (i.e. quartz grains in green calcite matrix).
1690-1700ft.	100% Sandy Clay	A.A.
1700-1710ft.	95% Sandy Clay	A.A. except <5% quartz grains, mainly v.f.-f.gr.; a little is indurated and darker and thus sandy claystone. Clay highly calc.
	5% Quartz	Pebbles - angular, fragments of boulders, colourless, the biggest seen: 7.5 x 5 mm.
	5% Calcareous-Clayey Sandstone	F.-m.gr. colourless quartz grains set in a clayey calcareous matrix.
	5% Pyrite	Chips.
1710-1720ft.	98% Sandy Clay	A.A. except up to 25% quartz grains.
	2% Calcareous-Clayey Sandstone	A.A., but sometimes chips of well sorted v.f.-f.gr. quartz grains (constituting about 75% of the rock), colourless, well rounded and polished set in a pale grey clayey calcareous matrix. At other times, sorting not nearly so good, silt-m.gr., but well-rounded although some grains are polished others frosted.
1720-1730ft.	60% Calcareous-clayey Sandstone	Quartz grains, dominantly colourless, a few red, well rounded and usually polished. Normally well sorted, either v.f.-f.gr. or m.gr., occasionally sorting poor. Two end members depend on matrix; much contains hardly any clay, thus calcareous sandstone, containing about 75-80% quartz; the other end member contains up to 40% clay matrix (although still calcareous). This occurs

DEPTH	% CONSTITUENTS	DESCRIPTION
		in both ranges of grain size. Overall colour is colourless-pale grey.
	38% Sandy Clay	A.A., a very little indurated claystone.
	2% Pyrite	Ranges from a little cement in the above sandstone, to chips of almost pure pyrite.
1730-1740ft.	90% Sandy Clay	A.A., except up to 40% quartz grains, sorting poor, v.f.-c.gr., but generally coarser overall than above. Well rounded, generally polished.
	10% Clayey-calcareous Sandstone	A.A.
	Trace	Pyrite, A.A.
1740-1750ft.	95% Sandy Clay	A.A. except up to 25% quartz grains.
	5% Clayey-calcareous Sandstone	A.A.
	Trace	Pyrite A.A.; large (5mm. across), flat, well rounded pebbles of iron rich (bright yellow) sandy clay (v. little quartz).
1750-1760ft.	95% Sandy Clay	A.A.
	5% Clayey-calcareous Sandstone	A.A.
1760-1770ft.	100% Sandy Clay	A.A., some indurated and thus claystone.
	Trace	Clayey-calcareous sandstone, A.A.
1770-1780ft.	100% Sandy Clay	A.A.
1780-1790ft.	100% Sandy Clay	A.A.
1790-1800ft.	100% Sandy Clay	A.A.

DEPTH	% CONSTITUENTS	DESCRIPTION
1800-1810ft.	70% Sandy Clay	A.A. except colour is reddish brown, about 25% quartz grains, silt-m.gr., mainly v.f.-f. gr., well rounded, some polished others frosted.
	30% Shale	Dark grey, fairly soft, calcareous, micromicaceous, carbonaceous?, containing upwards of 5% quartz grains (usually <1%), rounded, silt-m.gr. Indurated clay.
	Trace	Clayey-calc. sandstone, A.A.; pyrite A.A.. Hard white, non calc. chip.
N.B. Clays are not so hard when dry (have not been from about 1500ft. on). Rather, they tend to be brittle and break fairly easily.		
1810-1820ft.	95% Sandy Clay	A.A. a few fairly hard brown chips.
	5% Shale	A.A.
1820-1830ft.	85% Sandy Clay	A.A., about 25% quartz grains, sorting poor, mainly f.-m.gr.
	15% Shale	A.A.
1830-1840ft.	60% Sandy Clay	A.A.
	40% Shale	A.A. except some of it is very hard.
1840-1850ft.	70% Sandy Clay	A.A.
	30% Shale	A.A.
	Trace	Large greenish coloured, fractured quartz pebble, angular, about 5mm. across.
1850-1860ft.	80% Sandy Clay	A.A. up to 25% quartz grains, mainly colourless, a few red, sorting poor: v.f.-c.gr. but dominantly v.f.-f.gr. often the coarser fraction tends to be well sorted (i.e. bands of coarser material). Well rounded, high sphericity mostly frosted some polished clay is highly calcareous and red-brown.

DEPTH	% CONSTITUENTS	DESCRIPTION
	20% Shale	A.A.
	Trace	Limestone pebble, pinkish-white, approx. 5 mm. across, well rounded, hard.
1860-1870ft.	85% Sandy Clay	A.A.
	15% Shale	A.A.
1870-1880ft.	90% Sandy Clay	A.A.
	10% Shale	A.A.
	Trace	Quartz grain, pinkish, well rounded & high sphericity polished, 5mm. across; calc. sandstone, f.mgr., quartz (90%) in calc. matrix.
1880-1890ft.	95% Sandy Clay	A.A. some partly indurated thus claystone.
	5% Shale	A.A.
	Trace	Clayey - calcareous sandstone A.A.
1890-1900ft.	95% Sandy Clay	A.A. except up to 35% quartz grains, quite a lot of m.-c. grains, but dominantly f.gr.
	5% Shale	A.A.
	Trace	Lithic pebble, 1cm. long, rounded, low sphericity, yellow (Fe oxidised) clay with a v. few fine quartz grains in it. Hard pyrite.
1900-1910ft.	95% Sandy Clay	A.A., except overall grain size of quartz is slightly higher than above.
	5% Shale	A.A.
	Trace	Limestone pebble, green, 3mm. long, angular; calc. sandstone (about 95% quartz, f.gr.); pyrite in calcareous sandstone.

DEPTH	% CONSTITUENTS	DESCRIPTION
1910-1920ft.	70% Sandy Clay	A.A.
	30% Shale	A.A.
1920-1930ft.	90% Sandy Clay	A.A.
	10% Shale	A.A. green-grey, fairly hard-hard, slightly calcareous, containing upwards of 5% well rounded, colourless quartz grains, but usually <1%.
	Trace	Calcareous siltstone, about 90% quartz grains, in pale green calcareous matrix.
1930-1940ft.	90% Sandy Clay	A.A.
	10% Shale	A.A.
	Trace	V. hard, f.gr. black rock chips (basalt? limestone?), about .5-1cm. across; pinkish-red quartz pebble (1mm. across), rounded.
1940-1950ft.	80% Sandy Clay	A.A.
	10% Shale	A.A.
	Trace	Hard, dark green limestone.
1950-1960ft.	80% Sandy Clay	A.A. chocolate colour, clay highly calcareous. Up to 30% quartz grains, poorly sorted: silt-c.gr., mainly f.-m.gr., well rounded, high sphericity, some frosted, other polished. Some of the clay is slightly darker and indurated, thus claystone.
	20% Shale	A.A. dark blue-green grey, fairly hard-hard, slightly calcareous containing upwards of 5% quartz grains (usually <1%) silt-m.gr., well rounded, polished or frosted.
	Trace	Angular quartz pebble (approx. 5mm. across); dark brown - black, hard, microcrystalline

DEPTH	% CONSTITUENTS	DESCRIPTION
		limestone chips; calcareous sandstone A.A.; pyrite chips A.A.; white, well rounded, hard clay pebble (approx. 5mm. diam.).
1960-1970ft.	70% Sandy Clay	A.A.
	30% Shale	A.A.
	Trace	Limestone, A.A.; quartz pebbles A.A.; calc. sandstone A.A.
1970-1980ft.	60% Shale	A.A.
	40% Sandy Clay	A.A. except quite a lot is very hard claystone.
	Trace	Dark microcrystalline limestone, A.A.; pink granite?; calcareous sandstone A.A.; pink, hard limestone.
1980-1990ft.	60% Shale	A.A.
	38% Sandy Clay	A.A.
	2% Limestone	Dark grey, crystalline, very hard, containing a few well rounded m.-c.gr. quartz grains.
	Trace	Calcareous sandstone A.A.
1990-2000ft.	80% Shale	A.A.
	18% Sandy Clay	A.A.
	2% Limestone	A.A.
	Trace	Large pink-colourless angular quartz pebble; well rounded, broken, large red and yellow-brown lithic pebbles.
2000-2010ft.	70% Sandy Clay	A.A., except most of it is soft.
	28% Shale	A.A.
	2% Limestone	A.A.

DEPTH	% CONSTITUENTS	DESCRIPTIONS
2010-2020ft.	60% Sandy Clay	A.A.
	40% Shale	A.A.
	Trace	Limestone A.A.
CORE NO.4:	2022-2042.27ft. Recovered 20.27ft. (100%).	
2020-2030ft.	50% Sandy Clay	A.A. except quartz grains make up <10%.
	50% Shale	A.A.
	Trace	Calcareous sandstone A.A.; pyrite; subrounded quartz pebble.
2030-2040ft.	100% Sandy Clay	60% blue-green grey, 40% chocolate, each with quartz grains, generally <5% f.m.gr., well rounded. Very soft when wet, highly calcareous. Blue-green is slightly fissile.
	Trace	Large dolomite pebbles; large quartz pebbles.
2040-2050ft.	35% Dolomite	Crystalline, hard, blue-green.
	30% Sandy Clay	A.A.
	25% Calcareous-Clayey Sandstone	A.A. except some is very soft
	5% Calcareous Sandstone	A.A.
	5% Shale	Blue-grey, fissile, fairly soft.
2050-2060ft.	90% Dolomite	Pale blue-green colour, very hard, crystalline.
	10% Shale	Blue-grey, soft.
	Trace	Dark grey limestone; dark pyritic calcareous sandstone (quartz v.f.gr.).
CORE NO.5:	2061.25-2074.5ft: Recovered 13.25 ft. (100%).	

DEPTH	% CONSTITUENTS	DESCRIPTION
2060-2070ft.	70% Dolomite	A.A.
	15% Calcareous Sandstone	A.A., colourless
	15% (Sandy Clay	A.A.
	15% (Shale	A.A.
	Trace	Large, well rounded, brown lithic pebble.
2070-2080ft.	60% Calcareous Sandstone	A.A., colourless, pink, white, (with a little clay matrix). Quartz grains usually m.gr., well rounded, sometimes get coarse fraction, but as a rule well sorted. Occassional quartz pebbles in the sandstone.
	30% Dolomite	A.A., sometimes containing a few quartz grains.
	10% (Sandy Claystone	A.A.
	10% (Shale	A.A.
2080-2087ft.	95% Dolomite	A.A. except most of it darker, brownish colour.
	5% Shale	Pale blue-green.
	Trace	Quartz and lithic pebbles.

CORE NO. 6: 2087-2098.8ft. Recovered 11.8ft. (100%)

T.D. 2098.8ft.

APPENDIX C

CORE DESCRIPTIONS

N.B. P709/70 - P721/70, marked at the relevant depths on the core logs, refer to petrological work carried out by A.M.D.E.L. (Appendix E).

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY No. 1

LOCATION Approximately 80 miles W. of Oodnadatta

LAT. 27° 39' 46" S.

LONG. 134° 16' 39" E.

ELEVATION GR. 789 ft. DATUM M.S.L.

R.T. 792·25 ft.

CORE NO. 1

DEPTH 203·5–213 ft.

DATE DRILLED 9. Nov. 1970.

RECOVERY 9·5 FT. 100 %

FORMATION BULLDOG SHALE.

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
203·5				
204		20		
205		20		
206		17		
207		17		
208		17		
209		17		
210		17		
210·5				

203·5–209·0 ft : Interlaminated shale and sandstone, consisting of approx. 60% shale, 40% sandstone. Shale laminae are between 2·5–12·5 mm. thick, with sandstone laminae about 2·5 mm. or less.

Shale : blue-black when wet, dark grey when dry, dense, fairly soft, micaceous and slightly pyritic, slickensided.

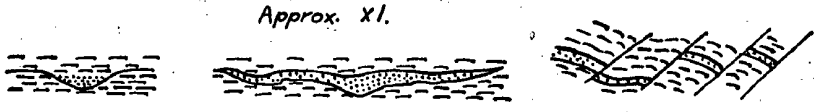
Sandstone : mainly white to pale grey, consisting of 70% quartz grains, 0·05–0·1 mm. in diameter, colourless, subangular to subrounded, 25% glauconite grains of the same size; 5% mica flakes (white); a trace of yellow coloured grains and possibly a little pyrite; all set in a soft, white clay matrix. Some of the laminae are of siltstone rather than fine grained sandstone.

The laminae show many sedimentary features such as "scour and fill," slumping, syndepositional faulting within the sandstone bands and shale fragments caught up in the sandstone laminae. Many of the sandstone bands are discontinuous, and are in fact lenses.

A good example of diagenetic faulting, running through both shale and sandstone laminae, occurs at 204·5 ft.

N.B. None of the laminae are flat, ie. ═══; they are all either disturbed or else show various sedimentary features, e.g. :

Approx. x1.



Dips vary from 0°–10°, but are predominantly horizontal.

209·0–213·0 ft : Interlaminated shale and sandstone, as above, except that there are not very many sandstone bands. The change is gradational, so that near the base of the core there is only about 20% sandstone. However, at 213 ft. there is again an increase in sand percentage.

Dips vary from about 5°–45°, and in completely different directions, considered to be due to slumping.

CORE BARREL 10' MINDRILL, STATIONARY-INNER TUBE. LOGGED BY R.C.N. THORNTON

CORE BIT MINDRILL

TIME–START 11·00 P.M. 9-11-1970. DATE 10-11-1970.

FINISH 1·55 A.M. 10-11-1970

PETROLEUM GEOLOGY SECTION

SHEET 1 OF 2 DRG. NO. S9224 Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL M.T. WILLOUGHBY No. 1.
LOCATION Approximately 80 miles W. of Oodnadatta
LAT. 27° 39' 46"S.
LONG. 134° 16' 39"E.
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft.

CORE NO. 1 (cont.)
DEPTH 203·5 – 213 ft.
DATE DRILLED 9 NOV. 1970
RECOVERY 9·5 FT. 100 %
FORMATION BULLDOG SHALE

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
210·5				
211		17		
212		17		
213		16		

CORE BARREL 10' MINDRILL. STATIC INNER TUBE LOGGED BY R.C.N. THORNTON.
CORE BIT MINDRILL
TIME—START 11·00 P.M. 8-11-1970 DATE 10-11-1970
FINISH 1·55 A.M. 10-11-1970

PETROLEUM GEOLOGY SECTION

SHEET 2 OF 2 DRG. NO. S 9224a Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL . MT. WILLOUGHBY No. 1 . CORE NO. 2

LOCATION Approximately 80 miles W. of Oodnadatta. . DEPTH 853 - 863·5 ft.

LAT. 27° 39' 46"S . DATE DRILLED . 11 NOV. 1970

LONG. 134° 16' 39" E . RECOVERY 0·5 FT. .5 %

ELEVATION GR. 789 ft . DATUM M.S.L. . FORMATION MOUNT TOONDINA BEDS

R.T. 792·25 ft

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY L06	DESCRIPTION
853				
854		33		
855		11		
856		8		
857		8		
858		9		
859		15		
860		16		

853·0-853·2 ft : Sandstone. pale grey to grey, slightly banded, with (x10) a green tinge overall, very hard. Consists of approx. 75-80% quartz grains, colourless; sorting good, very fine-medium grained, dominantly very fine - fine, subangular to rounded, mainly subrounded; sphericity medium to high. Other clastics consist of muscovite and biotite, the latter dominating; both in small flakes, to a total of about 2%. The clastic components are set in a white clay matrix and strongly cemented by calcite. This cement gives the pale green colour.

The sandstone is full of small scale current structures, mainly small crossbeds, many of which are etched out with very fine bands of biotite. The banding in the sandstone (ranging from 1-5 mm) also helps to show the crossbedding, and is probably due to varying amounts of clay matrix (paler where there is more clay).

The sandstone is cut by two very thin subvertical veins of white calcite.

Dip is impossible to determine because the crossbedding obscures the true bedding; but is probably approximately horizontal.

853·2-853·4 ft : Sandstone, as above, except softer, less strongly cemented and does not have the green tint. However, the matrix is highly calcareous.

853·4-853·5 ft. : Clayey Sand, pale grey, consisting of very fine grained quartz, colourless, and about 2% minute flakes of muscovite and biotite, set in a highly calcareous clay matrix. The ratio of clastics : matrix is approx 50:50. Soft.

Set in the clayey sand is a well rounded boulder (5cm x 3cm) of dark grey pyritic sandstone, which is very hard. The outer surfaces have a nodular appearance due to bumps of pyrite sticking up above the well rounded surface. One face is broken, although the edges have been rounded off, and shows fine horizontal banding. The quartz grains in the boulder are very fine grained and colourless, and are cemented together by pyrite. The boulder, from a visual estimation, contains about 80% pyrite, 20% quartz.

CORE BARREL . 10' MINDRILL. STATIONARY-INNER TUBE LOGGED BY R.C.N. THORNTON

CORE BIT . MINDRILL

TIME-START . 2·03 P.M. DATE . 12-11-1970.

FINISH . 4-12 P.M.

PETROLEUM GEOLOGY SECTION

SHEET 1 OF 2 | DRG. NO. S 9225 Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY No. 1
LOCATION Approximately 80 miles W. of Oodnadatta.
LAT. 27° 39' 46" S
LONG. 134° 16' 39" E
ELEVATION GR. 789 ft DATUM M.S.L.
R.T. 792.25 ft

CORE NO. 2 (cont'd.)
DEPTH 853 – 863.5 ft.
DATE DRILLED 11 Nov. 1970
RECOVERY 0.5 FT. .5 %
FORMATION MOUNT TOONDINA BEDS

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
860				
861		12		
862		10		
863		3		
		4		

853.5 – 863.5 ft. : No Recovery, due to the core catcher breaking and jamming the top 0.5 ft. of the core in the base of the core barrel.

CORE BARREL 10' MINDRILL Stationary inner-tube LOGGED BY R.C.N. THORNTON
CORE BIT MINDRILL
TIME – START 2.03 p.m. DATE 12-11-1970.
FINISH 4.12 p.m.

PETROLEUM GEOLOGY SECTION

SHEET 2 OF 2 | DRG. NO. S 9225a Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL . MT. WILLOUGHBY No 1 .
LOCATION *Approximately 80 miles W. of Oodnadatta.*
LAT. *27° 39' 46" S*
LONG. *134° 16' 39" E.*
ELEVATION GR. *789 ft.* DATUM *M.S.L.*
R.T. *792·25 ft.*

CORE NO. *3.*
DEPTH *1080 – 1087 ft*
DATE DRILLED *12 NOV. 1970.*
RECOVERY *4·8* FT. *68·4* %
FORMATION *UNIT 2*

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
1080				
		30		
1081				
		25		
1082				
		30		
1083				
P717/70				
		30		
1084				
P718/70				
		15		
1085				
		18		
1086				
		17		
1087				

1080·0 – 1080·6 ft : *Sandy Calcareous Clay.* *Greenish-grey colour, soft. Clastics consist of quartz grains, making up 30–40% of the rock, and a few white limestone fragments. The quartz grains are poorly sorted, from very fine – coarse grained, but dominantly fine-medium grained. Practically all are well rounded with high sphericity, especially the coarse grains. The grains are mainly colourless, a few yellow. The clay matrix is pale grey and highly calcareous.*

1080·6 – 1084·5 ft : *Sandstone Calcareous Claystone.*
(A.M.D.E.L. : Impure Sandy Argillaceous Limestone and Calcareous Sandstone. See petrological report.)
Blotchy greenish grey colour, massive, dense, structureless and fairly hard. Clastics comprise, on the whole, 10–30% of the rock, with a few bands of sandstone up to 60%, and consists of quartz grains, as above, except that there are a few very coarse grains to pebbles, and the colour of the quartz also includes rose quartz. There are also a little feldspar, a few small white fragments of limestone and trace amounts of tourmaline, garnet, zircon, staurolite, and opaque oxides. The matrix seems to be the same as that above, except much harder.

The horizon between 1083·0 – 1084·5 ft. also contains pebbles, the largest of which is 3x4 cm. and well rounded, of red feldspathic siltstone and limestone.

1084·5 – 1084·8 ft : *Clayey Calcareous Sandstone.* *Not quite so dark grey as above, massive, structureless and hard. Clastics consist of quartz grains, as above, but the percentage varies from 50–75%; also, a very little white mica, and some white limestone fragments. The percentage of quartz decreases downwards, however, until at the base of the core, the correct terminology would be Sandy Calcareous Claystone (with approx. 20% quartz). No lithic pebbles were observed. The matrix consists of grey, highly calcareous clay.*

A possible indication of dip is the contact between the claystone and sandstone at 1084·5 ft., which is at about 5°.

1084·8 – 1087·0 ft : *No recovery, due to coring in soft formation that fell out of the core barrel on retrieval.*

CORE BARREL . *10' MINDRILL Stationary – Inner Tube* LOGGED BY *R.C.N. THORNTON.*
CORE BIT . *MINDRILL*
TIME – START . *7:05 P.M.* DATE . *13th. Nov. 1970.*
FINISH . *9:50 P.M.*

PETROLEUM GEOLOGY SECTION

SHEET *1* OF *1* DRG. NO. S 9226 Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY No. 1.
LOCATION Approximately 80 miles W. of Oodnadatta.
LAT. 27° 39' 46" S.
LONG. 134° 16' 39" E.
ELEVATION GR. 789 ft DATUM M.S.L.
R.T. 792.25 ft

CORE NO. 4
DEPTH 2022 – 2042.27 ft.
DATE DRILLED 21. Nov. 1970.
RECOVERY 20.27 FT. 100 %
FORMATION UNIT 2

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
2022				
2023		12		
P 716/70 →				
2024		18		
2025		23		
2026		26		
2027		22		
2028		23		
2029		22		

2022.0 – 2023.2 ft. : Interbedded calcareous, clayey sandstone and shale.

Sandstone : Composed of about 60% quartz grains, colourless, fine – coarse grained, poorly sorted, well rounded, polished, high sphericity. The matrix consists of highly calcareous chocolate brown clay. The rock is hard.

Shale : Chocolate brown colour, containing 1–2% fine grained quartz grains. The shale is slightly calcareous and brittle.

The ratio of sandstone : shale is approx. 60:40, and the interbeds dip at about 5°. The shale interbeds vary between 5–10 mm. thick.

2023.2 – 2031.1 ft. : Dense massive sandy claystone, containing lithic pebbles.

Claystone : Chocolate brown colour, highly calcareous, micaceous (muscovite ?), hard, massive, dense, containing up to 50% quartz grains, silt – coarse grained, mainly fine to medium grained, fairly well sorted, well rounded, high sphericity, polished.

Pebbles : Generally about 1 c.m. across, but some are as large as 4 x 2 cm. Consist of lithics of various kinds, igneous, metamorphic, and sedimentary, but predominantly very hard, pale green dolomite. The pebbles make up 1–2 % of the rock, and are generally subrounded to rounded.

There is no indication of dip, but probably as above, ie, about 5°

N.B. XRD analysis of a claystone sample at 2023.3 ft, gives the following minerals in estimated order of abundance: Quartz + 2 feldspars + dolomite + calcite + mica + chlorite.

CORE BARREL 20' MINDRILL Stationary LOGGED BY R.C.N. THORNTON
CORE BIT MINDRILL – inner tube
TIME – START 12.45 P.M. DATE 22 NOV. 1970
FINISH 7.38 P.M.

PETROLEUM GEOLOGY SECTION

SHEET 1 OF 3 DRG. NO. S 9227 Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL . M.T. WILLOUGHBY . No. 1. .
LOCATION Approximately 80 miles W. of Oodnadatta
LAT. 27° 39' 46" S.
LONG. 134° 16' 39" E.
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft

CORE NO. 4 (CONT'D.)
DEPTH 2022–2042·27 ft.
DATE DRILLED 21. NOV. 1970.
RECOVERY 20·27 FT. 100 %
FORMATION UNIT 2.

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY %	DESCRIPTION
2029				
2030		15		2031·1–2032·0 ft.: Hard, dense, calcareous Sandstone, consisting of loosely packed quartz grains (70–80% of the rock), predominantly colourless, a few orange, very fine–medium grained, subangular–subrounded, fairly high sphericity, well polished, feldspar (up to 5%) and trace amounts of lithic, dolomite, opaque oxide, garnet, tourmaline, and zircon grains. The matrix is pale green–grey, slightly clayey, calcite. Where there is more clay, the matrix tends to be pink. The rock is hard. There is a band of large (3x2) dolomite pebbles at 2031·5 ft. There is no indication of dip, apart from the top contact (about 10°), but the formation is disturbed and there are a few subvertical brown clay veins running through it. The bottom contact is not flat, but looks to be a rather severe "scour and fill".
2031		19		
P719/70				
2032		14		2032·0–2032·4 ft.: Sandy claystone as between 2023·2–2031·1ft. but no lithic pebbles observed. Contains a few subvertical hairline calcite veins. The bottom contact is horizontal, but uneven.
2033		20		2032·4–2032·8 ft.: Sandstone as between 2031·1–2032·0 ft, except the matrix is possibly slightly more clay rich. Contains a few large dolomite pebbles. The bottom contact is nearly horizontal, but uneven.
2034		19		2032·8–2034·0 ft.: Sandy claystone as between 2023·2–2031·1ft. Contains a few large dolomite pebbles.
2035		21		2034·0–2037·4 ft.: Interbedded calcareous, clayey sandstone and shale as between 2022·0–2023·2 ft. The banding dips at 1–2°. The shale bands are between 5m.m. and 2–3cm. thick, and the ratio of sandstone to shale is about 60:40. The shales break up into small fragments and the core disintegrates on being wetted (which suggests an expanding lattice clay, like montmorillonite), but hard when dry.
2036		28		

CORE BARREL 20' MINDRILL. Stationary inner-tube. LOGGED BY R.C.N. THORNTON.
CORE BIT. MINDRILL.
TIME–START 12·45 p.m. DATE. 22 NOV. 1970
FINISH 7·38 p.m.

PETROLEUM GEOLOGY SECTION

SHEET 2 OF 3 | DRG. NO. S 9227a

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY No. 1.
LOCATION Approximately 80 miles N. of Oodnadatta.
LAT. 27° 39' 46" S.
LONG. 134° 16 39" E.
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft.

CORE NO. 4. (Cont°).
DEPTH 2022-2042·27
DATE DRILLED 21. Nov. 1970.
RECOVERY 20·27 FT. 100 %.
FORMATION UNIT 2.

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
2036				
2037		25		2037·4-2037·8 ft. : Interbedded chocolate coloured shale (approximately 60%) and blue-green-grey shale (approx. 40%), highly calcareous, containing very minor silt grains. The blue-grey bands are a few m.m.s. thick. The banding is nearly horizontal.
				2037·8-2038·0 ft. : Calcareous, clayey sandstone as between 2022·0-2023·2 ft., with only very minor shale bands.
2038		30		2038·0-2039·6 ft. : Banded chocolate coloured shale (and very minor blue-grey) and calcareous clayey sandstone, as above. Predominantly shale with only a few thin coarse bands. There is a band of blue-grey shale, about 5mm. thick and dipping at approximately 5°, at 2039·6 ft.
2039		30		
P720/70 →				
2040		17		2039·6-2042·27 ft. : Clayey dolomite sandstone consisting of quartz (40-50% of the rock), potash feldspar (3-5%), lithic (3-5%) and dolomite (3-5%) grains, with trace amounts of opaque oxide, calcite, garnet, zircon and apatite grains. The grains are subangular to subrounded, fine-coarse grained, poorly sorted, and very loosely packed. The pale grey matrix (40-50% of the rock) is cloudy and made up of very fine grained dolomite and clay. The rock is hard. Approximately 20-25% of the rock overall, comprises pale grey dolomite pebbles, many of them large (5 x 2 cm.) and generally subrounded to rounded.
2041		12		
2042		11		

CORE BARREL 20' MINDRILL. Stationary Inner-tube.
CORE BIT MINDRILL.
TIME-START 12·45 p.m.
FINISH 7·38 p.m.
LOGGED BY R.C.N. THORNTON.
DATE 22 NOV. 1970

PETROLEUM GEOLOGY SECTION

SHEET 3 OF 3
DRG. NO. S 9227b Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY No. 1.
LOCATION Approximately 80 miles W. of Oodnadatta.
LAT. 27° 39' 46" S.
LONG. 134° 16' 39" E.
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft.

CORE NO. 5.
DEPTH 2061·25 – 2074·50 ft.
DATE DRILLED 22 Nov. 1970.
RECOVERY 13·25 FT. 100 %
FORMATION UNIT 3.?

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
2061·25				
2062		10		
2063		22		
2064		15		
2065		21		
2066		5		
2067		12		
2068		20		

2061·25 – 2061·40 ft. : Dolomite : pale grey, hard, dense, finely crystalline.

2061·40 – 2062·55 ft. : Interlaminated pale grey dolomite and darker green-grey dolomicrite :
Dolomite : consists of fine-medium crystalline, anhedral equant grains of dolomite (95%), calcite and quartz. In a few cases, very thin laminae occur (<1 m.m. thick) of silt-very fine grained quartz (40%) in a dolomite matrix (60%). Dolomite was deposited under a rather higher energy enviroment than:
Dolomicrite : fairly hard, very finely crystalline (<0·01 mm.), with very fine detrital grains of quartz, mica, opaques and clay. The colour is thought to be due to a very small amount of chlorite. Many of the laminae break horizontally along shiny, well polished surfaces, presumably due to a very thin concentration of clays. Dolomicrite was presumably deposited as a calcareous mud and subsequently dolomitized.
Most of the dolomicrite bands are between 1-5 mm. thick, with a few being 1 c.m. thick, whereas, most of the dolomite bands are in the order of 1-2 c.m. thick.
Bedding is horizontal overall, however, the laminae have been disturbed to form small scale syngenetic thrust faults and other load structures, as well as current structures, such as scour and fill, and lenses of coarser material in the dolomicrite.

2062·55 – 2068·05 ft. : Dolomite : pale grey, hard, dense, massive, finely crystalline. Much of the core shows subhorizontal funnels, about 2 m.m. in dia., presumably due to biologic or diagenetic factors. Occasionally, very small lenses of quartz grains (fine to medium grained) occur within the dolomite.
Shale : black, very thin laminae occur, often formed into well developed large stylolites, cutting right across the core, with a displacement of about 1 c.m.
The dolomite tends to fracture vertically, due to a vertical set of joints.

CORE BARREL 20' MINDRILL. Stationary inner tube.
CORE BIT MINDRILL.
TIME – START 3·07 P.M.
FINISH 7·10 P.M.
LOGGED BY R.C.N. THORNTON.
DATE 23-11-70.

PETROLEUM GEOLOGY SECTION

SHEET 1 OF 2
DRG. NO. S 9228 Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL . M.T. WILLOUGHBY No. 1.
LOCATION Approximately 80 miles W. of Oodnadatta.
LAT. 27° 39' 46" S.
LONG. 134° 16' 39" E.
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft.

CORE NO. 5 (CONT'D.)
DEPTH 2061·25 – 2074·50 ft.
DATE DRILLED . 22 NOV. 1970.
RECOVERY 13·25 FT. 100 %
FORMATION . UNIT 3.

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
2068				
2069		23		
2070		24		
P115/70				
2071		21		
2072		23		
2073		21		
P721/70				
2074		16		
		13		

2068·05 – 2073·05 ft. : Interlaminated, pale grey dolomite and dark green-grey dolomicrite.
Dolomicrite : very finely crystalline (<0·01 m.m.) Accessory minerals are quartz, muscovite, opaques and chlorite, the last giving the green colouration.
Dolomite : dolomite (95%), calcite and quartz occur as anhedral, equant grains up to 0·03 m.m. diameter, with trace amounts of biotite, muscovite, opaques and tourmaline. The micas show a weak parallelism with the bedding. A very few small lenses of quartz occur. The dolomite beds are graded, having a sharp lower boundary with the dolomicrite, and grading upwards in about 2 m.m. back into the dolomicrite.
Bedding is horizontal overall, but most of the laminae have been contorted to form various lode structures such as small scale faulting and folding.
Shale : very minor, thin laminae.

2073·05 – 2073·75 ft. : Dolomite : pale grey, hard, dense, massive, finely crystalline, consisting of dolomite (98%), quartz (1%), and trace amounts of calcite, feldspar, mica, opaques and leucoxene. Layers 1-2 mm. thick contain most of the detrital mineral grains and these layers show indistinct graded bedding. The dolomite is slightly coarser where associated with the coarser grained detrital minerals. Elongate grains parallel bedding, which is horizontal.

2073·75 – 2073·95 ft. : Contorted laminae of pale grey dolomite and dark grey dolomicrite, as above.

2073·95 – 2074·50 ft. : Dolomitic clayey sandstone : overall colour-grey, comprised of quartz grains, colourless, subangular to subrounded, sphericity medium, fine to coarse grained, mainly fine to medium, some polished, others frosted. A few red grains occur. The matrix is pale grey clayey dolomite, and the ratio of clastics to matrix is about 50:50.

CORE BARREL 20' MINDRILL. Stationary inner tube.
CORE BIT . MINDRILL.
TIME – START 3·07 P.M.
FINISH 7·10 P.M.
LOGGED BY R.C.N. THORNTON.
DATE . 23. NOV. 1970

PETROLEUM GEOLOGY SECTION

SHEET 2 OF 2
DRG. NO. S 9228a 8a

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY No. 1
LOCATION Approximately 80 miles West of Oodnadatta.
LAT. 27°39'46" S.
LONG. 134°16'39"E
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft.

CORE NO. 6
DEPTH 2087 - 2098·8 ft.
DATE DRILLED 23 Nov. 1970
RECOVERY 11·8 FT. 100 %
FORMATION Unit 3

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG.	DESCRIPTION
2087				2087·0-2088·1 ft : Dolomite, pale green-grey to dark grey, hard, dense, massive, structurless, medium crystalline. Contains a few partly filled vugs up to 5mm. across of sparry calcite, coarse euhedral colourless crystals. A few stylolites occur made up of black shales, slightly metamorphosed to give a fine schistosity parallel to the contact with dolomite. The coarse stylolite shown contains a calcite vug (0·5 mm across)
2088		19		2088·1-2088·4 ft : Dolomite as above, except that included in it are about 1-2% quartz grains, colourless (look black in the core), fine - medium grained angular - subround.
I → P709/70 →				2088·4-2088·8 ft : Dolomite occurring in two modes. Blocks of DOLOMICRITE, pale grey, very finely crystalline, granular intergrowth of equant grains 0·01 mm across, that have been disturbed by the later intrusion of DOLOMITIC SAND, darker grey, speckled, coarser, containing coarse sparry areas and fragments of dolomicrite, together with quartz, chert and microcline. A silicate concretion, pale-blue - white, very finely crystalline, 4mm. long, occurs within the dolomicrite.
2089		16		
2090		18		2088·8 - 2093·5 ft : Dolomite pale grey, dense, hard, massive, finely crystalline. Shale bands : black, usually very thin (generally <0·5 mm although occassionally thicker) contain a few silt grains. They occur about every 0·5 - 5·0 cm. and are most abundant between 2089 - 2090·5 ft., but very scarce between 2091·5 - 2093·5 ft. Bedding is etched out in the dolomite by these bands, and also by slightly darker and coarser bands in the dolomite. On average, dip is horizontal. Silicate concretions occur through this horizon, up to 6 x 4 cm in size, they tend to be pale blue - pale grey and are composed of an intergrowth of microcrystalline quartz and dolomite, in a microcrystalline quartz matrix. They sometimes show concentric banding, in other cases the intergrowth is dendritic. They are considered to be diagenetic, especially as silicification is not always confined to the concretious but passes into the surrounding dolomite. However, bedding in the dolomite curves around the concretions so they must have grown during or very recently after sedimentation and prior to compaction.
II → 2091 P710/70		18		
P711/70 →				2092·25 ft : Band of very pale grey DOLOMICRITE, about 2cm. thick in rather coarser grey dolomite, similar to that at 2088·5 ft. except that the dolomicrite has not been so badly disturbed and the enclosing dolomite is not so coarse as the dolomitic sand. The dolomicrite seems to show slump structures.
P712/70 III → 2092		15		
2093		17		2093·5 - 2097·0 ft : Dolomite pale-grey, dense, hard, massive, finely crystalline. Shale bands fairly frequent between 2093·5 -
2094		15		

N.B. Roman numerals I - V refer to segments of the core described in greater detail in Appendix D.

CORE BARREL 20' MINDRILL STATIONARY INNER TUBE
CORE BIT MINDRILL
TIME - START 2·05 p.m.
FINISH 5·57 p.m.
LOGGED BY R.C.N. THORNTON.
DATE 24 NOV. 1970.

PETROLEUM GEOLOGY SECTION

SHEET 1 OF 2
DRG. NO. S 9229 Ba

DEPARTMENT OF MINES — SOUTH AUSTRALIA

CORE DESCRIPTION

WELL MT. WILLOUGHBY NO. 1
LOCATION Approx. 80 miles West of Oodnadatta.
LAT. 27° 39' 46"S
LONG. 134° 16' 39"E
ELEVATION GR. 789 ft. DATUM M.S.L.
R.T. 792·25 ft

CORE NO. 6 (contd.)
DEPTH 2087 - 2098·8 ft.
DATE DRILLED 23 Nov. 1970
RECOVERY 11·8 FT. 100. %
FORMATION, Unit 3

DEPTH IN FEET	GRAPHIC LOG	DRILL TIME MINS	RECOVERY LOG	DESCRIPTION
2094				
2095		16		
2096		14		
2097		13		
P713/70 → IV →				
2098		13		
V → P714/70 →		57		
2099				

2094·0 ft. but elsewhere infrequent, but where they do occur stylolites are common. A few concretions occur, similar to those between 2088·8 - 2093·5 ft.

2094·5 ft. : Fine blue flecks in the core : flouride ? The dolomite fractures vertically due to a vertical set of joints ; probably also a horizontal set. Vertical fracturing caused the core to become jammed in the barrel.

2097·0 - 2098·5 ft. : Dolomite, pale-grey, dense, hard, massive, consisting of pure subhedral, granular dolomite. Crystal size ranges from 0·25 - 0·02 mm, with irregular patches of similar sized crystals. A very few thin styolites occur.

Nodule : 7 x 4 cm, very different in appearance from the concretions observed higher in the core, it has sharp boundaries with the enclosing dolomite. Consists of brown stained, microcrystaline granular quartz ovoids and laths up to 3mm long, cemented by pale blue chalcedony. Scattered through both the ovoids and laths are broken dolomite rhombs, on average 0·026 mm. across. At the contact with the sediment there are half filled vugs containing coarse euhedral dolomite crystals.

2098·5 - 2098·8 ft. : Dolomite of two different types. The most abundant form is grey, hard, dense, massive, consisting of granular dolomite anhedra 0·2 mm. diam. Enclosed in this ALGAL DOLOMITE, buff coloured, composed of anhedra, 0·01 - 0·02 mm diam., containing a variable amount of ferruginous staining. Variations in the staining show the structures in these areas which are considered to be algal stromatolites, in the main vertically stacked, hemispheroids of the type SH-V (Logan et al 1964).

Bedding throughout the core is horizontal and porosity is virtually nil.

CORE BARREL 20' MINDRILL STATIONARY INNER TUBE
CORE BIT MINDRILL
TIME — START 2·05 pm
FINISH 5·57 pm.

LOGGED BY R.C.N. THORNTON
DATE 24 NOV. 1970

PETROLEUM GEOLOGY SECTION

SHEET 2 OF 2 | DRG. NO. S 9229a Ba

P.F. Nº S6004 MD

APPENDIX D

DESCRIPTION OF FIVE PIECES OF CORE FROM CORE NO. 6

N.B. The sketches accompanying each description are of sections through the centre of each core. The arrows point to the base of the core. Thin sections were cut at right angles to the faces shown.

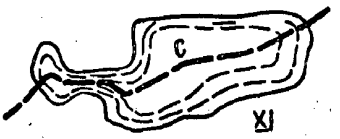
Although information has been taken from the petrologic descriptions (Appendix E), not all the information has been incorporated in this report.

DOLOMICRITE (M): pale grey, very finely crystalline, consisting of a granular intergrowth of equant dolomite grains, 0.01mm. across. It shows some structure, due to banding, etched out by very thin, slightly darker bands. The banding is not horizontal but has been disturbed by the later intrusion of:

DOLOMITIC SAND(S): darker grey than the micrite and speckled. Coarser, containing coarse sparry areas and fragments of micrite together with quartz, chertz and microcline. The latter are subangular to rounded grains, fine to coarse grained, poorly sorted. There are slight indications of bedding.

N.B. Dolomitization of the micrite and sand may have occurred at the same time.

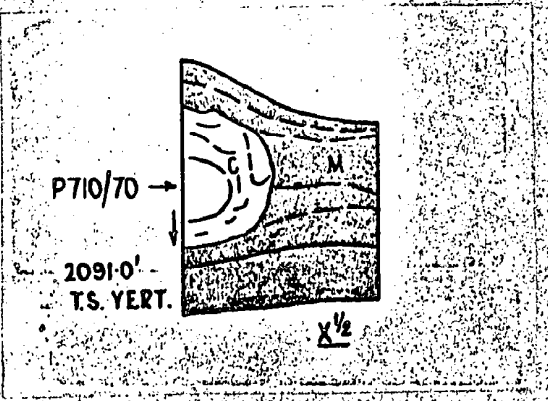
SILICATE CONCRETION (C): pale blue-pale grey-white, very finely crystalline silica and chert in a microcrystalline silica cement. Diffuse concentric bands of dolomite, crystal size 0.01-0.4mm., occur within the cement. The concretion has/been broken up by the later intrusion of dolomitic sand, as shown in the sketch, implying that its formation must have occurred during, or only very shortly after, sedimentation of the micrite, or else formed after the dolomitic sand was intended.



Original shape of concretion prior to disruption by dolomitic sand (along thick broken line).

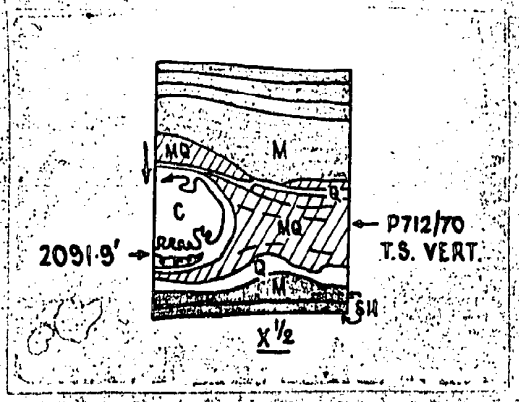
DOLOMICRITE (M): banded pale and slightly darker grey (1 cm. bands), very finely crystalline, consisting of a granular intergrowth of equant dolomite grains, 0.01 mm. across. Microscopically, the material is completely featureless. The banding curves slightly around:

?CONCRETION (C): there is a sharp junction between the dolomicrite and the ? concretion which is rimmed by 100% microcrystalline (0.01 mm.) quartz. Passing from the contact, towards the centre of the ? concretion the amount of quartz decreases and dolomite occurs. At first the dolomite consists of a sprinkling of exceedingly fine-grained material, but further away from the contact large dolomite euhedra (0.4 mm.) also occur. 4 mm. from the contact there is no quartz any more. Pure dolomite occurs at the centre, where lens shaped areas of microcrystalline dolomite, and new, coarser, dolomite occur together in a very irregular and diffuse pattern.



In one place, at the contact of ?concretion and dolomicrite an irregular vug (4 mm. across) occurs filled with fibrous chalcedony and an inner area of megaquartz.

Where quartz and dolomite occur together, the carbonate crystals extinguish together, suggesting carbonate replacement by quartz and thus making it doubtful that silicification could have occurred within the sediment (B.G. Steveson, A.M.D.E.L., pers. comm.). This suggests silicification of a dolomite pebble and then transport to this site. However, there is at one point indication that the bedding in the dolomicrite may, in fact, pass into the outer rim of the ?concretion and its origin is therefore in doubt.



DOLOMICRITE (M): pale grey, dense, hard, massive, finely crystalline (0.02 mm. diam.). Bedding is etched out by thin dark bands of rather coarser grained dolomite (0.05 mm.) containing very minor amounts of similar sized quartz, biotite, muscovite and opaques.

DOLOMICRITE (MQ): slightly paler grey than above. The dolomite anhedra are cemented by microcrystalline quartz. This grades rapidly into:

QUARTZ BANDS (Q): white, microcrystalline quartz occupies most of the bands. A little fine grained, anhedral dolomite occurs, together with isolated dolomite euhedra that look to have grown at the expense of the quartz.

CONCRETION (C): pale blue-grey, consisting of intergrown dolomite and microcrystalline quartz in places in an unusual dendritic pattern.

SHALE BANDS (Sh): thin, black, slightly metamorphosed to give a fine schistosity parallel with bedding.

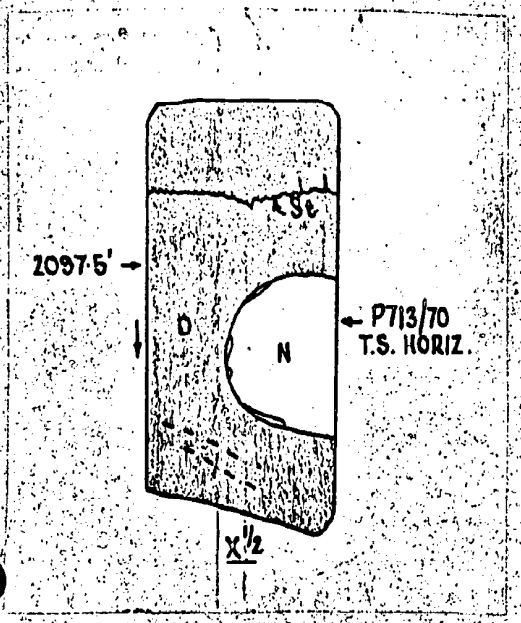
The boundaries between C and MQ are diffuse and the two are considered to have developed diagenetically at the same time. But the Q bands cut through both and must have developed afterwards. The euhedral dolomite in Q may well be an even later development.

The bedding observed within M curves around C and so the latter's development must have occurred during, or very soon after, sedimentation.

DOLOMITE (D): pale grey, dense, hard, massive, consisting of pure subhedral granular dolomite. Crystal size varies from 0.25 mm. to 0.02 mm., with irregular patches of similar sized crystals. This may have been due to either coarser recrystallisation of micrite than occurred in other parts of the core or to a variety of grain size in the original sediment.

STYLOLITE (St): black, thin, slightly schistose.

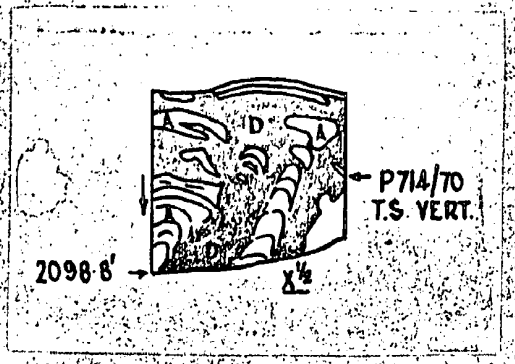
NODULE (N): very different in appearance from the concretions observed higher in the core, it has sharp boundaries with the enclosing dolomite and is made up of three components. The most abundant of these is microcrystalline granular quartz, occurring in rounded ovids and laths up to 3 mm. long, which is commonly stained brown by ferruginous material. Cementing these laths is pale blue chalcedony. Scattered over both the ovoids and chalcedony are broken rhombs of dolomite, on average 0.025 mm. across. At the contact of the nodule with the sediment are partly filled vugs containing coarse euhedral dolomite crystals.



Both the dolomite and the silica in the nodule appear to be secondary, but it cannot be said at what stage of diagenesis this occurred, especially as the origin is unknown. However, the broken nature of the dolomite rhombs must indicate that they were formed prior to being enclosed by the silica. The final stage of crystallisation was probably the growth of equant quartz crystals (0.07 mm. in size) within the chalcedony areas.

DOLOMITE (D): grey, hard, dense, massive consisting of granular dolomite anhedra, 0.2 mm. diameter.

ALGAL DOLOMITE (A): buff coloured, hard, consiting of granular dolomite anhedra, 0.01-0.02 mm. diam., containing a variable amount of pale ferruginous staining. Variations in the staining show the structure of these areas which are considered to be algal stromatolites. They mostly seem to be vertically stacked hemispheroids of the type SH-V (Logan et al., 1964), although the uppermost areas possibly show some lateral linking between the hemispheroids. By definition, these sediments are therefore indicative of an intertidal environment.



A few vugs, up to 6 mm. across, occur within, and a couple of subhorizontal veins cut through, both dolomites. They are filled with CALCITE anhedra similar in size to the adjacent dolomite.

APPENDIX E

PETROLOGICAL REPORTS OF CORES

Carried out by the Australian Mineral Development Laboratories

(a) Report MP 2624/71

Calcareous and Dolomitic Sediments from Mt. Willoughby No. 1 Drill Hole.

by S. Whitehead and Dr. R.N. Brown.

(b) Report MP 2523/71

Petrography and Xray Diffraction Studies of Specimens from Mt. Willoughby No. 1

by Dr. B.G. Stevenson and Dr. R.N. Brown

CALCAREOUS AND DOLOMITIC SEDIMENTS FROM MT. WILLOUGHBY NO. 1 DRILL HOLE

1 SUMMARY OF SPECIMENS

P717/70 HW244 (1083.5 ft.)	Impure, sandy and argillaceous limestone with a pebble of feldspathic siltstone. Poorly sorted, detrital grains and rock fragments are scattered through extremely fine-grained calcite containing an undetermined amount of argillaceous material.
P718/70 HW245 (1084.0 ft.)	Calcareous sandstone (50-60% quartz) grading to sandy, argillaceous limestone. Pebble is of limestone with no distinctive features. Few lithic grains in the sandstone include quartz-mica schist, gneiss and feldspathic sandstone. Part of the matrix calcite has recrystallised to a clear mosaic and some of this occurs as radiating prismatic crystals.
P719/70 HW246 (2031.4 ft.)	Calcareous sandstone with dolomite pebbles. Matrix is mainly of clean, recrystallized calcite but there are a few patches of argillaceous material. Pebbles are all of dolomite similar to dolomites of cores 5 and 6 - specimens P721/70, 711, 712 and 714/70. The rock also contains rounded, detrital grains of dolomite.
P720/70 HW247 (2039.75 ft.)	Dolomitic sandstone with pebbles of dolomite. Detrital mineral grains and rock fragments are cemented by cloudy, fine-grained dolomite containing an undetermined amount of clay.
P721/70 HW248 (2073.5 ft.)	Dolomite. Composed mainly of fine-grained dolomite with minor detrital quartz, feldspar and mica in some layers 1-2 mm. thick. There are a few thin seams of brown stained material associated with a little mica and quartz. These are similar to seams of brown material in a dolomite pebble in specimen P719/70.

2. X-RAY WORK

2.1 Procedure

Portions of samples P717/70 and P718/70 were powdered and mounted in the X-ray diffractometer. Diffraction patterns were recorded using cobalt radiation.

2.2 Results

Both samples were shown to consist of quartz, calcite, feldspar, mica and (probably) chlorite.

2.3 Remarks

Because these rocks are too well cemented to disperse in water for sedimentation of the -2 micron fraction, it was not possible to report specifically on this fraction, as was requested. More definite information on the fine fraction, in particular the identification of chlorite, could probably be obtained if necessary, by grinding and sedimenting procedures but the urgency of the work did not permit this.

3. DESCRIPTION OF SAMPLES

Sample P717: TS 26053: HW224

Location:

Mt. Willoughby No. 1 hole - 80 miles w of Oodnadatta. Core 3, 1083.5 ft.

Rock Name:

Impure, sandy and argillaceous limestone with siltstone pebble.

Hand Specimen:

A pale, grey rock containing detrital mineral grains and rock fragments up to 2 mm. in a very fine-grained matrix. There is no visible evidence of layering or of graded bedding. The specimen includes part of one pebble of reddish coloured rock.

Thin Section:

An optical estimate of the constituents gives the following:

	%	Grain size (mm)
Detrital quartz	25-30	0.02-1
Detrital potash feldspar	1-2	0.1 -0.5
Detrital plagioclase	Trace	0.05-0.1
Detrital lithic grains	Trace-1	0.2 -0.4
Detrital calcite (limestone)	1-2	0.2 -1
Tourmaline	Trace	0.15
Garnet	Trace	0.05-0.1
Opaque oxides	Trace	0.05
Pebble (feldspathic siltstone)		few cm
Matrix	65-70	0.05

Detrital mineral grains and lithic grains are well-rounded to subangular, poorly sorted, and are scattered through a very fine-grained, carbonate-rich matrix. Most of the detrital grains are not touching.

There is no definite evidence of layering but a few elongate quartz and feldspar grains show parallel orientation.

Many of the quartz grains show strain and a few are composites of several quartz grains derived from a metamorphic or granitic rock.

Potash feldspar grains include both microcline and orthoclase and a few showing perthitic intergrowth. Some are cloudy and were probably weathered before incorporation in the sediment.

The calcite (or limestone) grains are well-rounded and are composed of a mosaic of calcite crystals up to 0.1 mm in size, i.e. they are much coarser grained than the carbonate in the surrounding matrix. This difference in grain size and the general appearance strongly suggests that these grains are in fact of detrital calcite and are not former feldspar or lithic grains which have been subsequently replaced by calcite, however this possibility cannot be entirely excluded. Staining does not show any other carbonate mineral in these detrital grains.

Lithic grains are not common and they differ in composition. A few are cloudy and appear to have been weathered. Some contain sericite and quartz and may have been derived from granitic or gneissic rocks. One has a gneissic texture and is composed of calcite, feldspar and granulated or microcrystallin quartz with streaks of cloudy, undetermined material and traces of very fine-grained dolomite.
Garnet and tourmaline grains are subangular to subrounded and show no evidence of concentration along layers. Tourmaline grains vary in colour and may have not come from the same source.

Siltstone Pebble

Part of the large pebble is included in the section and is composed predominantly of closely packed, well sorted, angular to subrounded quartz and feldspar grains 0.03 - 0.05 mm. in size. There are also 10-15% of chloritic and sericitic grains, 1-2% opaque oxides and leucoxene or sphene, and a few mica flakes. There has been some interpretation of grains by pressure solution and secondary quartz and/or feldspar fills a few interstices. Calcite also fills a few interstices.

The siltstone is heavily stained by red-brown iron oxide which occurs as films along all grain boundaries.

Layering in this pebble is distinctly shown by variations in the amount of iron oxide staining and by slight variations in grain size.

There is no evidence of metamorphism.

Matrix. This is very fine-grained (less than 0.05 mm) and is a mixture of carbonate with pale brown, argillaceous material. Staining with alizarin red S shows much of the carbonate to be calcite but small grains of dolomite may also be present.
Because of the small grain size and general cloudiness the identity of the argillaceous mineral cannot be determined by optical properties.

Minute opaque grains are scattered through much of the matrix.

Sample P718/70: TS 26054: HW245

Location:

Mt. Willoughby No. 1 Core 3 depth 1084.0 ft.

Rock Name:

Calcareous sandstone grading to sandy, argillaceous limestone.

Hand Specimen:

A grey rock containing more abundant detrital mineral grains than specimen P717/70.

Thin Section:

An optical estimate of the constituents gives the following:

	%	Grain size (mm)
Detrital quartz	50-60	0.05-1
Detrital potash feldspar	3-5	0.1 -0.6
Detrital plagioclase	Trace	0.2 -0.5
Detrital lithic grains	3-5	0.2 -2
Detrital calcite grains	Trace	0.2
Garnet	Trace	0.1 -0.2
Staurolite	Minute trace	
Tourmaline	Trace	0.2
Zircon	Trace	0.3 -0.1
Opaque oxides	Trace	0.1
Pebble (limestone)		
Matrix	30-40	varies
(more in some parts)		

Detrital mineral grains and rock fragments are well-rounded, and a few sub-rounded to sub-angular. They are loosely packed and are cemented by a fine-grained matrix composed of calcite and argillaceous material.

Special features

Detrital mineral grains and rock fragments are much more abundant than in specimen P717/70 and in general are better sorted. They are loosely packed but most of them are still not touching.

The core specimen is not of uniform composition and in places the fine-grained matrix comprises 70-80% of the rock. This contains a considerable amount of argillaceous material.

Lithic grains include well-rounded fragments of quartz-feldspar-mica schist, quartz-feldspar gneiss, and a grain of feldspathic sandstone similar to, but coarser grained than the pebble of feldspathic siltstone described in specimen P717/70. It also shows less iron oxide staining than the pebble in P717/70.

Limestone Pebble. The thin section contains part of a large pebble. This is composed mainly of a uniform, fine-grained (0.05 mm), cloudy mosaic of calcite crystals with minor dolomite and contains a few scattered quartz grains, traces of mica and of argillaceous material. It shows no distinctive features but is cut by very thin veins of transparent calcite.

Matrix. Much of the matrix of this rock is similar to that in specimen P717/70 and is composed of very fine-grained, pale brown argillaceous material, fine-grained calcite, and possibly a little fine-grained dolomite.

In places the matrix is now composed of clear, recrystallized calcite with grain sizes varying up to 0.1 mm. Some of this shows traces of radiating prismatic crystals.

Similar, coarser grained calcite has also invaded a few detrital feldspar and lithic grains.

Sample P719/70: TS 26055: HW246

Location:

Mt. Willoughby No. 1 Core 4 depth 2031.4 ft.

Rock Name:

Calcareous sandstone with dolomite pebbles

Hand Specimen:

A fine-grained, sandstone containing a few large pebbles.

Thin Section:

An optical estimate of the constituents gives the following:

	%	Grain Size (mm)
Detrital quartz	70-80	0.05-0.3
Detrital potash feldspar	3-5	0.05-0.3
Detrital plagioclase	Trace	0.05-0.1
Lithic grains	Trace	0.1 -0.5
Dolomite grains	Trace	0.05-0.1
Opaque oxides	Trace	0.05-0.1
Garnet	Trace	0.05-0.2
Tourmaline	Trace	0.05-0.1
Zircon	Minute trace	0.05
Matrix calcite	20-30	0.05-0.2
Dolomite pebbles		

Detrital mineral grains and rock fragments are subrounded to subangular and poorly sorted. They are loosely packed and many are just touching or are not quite touching. Interstices have been filled by clean, medium grained calcite possibly with traces of very fine-grained dolomite. There are a few patches of pale brown, argillaceous material containing only a few, minute carbonate grains.

Lithic grains include a few of cloudy, feldspathic siltstone, cloudy quartz-feldspar rock, a few of granulated or micro-crystalline quartz and a few of fine-grained dolomite.

The large pebbles exposed in the section are all of fine-grained dolomite containing a few opaque oxide grains and a few quartz grains. Grain size of the dolomite is 0.01-0.05 mm. One pebble shows thin seams of brown stained material.

This dolomite is very similar to the dolomite of specimen P721/70 (Core 5 at 2073 ft.) and also to dolomites from Core 6 - specimens P711, 712, 714/70 from 2091.2, 2091.9 and 2098.8 ft. respectively but it is finer grained than dolomite in specimen P713/70 (Core 6 at 2097.5 ft.).

Dolomite in specimen P715/70 (HW242 Core 5 at 2070.7 ft.) is finer grained than in these pebbles and contains more argillaceous material and detrital mineral grains.

Sample P720/70: TS 26056: HW247

Location:

Mt. Willoughby No. 1 Core 4 at 2039.75 ft.

Rock Name:

Dolomitic sandstone with pebbles of dolomite

Hand Specimen:

A pale grey, sedimentary rock containing detrital mineral grains and rock fragments of very variable size. Larger pebbles are of fine-grained, grey rock.

Thin Section:

An optical estimate of the constituents gives the following:

Rock	%	Grain Size (mm)
Detrital quartz	40-50	0.03-0.5
Detrital potash feldspar	3-5	0.03-0.3
Detrital lithic grains	3-5	0.1 -2
Opaque oxides	Trace	0.05
Calcite grains	Trace-1	0.05-0.2
Garnet	Trace	0.03-0.1
Zircon	Trace	0.03-0.1
Apatite	Minute trace	0.03-0.1
Dolomite grains	3-5	0.2 -3
Matrix (Dolomite and clay)	40-50	
Pebbles - fine-grained dolomite		

The detrital mineral grains are subangular to subrounded, poorly sorted and very loosely packed. They are cemented by a cloudy matrix composed of very fine-grained dolomite and an undetermined amount of clay which is largely obscurred by the carbonate.

All pebbles included in the section are of dolomite but this shows some variation in grain size. In some pebbles it is 0.01 -0.05 mm. in others 0.05-0.1 mm. One large pebble is composed of dolomite with 3-5% calcite. Dolomite crystals are 0.03-0.06 mm. and the calcite fills some interstices. Indistinct layering in this pebble is shown mainly by brown staining.

The dolomite grains and pebbles in this rock are similar to dolomites from cores 5 and 6.

Sample P721/70: TS 26057: HW248

Location:

Mt. Willoughby No. 1 Core 5 at 2073.5 ft.

Rock Name:

Dolomite

Hand Specimen:

Pale grey, fine-grained rock with a few very thin seams of dark micaceous material.

Thin Section:

An optical estimate of the constituents gives the following:

	%	Grain Size (mm)
Dolomite	97-98	0.01-0.05
Calcite	Trace	0.05
Detrital quartz	1-2	0.02-0.08
Detrital feldspar	Minute trace	0.05
Detrital mica	Trace	0.05
Opaque grains and leucoxene brown staining	Trace-1	0.05

The rock is composed predominantly of fine-grained dolomite.

Layers 1-2 mm. thick contain most of the detrital mineral grains and these layers show indistinct graded bedding. The dolomite is slightly coarser grained where associated with the coarser grained detrital grains.

Elongate mineral grains are parallel to the layering.

The thin seams of brown-stained material contain a slight concentration of mica and quartz but do not appear to be true stylolites.

They are somewhat similar to the seams of brown material in the dolomitic pebble in specimen P719/70 (HW 246).

PETROGRAPHY AND X-RAY DIFFRACTION STUDIES OF SPECIMENS FROM MT. WILLOUGHBY NO.1

Sample P709/70: TS 26019:

Location:

Mt. Willoughby No. 1 Core 6, 2088.7 ft. HW 236

Rock Name:

Finely crystalline dolomite

Hand Specimen:

These rocks are similar to each other and can be described as a group. All are compact, fine-grained sediments, pale-creamy to grey in colour. Whilst P711, 713, 714 and 715 have thin, laminar beds, the remaining samples contain lenses or nodules of pale, fine-grained material. P712 contains an irregular bed of this material whereas P713 contains a large pebble (apparently 3-4 cm. in diameter) within the laminar bedding.

P715 is a more impure limestone and is darker in colour than the remainder.

P716 is different from the above specimens; it is a dark purply-grey clay stone, free of any sedimentary structures.

Thin Section:

An optical estimate of the constituents gives the following:

	%
Dolomite	75-80
Quartz	20
Microcline/albite	Less than 1
Chert	1
Opaques	Trace

Most of the slide consists of a granular intergrowth of equant dolomite grains, 0.01 mm. across. This is a micrite and the material is completely featureless.

A band about 4 mm. thick, within the dolomite, caries coarser sparry areas together with quartz, chert and microcline. The latter are sub-angular to rounded grains, rather poorly sorted. Diameters range from 2 mm. to 0.1 mm. Some of the smaller grains appear to be reacting with the dolomite matrix.

In another part of the section the same suite of silicate minerals occurs but the cement here consists of microcrystalline silica. The material is a featureless array of crystals, less

than 0.01 mm. in diameter. Within the cement are bands containing dolomite which ranges from less than 0.01 mm. in size to anhedra 0.4 mm. across. These bands have diffuse margins.

At the contact between the micrite and the quartz cement it appears that new coarser dolomite has grown at the expense of the quartz cement, euhedral dolomite grows from the micrite into the quartz. Feldspars are rounded, but fresh. Both microcline twinning and albite twinning is present.

The irregular band of quartz-cemented material is possibly some kind of fill structure within the micrite material above and below it.

Sample P710/70: TS26020:

Location:

Mt. Willoughby No. 1 Core #6 2091 ft. HW 237.

Rock Name:

Finely crustalline dolomite

Thin Section:

An optical estimate of the constituents gives the following:

	%
Dolomite	85
Quartz	5
Chalcedony	5-10
Calcite	Trace

Much of this rock consists of micrite similar to that described in P709/70.

Near one end of the slide, however, a bedding surface can be seen; at this plane there is a sharp junction between micrite and microcrystalline (0.01 mm) quartz. Passing down from this contact the amount of quartz (100% at the contact) decreases as micritic dolomite occurs. This dolomite is, at first a sprinkling of exceedingly fine-grained material but further away from the bedding plane, the larger euhedra (mentioned in the description of P709/70) occur also. Four millimetres from the bedding plane the rock is entirely micrite.

Further down the bore there is another area in which this microcrystalline quartz occurs but here the contact with the micrite is irregular and gradational.

Lens-shaped areas of micrite, new, coarser dolomite and quartz occur together in varying proportions in a band approximately parallel to bedding. The structure in this part is quite irregular and diffuse - it can best be seen by examining the thin section by eye.

The slide also carries a vug, now filled with fibrous chalcedony and an inner area of megaquartz. The vug, which has an irregular bulbous shape is 4 mm. across. Smaller (approximately 0.3 mm.) areas of fibrous chalcedony also occur.

Calcite occurs only in late veins, parallel to bedding, and approximately 0.1 mm. wide.

Sample P711/70: TS 26021:

Location:

Mt. Willoughby No. 1 Core #6 2091.7 ft. HW 238

Rock Name:

Finely crystalline dolomite

Thin Section:

An optical estimate of the constituents gives the following:

	%
Dolomite	90
Quartz	10
Opaques	Trace
Calcite	Trace-1

Dolomite anhedra, 0.02 mm. in diameter, occupy almost all of this section. This material has a granular texture and is free of any structure. Rare detrital grains of quartz are present with the dolomite.

Part of an oval, lens-shaped object can be seen. This consists of a granular intergrowth of microcrystalline quartz similar to that in P709/70 and P710/70. Zones of apparently newly crystallised dolomite are present here also - as in the other rocks mentioned above. This dolomite defines broad zones parallel to the margins of this lens. (These can again be seen by examining the thin section with a hand lens). The edge of the quartz bearing lens is sharp but the dolomite anhedra penetrate into it making the contact highly irregular.

Irregular brown, ferruginous staining occurs in different parts of the rock. These often define the bedding but this is difficult to detect under the microscope.

A fracture, 0.5 mm. wide, passes across the section; it is filled with large dolomite and calcite anhedra, elongated parallel to the length of the fracture. The calcite occurs in the centre of the fracture usually, but the calcite fills the fracture in some parts.

Sample P712/70: TS 26022:

Location:

Mt. Willoughby No. 1 Core #6 2091.9 ft. HW 239.

Rock Name:

Finely crystalline dolomite.

Thin Section:

An optical estimate of the constituents gives the following:

	%
Dolomite	90-95
Quartz	5-10
Biotite	Trace
Opaques	Trace
Muscovite	Trace

Most of this rock consists of micrite material displaying no structures. Individual crystals are 0.02 mm in diameter. In some areas the dolomite anhedra are cemented by microcrystalline quartz. This material passes rapidly into material in which this quartz occupies most of the rock. Here isolated dolomite euhedra occur (as described in P709/70 - 711/70) along with finer-grained anhedral dolomite.

These quartz-rich areas are separate beds - as can be seen clearly in the thin section.

Bedding is indicated by the presence of layers of rather coarser grained dolomite (0.05 mm) which contain very minor amounts of similar sized quartz, biotite, muscovite and opaques.

Sample P713/70: TS 26023:

Location:

Mt. Willoughby No. 1 Core #6 2097.5 ft. HW 240.

Rock Name:

Dolomite with chalcedony

Thin Section:

An optical estimate of the constituents gives the following:

	%

The section consists of two distinct lithologies; a chalcedony cemented impure dolomite and a pure dolomite. The latter is 100% dolomite and the former has the following minerals:

Dolomite	5-15
Chalcedony and micro-crystalline quartz	85-95

The pure limestone consists of subhedral dolomite in a granular array. Crystals vary from 0.25 mm to 0.02 mm in size, there being irregular areas of similarly-sized crystals.

The other half of the thin section consists of rounded, ovoids, up to 3 mm long. These consist of microcrystalline granular quartz commonly stained brown by ferruginous material where the stain is dark, the ovoids are well-defined; elsewhere they tend to have rather diffuse outlines.

Cementing these ovoids is chalcedony, which is granular near the ovoids, but fibrous in the centres of the largest areas of chalcedony. The very last stage of crystallisation was the development of equant quartz crystals (0.07 mm in size).

Scattered over both the ovoids and the silica cement are dolomite grains, many of which appear to be fragments of broken anhedra. Unbroken rhombs are rare. They are up to 0.3 mm diameter - many of the broken fragments are 0.025 mm. across on average.
Both the dolomite and the silica of this part of the rock appear to be secondary.

No satisfactory hypothesis of origin has been established for the rock, other than that it is a sediment.

Sample P714/70: TS 26025

Location:

Mt. Willoughby No. 1 Core #6 2098.8 ft. HW 241.

Rock Name:

Dolomite

Thin Section:

An optical estimate of the constituents gives the following:

	%
Dolomite	99
Quartz	Trace
Calcite	1

This rock consists almost entirely of a granular intergrowth of dolomite anhedra. There are two modes in the grain size distribution - about half the section is occupied by grains of 0.01 - 0.02 mm diameter, whilst the remainder of the dolomite has a size of the order of 0.2 mm.

The finer-grained material carries a variable amount of pale, ferruginous stain - variations in this define the bedding. The coarser material is massive - these relations can be seen on examining the slide with the naked eye.

Amongst the dolomite are irregular areas, up to 6 mm long, which consist of calcite anhedra, similar in size to the adjacent dolomite.

Sample P715/70: TS 26025:

Location:

Mt. Willoughby No. 1 Core #5 2070.7 ft. HW 242.

Rock Name:

Lutaceous dolomite

Thin Section:

An optical estimate of the constituents gives the following:

	%
Dolomite	93-95
Calcite	5
Clays	?1
Quartz	2-5
Opaques	Trace -1
Tourmaline	Trace
Biotite	Trace
Muscovite	Trace

This rock consists of beds of fine-grained dolomite with coarser beds of quartz, calcite and micas. The sediment shows graded bedding.

The dolomite-rich beds are fine-grained and in many parts the crystals cannot be distinguished even under the highest power. Accessory minerals in these beds are quartz, muscovite, opaques and ?clays. Grains larger than 10 microns in diameter are rare in these beds.

The coarser beds have a more varied mineralogy and texture. Dolomite, calcite and quartz commonly occur as anhedral, equant grains up to 30 microns in diameter.

Occasionally dolomite rhombs can be recognised. These three minerals (dolomite, calcite and quartz) are major components of these beds whereas biotite, muscovite, opaques and tourmaline are accessories. Generally the micas occur as elongate crystals between 20 and 100 microns in length. Ragged, anhedral grains are not uncommon and very elongate, bent subhedra are occasionally recognised. There is a weak parallelism of the longest axes of the micas, corresponding to the bedding planes. Tourmaline and opaque minerals (?magnetite) are rare accessories occurring as equant, somewhat rounded grains.

The coarser, dolomite-calcite-quartz beds have a sharply defined base on the fine-grained dolomite and they grade upwards, in about 2 mm, into similar material. This feature suggests that the sediments are the "right way up". However, the bedding is somewhat irregular in some parts of the section containing isolated masses of coarse beds within the pure dolomite beds.

1. XRD WORK

Diffractometer traces were made. The three samples on which clay work was specifically requested (.002 mm, P711, 715, 716) were too consolidated to disperse in water and had to be examined in bulk, as for the other samples. Information on clay minerals will be poor because of this.

1.1 Results

Minerals in estimated order of abundance.

P709/70 Dolomite + quartz + tr. feldspar.

P710/70 Quartz + dolomite + calcite.

P712/70 Quartz + dolomite.

P713/70 Dolomite + quartz + tr. feldspar + tr. calcite.

P714/70 Dolomite + calcite + quartz + tr. feldspar

P716/70* Quartz + 2 feldspars + dolomite + calcite + mica + chlorite.

P715/70* Dolomite + quartz + feldspar + mica + chlorite + tr. calcite.

P711/70* Dolomite + quartz + tr. probable montmorillonite.

* See note above.

2. CONCLUSIONS

These rocks are predominantly dolomites, consisting of micrite-like material. While the origin of this material is not known, it is clear that the coarser anhedral dolomite, sometimes observed is secondary.

Calcite commonly occurs as a late vein-filling mineral.

APPENDIX F

WELL VELOCITY SURVEY OF MOUNT WILLOUGHBY NO.1

by

B.E. MILTON
SENIOR GEOPHYSICIST
SEISMIC GEOPHYSICS SECTION

Appendix 'F'

WELL VELOCITY SURVEY OF MOUNT WILLOUGHBY No. 1

by

B.E. MILTON
SENIOR GEOPHYSICIST

ABSTRACT

Interval and average velocities have been determined in the South Australian Department of Mines stratigraphic well Mount Willoughby No. 1 to a depth of 2084 feet below surface. The most significant feature of the geological log is a very dense crystalline dolomite intersected at 2042 feet below surface. The interval velocity of this material is about 18000 feet per second. This information identifies the origin of a high speed seismic refractor, which was the main purpose of the well, and enables a more certain interpretation of seismic and other geophysical data in this region.

INTRODUCTION

During exploration of the western Arckaringa Basin, a region in the north and northwest was found to display anomalous geophysical characteristics relative to the area to the south and southeast, where it has been determined that Permian sediments rested directly on crystalline basement. In this locality, a distinctive gravity ridge is associated with a magnetic trough with a maximum depth of greater than 6000 feet interpreted from the aeromagnetic data. Seismic refraction profiling also revealed an horizon at a depth of about 2000 feet below surface with a velocity of 21000 feet per second, in contrast with a persistent velocity of 187000 feet

per second for crystalline basement which, to the south of the gravity high, lies at a depth of 35000 feet (Milton, 1970).

Identification of the high speed refractor appeared vital to an understanding of the geology of this sector of the Arckaringa Basin, and a stratigraphic well located from an analysis of gravity and seismic data was drilled in November, 1970. The co-ordinates are 134° 16'39"E 27° 39'46"S (offset about 350 feet NNW of shot point JC44). A velocity log of the well enabled the identification of the high speed refractor, as described in the following sections.

PROCEDURE

Equipment used for the well shoot consisted of a Seiscor GCE 101 pressure sensitive well geophone borrowed from the Bureau of Mineral Resources, and the South Australian Department of Mines S.I.E. P19 12 channel seismograph unit with photographic recording. The geophone was linked to the recording equipment by the cable of a Failing logger with a capacity of 3000 feet, and as this cable was not strong enough to carry the weight of the geophone, a thin steel cable was used to support the seismometer.

A single shot point drilled by hand auger was located 83 feet from the well on a bearing of 73° east of north. Small charges of 'Anzomex' primer were adequate to obtain good to fair breaks, the largest charge used being 36 oz. Records were obtained at differing levels by raising the geophone in the hole. A delay time of 2 to 3 milliseconds were applied to the recorded times to adjust for amplifier response.

The well was drilled to a depth of 2096 feet below surface, but the bottom hole was not reamed out after coring, so that the deepest velocity information was obtained from 2084 feet. The depths of the shallower positions were chosen from a consideration

of the lithologic log and the electric and radio-active logs. The shallowest geophone depth of 171 feet was 29 feet below the base of the casing.

The total logging depth recorded was 2111 feet compared with the driller's depth of 2099 feet, and the cause of this discrepancy has not been established. Logging depths have been adjusted using a ratio of 2099/2111.

RESULTS

The reduction of observed times and depths is recorded on the Computation Sheet. Corrections have been made to a datum of 782 feet relative to M.S.L., i.e. 7 feet below the surface elevation of the well. The surface velocity of 1650 feet per second was determined from seismic operations undertaken earlier in 1970.

The time-depth, average velocity-depth and interval velocity-depth relationships are presented in graphical form in drawing 71-44. Correlation of interval velocities with the lithological log shows the following approximate relationships:

		Depth below surface to formation top
Bulldog Shale	6090 feet per second	0 feet
Cadna-Owie Formation	5130 "	326 "
Algebuckina Sandstone	6730 "	470 "
Mount Toondina Beds	7890 "	651 "
Unit 2 - Lower Permian	8010 "	956 "
	9430 "	1239 "
	10620 "	1736 "
Dolomite - (Devonian?)	18000 "	2042 "

Two changes of velocity occur within Unit 2, the second of which can be attributed to a change in lithology at 1748 feet. This change is also apparent on the gamma and neutron logs. The variation in lithology related to the velocity change at 1239 feet, is however, not obvious and could be related to discontinuties showing on the radio-active logs at 1200 or 1275 feet approximately.

The interval velocities compare with those obtained from refraction profiles from the area to the south where crystalline basement is overlain by Permian and younger sediments, as follows:

Cadna-Owie Formation	- 7000/7500 feet per second
Mount Toodina Beds (top of Permian)	- 7500/9000 "
Unit 2	- 13000(?) "

and from the refraction surveys over the Wintinna gravity high:

Devonian(?) dolomite = 21000 feet per second

Assuming that the relationship between the refraction and interval velocities is approximately $Vel_{interval}/Vel_{refraction} = 0.9$, then the values of Mount Willoughby No. 1 for the Cadna-Owie Formation and Unit 2 are low, while the Permian and dolomite values appear reasonable.

A comparison of interval velocities with those obtained from a well shoot of Cootanoorina No. 1 (Kendall, 1967) and an intergrated sonic log from Weedina No. 1 (Pexa, 1970) is as follows:

	Mt. Willoughby	Cootanoorina	Weedina
Mt. Toondina Beds	7890	7520/8070	8500 (average)
Unit 1	absent	8240/10600*	8100 "
Unit 2	8000/10600	11100**	10100 "
Dolomite	18000		15500/18800

*10600 feet per second originates from a marine shale within Unit 1

**Derived by assuming a velocity of 18000 feet per second for the

Shothole information – Elevation, Distance & Direction from Well: El 787 Bearing 319° 83ft. from Well

Department of Mines Well: Mount Willoughby No 1

Elevation Derrick Floor: 792

Total Depth: 2099

LOCATION: Coordinates 134° 16' 39" E. 27° 39' 46" S.; ~~Section, Township, Range~~; WINTINNA 1:250,000; ~~County~~; ~~Area or Field~~; WINTINNA ARCKARINGA 1"=1MILE BASIN

Record Number	Shothole Number	D_{gm}	D_s	t_{us}	t_r	T Reading	T Polarity	T Grade	D_{gs}	H	tan i	cos i	T_{gs}	Δsd	$\frac{\Delta sd}{V}$	T_{gd}	T_{gd} Average	D_{gd}	ΔD_{gd}	ΔT_{gd}	Vi Interval Velocity	Va Average Velocity
13	1	171	3½	·002	·056	·0635	Up	P	165·5	83	·5015	·89389	·0545	1½	·001	·0535		164				3065
12		345	4	25	565	·0875		F	339		·2448	·97132	·0826	1	05	0821	·0821	338	174	·0286	6085	4115
11		"	4	25	545	·0875		F	"		"	"	"	1	05	"		"	124	·0242	5125	
10		469	4	25	54	·1110		P	463		·1793	·98431	·1068	1	·05	·1063		462	179	·0266	6730	4345
9		648	3½	2	55	·1375		G	642·5		·1292	·99175	·1339	1½	1	·1329		641	298	·0384	7760	4825
8		946	3	2	535	·1755		G	941		·0882	·99612	·1723	2	1	·1713		939	294	·0367	8010	5480
7		1240	5	3	54	·2110		F	1233		·0673	·99775	·2080	0	0	·2080		1233	248	·0261	9500	5930
6		1488	3½	2	54	·2380		G	14825		·0560	·99844	·2351	1½	1	·2341		1481	249	·0266	9360	6325
5		1737	3	2	55	·2645		F	1732		·0479	·99886	·2617	2	1	·2607		1730	293	·0276	10615	6635
3		2030	3½	2	50	·2920		G	20445		·0410	·99915	·2893	1½	1	·2883		2023	54	·0030	18000	7015
2		2084	4	25	49	·2945		F	2078		·0399	·99920	·2918	1	05	·2913		2077				7130

Shot 1: Shoot box test.
4: Misfire.

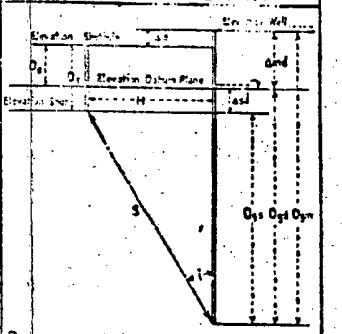
TD driller 2099'.
TD logger 2111'.

KB. 3'3".

$D_{gm} = D_{logger} \times \frac{2099}{2111} - 3'3"$

$T_{gs} = (t_r - .0025$ amplifier delay time$) \cos i$

Elev. Datum 782'



D_{gm} = Geophone depth measured from well elevation
D_{gs} = " " " " " shot "
D_{gd} = " " " " " datum "
D_s = Depth of shot
D_e = Shothole elevation to datum plane
H = Horizontal distance from well to shotpoint
S = Straight line travel path from shot to well geophone
t_{us} = Uphole time at shotpoint
T = Observed time from shotpoint to well geophone.
t_r = " " " to reference geophone.
Δe = Difference in elevation between well & shotpoint.
Δsd = " " " " shot & datum plane.
$\Delta sd = D_s - D_e$
$D_{gs} = D_{gm} - D_s \pm \Delta e$; $\tan i = \frac{H}{D_{gs}}$
T_{gs} = $\cos i$ T = Corr. travel time from shot elev. to geophone
$T_{gd} = T_{gs} \pm \frac{\Delta sd}{V}$ " " " " datum plane "
$D_{gd} = D_{gm} - \Delta sd$
Vi = Interval velocity = $\frac{\Delta D_{gd}}{\Delta T_{gd}}$
Va = Average " = $\frac{D_{gd}}{T_{gd}}$

Surveyed by: J. McG. Hall
Date: 28/11/70
Weathering Data: $V_w = 1650/S$
Casing Record

Well Velocity Calculation Form

TABLE 1.

ACKNOWLEDGEMENTS

The field operation was directed by J. McG. Hall, Assistant Senior Geophysicist, of the South Australian Geological Survey.

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APPENDIX G.

MOUNT WILLOUGHBY NO. 1 WELL: PALAEONTOLOGICAL EXAMINATION OF SELECTED MATERIAL

by

DR. B. McGOWRAN and W.K. HARRIS

PALAEONTOLOGY SECTION

PLATE 1:: PIECES OF CORE NO.6

Fig. 1 2088.5 feet: Dolomicrite (pale grey) disturbed and disrupted by the later intrusion of dolomitic sand (dark grey). Note the microcrystalline silicate concretion (white to very pale grey).

Fig. 2 2098.8 feet: Algal stromatolites (pale grey) in crystalline dolomite (dark grey).

Fig. 3 2091.9 feet: Ovoid concretion of intergrown microcrystalline quartz and dolomite enclosed in dolomicrite (dark grey). Note the two thin white bands of microcrystalline quartz.

2097.5 feet: Nodule, consisting of laths and rounded ovoids of microcrystalline granular quartz cemented by chalcedony, enclosed in dolomicrite (dark grey).

N.B. For a fuller description of these sections see Appendix D.

PLATE 2: PHOTOMICROGRAPHS OF A THIN SECTION FROM CORE NO. 6 (Depth: 2088.7 feet)

Fig 1: Contact of dolomicrite with clastic quartz, chert and microcline. x60

Fig 2: Dolomite euhedra in microcrystalline silica. The darker material is dolomicrite. x60

N.B. Both photomicrographs have been taken from A.M.D.E.L. thin section No. P709/70.

DEPARTMENT OF MINES
SOUTH AUSTRALIA

Pal.Rept. 1/71
G.S. No. 4594
Rept.Bk.No. 71/13
D.M. No. 612/70

MT. WILLOUGHBY NO. 1 WELL: PALAEONTOLOGICAL EXAMINATION OF SELECTED MATERIAL

Brian McGowran and Wayne K. Harris

Palaeontology Section

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DEPARTMENT OF MINES
SOUTH AUSTRALIA

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MT. WILLOUGHBY NO. 1 WELL: PALAEONTOLOGICAL EXAMINATION OF SELECTED MATERIAL

Brian McGowran and Wayne K. Harris

Palaeontology Section

ABSTRACT

Intersected Bulldog Shale is low, biostratigraphically well below the Coorikiana Member. The Algebuckina/Mt. Toondina contact can be placed at 655ft. Lithological and palynobiofacies evidence shows that base Mt. Toondina Beds is at 960ft. but that the section below this is either low Unit 1 or Unit 2. The contact is lower than at Cootanoorina biostratigraphically, and is presumed therefore to be older.

The stratigraphy of Lambina No. 1 is revised to the extent that the Mt. Toondina/Unit 1 or Unit 2 contact is raised to a transitional interval below 936ft. Criteria available at Mt. Willoughby are not useful here, perhaps because of transition, but particularly because contamination is heavy. Subsequent drilling in the Arckaringa Basin should include much more coring.

INTRODUCTION

Problems in the analysis of well logs and recovered lithologies from Mt. Willoughby No.1 led to a request from Mr. R.C.N. Thornton (Petroleum Exploration Division, GSSA) for a palaeontological study; hopefully, microfossils distribution would be pertinent to rock stratigraphic boundaries and correlations. Specifically, the problems were: the position of the Bulldog Shale section; the Algebuckina Formation/Mt. Toondina

Beds ; boundary (i.e. Mesozoic/Palaeozoic boundary); the Mt. Toondina Beds/Unit 1 boundary. Problems associated with the section drilled in Lambina No.1 arose early in the investigation. Samples were selected by comparing well logs. Reference is made to reports on both stratigraphic boreholes (1,2) for data on sites, drilling, and lithological and geophysical logs.

MATERIAL EXAMINED

Selected samples were examined for foraminifera or other microfossils in washed residues (Mp in Table 1) and for spores, pollen and noncalcareous microplankton in palynological preparations (Pn in Table 1). Table 1 includes essential conclusions.

TABLE I: SAMPLES EXAMINED, MT. WILLOUGHBY NO. 1

DEPTH (FT.)	MATERIAL		FORMATION	AGE	PALYN. SAMPLE
206	Core 1	PnMp	Bulldog Shale.	L. Cretaceous, C. hughesi s-zone.	S2186
211	Core 1	PnMp	" "	"	S2187
360-70	cuttings	Pn	Cadna-owie Form.	" , no older than "	S2201
610-20	"	Pn	Algebuckina Sst.	L. Cretaceous cavings only.	S2198
640-50	"	Pn	"	"	S2199
680-90	"	Pn	?Mt. Toondina Beds.	"	S2200
740-50	"	PnMp	Mt. Toondina Beds	L. Permian, Stage 3.	S2192
780-90	"	Pn	"	"	S2193
800-10	"	Mp	"		
840-50	"	Mp	"		
853	Core 2	Pn	"	L. Permian, Stage 3.	S2188
880-90	cuttings	PnMp	"	"	S2194
940-50	"	PnMp	"	"	S2195
980-90	"	PnMp	Unit 1 or Unit 2	L. Permian, Stage 2, with microplankton.	S2196
1000-10	"	Mp	"	"	
1020-30	"	PnMp	"	"	S2197
1040-50	"	PnMp	"	"	S2202
1081	Core 3	PnMp	"	"	S2190
1084.5	Core 3	PnMp	"	"	S2189
1100-10	cuttings	Mp	"		
1180-90	"	Mp			
2042	Core 4	Pn	Permian	(barren)	S2191
2087	Core 6	Pn	"	"	S2184
2091	Core 6	Pn	"	"	S2185

BULLDOG SHALE - LOWER CRETACEOUS

Core 1 at 206 ft. and 211 ft. yielded a well preserved and diverse assemblage referable to the Cyclosporites hughesi subzone of the Dictyotosporites speciosus zone (3). The nominate species is present. Marine influence is shown by the presence of abundant noncalcareous microplankton of the Dingodinium cerviculum zone (4). Core 1 therefore is low in the Bulldog Shale (5).

Foraminifera are rare in core 1 and are also poorly preserved, being crushed and flattened. The most common species is Trochammina minuta; others include Pseudobolivina engeninensis, Bigerina loeblichae, cf. Ammobaculites irrapatinensis and ?Reophax sp. The entirely arenaceous nature of this assemblage and its specific composition indicate that core 1 probably is in the lowest microfaunal zone of Trochammina raggatti - Textularia anacooraensis (6). That is, microfaunal evidence agrees with palynology that the encountered section is well below the Coorikiana Member.

CADNA-OWIE FORMATION - LOWER CRETACEOUS

Cuttings from 360-370ft. yielded a well preserved and diverse microflora which, definite contamination by caving notwithstanding, indicates that the age is no older than the Cyclosporites hughesi subzone. Thus identification of the Cadna-owie Formation is supported biostratigraphically (5,7).

ALGEBUCKINA SANDSTONE

Two samples, 610-620ft. and 640-650ft., yielded no microfossils other than downhole contaminants.

PERMIAN

The Algebuckina/Mt. Toondina (i.e. Mesozoic (Permian) and Mt. Toondina/Unit 1 (? or 2) contacts could be studied only on the basis of cuttings. Although both Permian formations were cored some caution is necessary in considering results.

MT. TOONDINA BEDS

Permian microfloras are present in cuttings 740-750ft. and continue beyond cuttings 940-950ft. The assemblages are dominated by Parasaccites spp. and Granulatisporites trisinus, striate bisaccate pollen and Marsupipollenites sp. are also present. These data identify Permian palynological Stage 3(8), and indicate low Stage 3 rather than high. The low frequency of striate bisaccate pollen supports this.

No noncalcareous microplankton or foraminifera were found in the samples examined.

All palaeontological evidence, positive and negative, supports cuttings lithologies in identifying Mt. Toondina Beds as high as 740ft. Examination of cuttings 640-650ft. and 740-750ft. supports identification of the Algebuckina/Mt. Toondina contact at 655ft.

PERMIAN UNIT 1 or UNIT 2

Core 3 is a diamictite, an important rock type in the lower part of the Permian succession (9). This grey, calcareous clay, plastic when wet, with rounded and frosted quartz grains, is found in cuttings up to 960 feet although lithologies are mixed. At 940-950ft. the dominant lithology is a clayey micaceous siltstone typical of the Mt. Toondina Beds. Samples above and below the 940-970ft. interval confirm lithologically the well log evidence (1) for an important contact at 960ft. (corrected depth). We consider this to be the base of the Mt. Toondina Beds, and fossil evidence provides strong confirmation.

With the exception of occasional contaminants from the Cretaceous no foraminifera were found in any of the samples examined.

The base of the Mt. Toondina Beds in some sections is marked by the disappearance upwards of marine indicators: foraminifera and noncalcareous microplankton. Although no foraminifera were found microplankton are present in cuttings from 980-990ft. to 1040-1050ft. and in Core 3 at 1081ft. and 1084ft. 6in. The environmental significance of their presence-or-absence (7) is enhanced by preservational aspects: spores and pollen at 940-950ft. and above are preserved much better than at 980-990ft. and below, and corrosion in the lower samples is interpreted as being due to attack by marine micro-organisms.

The spore-pollen component of the core 3 assemblage has abundant Parasaccites spp. together with Sulcatisporites ovatus Punctatisporites gretensis and Microbaculispora tentula.

None of the elements characterizing palynological Stage 3 are present and those species that are, characterize Stage 2(8). Cuttings up to 980-990ft. can also be placed in Stage 2, being remarkably free of cavings from the Mt. Toondina Beds. Thus the Mt. Toondina Beds/Unit 1 or 2 contact at 960ft. is also the biostratigraphic Stage 3/Stage 2 contact.

Stage 2 microfloras are typical of Unit 2 and the lower section of Unit 1 (7). The apparent absence of foraminifera from microplankton-bearing samples supports this. The lithology of core 3 and cuttings is consistent both with some of the diamictites of Unit 2 (9) and with the plastic, sandy clays of Unit 1. We cannot go beyond an identification of "lower Unit 1 to Unit 2" for the section below 960ft.

The Stage 3/Stage 2 contact, identified at 960ft., was placed at about 2100ft. in Cootanoorina No.1 (7). Thus, at least 400ft. of Unit 1 is represented by the Mt. Toondina Beds in Mt. Willoughby No.1, or there is an hiatus. The first possibility is considered more likely on evidence from Lambina No.1 (below).

PRE-PERMIAN

No acid-resistant microfossils were found in samples from the dolomitic rocks of cores 5 and 6, and so there is no biostratigraphic evidence to hand as to age.

NOTE ON LAMBINA NO. 1

Results obtained in the stratigraphy of Mt. Willoughby No. 1 suggested, in comparing the well-log profiles, a subdivision of the section in Lambina No.1 somewhat different from that proposed previously (2). Accordingly, samples listed in Table 2 have been examined and are discussed briefly here.

Core 1 in typical Cadna-owie Formation lithology was barren palynologically.

Cuttings from 850-860ft. agreed with the Algebuckina Sandstone lithologically, although downhole contamination by Bulldog Shale is very bad. Cuttings 870-880ft. are similar, but a log break at 850ft. appears to be the Mesozoic/Permian contact (2).

Cuttings from between 890ft. and 1100ft. were washed, but yielded no microfossils apart from occasional Lower Cretaceous contaminants.

Cuttings from 890-900ft. and 910-920ft. show typical Mt. Toondina Beds lithology although the palynological data are not clear.

Cuttings from 930-1020ft. have varyingly mixed lithologies ranging from the silty, micaceous, noncalcareous Mt. Toondina Beds to grey, sandy, calcareous, plastic clays similar to those identified herein as Unit 1 or Unit 2 in the Mt. Willoughby section. Contamination clearly is very heavy, but the inspection did not contradict Thornton's (2) analysis in which a brief alternation of the two lithologies correlates with two well-defined highs in gamma-ray count, centred on 950 and about 1000ft. respectively. The Mt. Toondina Beds/Unit 1

TABLE II: SAMPLES EXAMINED, LAMBINA NO. 1

DEPTH (FT.)	MATERIAL		FORMATION	AGE	PALYN. SAMPLE
593	Core 1	Pn	Cadna-owie Formation	(Barren)	-
899-900	Cuttings	Mp	Mt. Toondina Beds		
910-20	"	PnMp	Mt. Toondina Beds.	L. Permian, Stage indet.	S211
930-40	"	Mp	?		
950-60	"	PnMp	?Mixture	L. Permian, Stage 3.	S2210
970-80	"	Mp	"Mt. Toondina Beds"		
990-1000	"	Mp	"		
1010-20	"	PnMp	?Mixture	L. Permian, Stage indet.	S2209
1030-40	"	Mp	Unit 1 or Unit 2		
1050-60	"	PnMp	Unit 1 or Unit 2	L. Permian, Stage indet.	S2208
1070-80	"	Mp	"		
1090-1100	"	Mp	"		
1445	Core 3	Pn		L. Permian, Stage 2, with microplamkton.	

or Unit 2 contact could be as high as the well defined horizon at 936ft. (2) even though a good Stage 3 microflora with no microplankton was found at 950-960ft. The choice between this horizon and the equally well marked level at about 985ft. would appear to be arbitrary. Contamination has swamped the cuttings and precluded the use of microplankton and palynological Stages.

Core 3 at 1445 ft. has a good Stage 2 microflora, (8) and also includes microplankton.

If, then, there is the repetition of lithologies as indicated (2) below 936ft. - and not contradicted by our study, but identified as the change from Unit 1 (?2) to Mt. Toondina Beds - this is good evidence that the formations are not disconformable. Extrapolating to Mt. Willoughby, the (better defined) contact in that section is likely to be lower (older) than at Cootanoorina on the evidence of the palynological Stage 3/Stage 2 boundary. Thus we have, perhaps, confirmation of the suggestion (10) that the base of the Mt. Toondina Beds is significantly allochronous.

CONCLUDING REMARKS

This study was carried out in response to certain questions which arose during preparation of the Mt. Willoughby No.1 Well Completion Report. It is highly selective in its scope. The lack of foraminifera meant that a routine study based on original and washed cuttings would be unrewarding. However, the inadequacy of the material for palynological analysis is the more important point here. The nature and distribution of microfossil assemblages are significant in the Permian of the Arckaringa Basin

(9; ref. therein) and the main thing now outstanding is a sufficiently refined, locally based biostratigraphic framework. This can be provided only by palynology, and undoubtedly it will help to clarify various problems both within the area and in integrating the story into that of the Australian Permian at large. To do this one can go only so far on the basis of micro-floral successions documented in eastern and West Australia (8, 11); local confirmation and perhaps refinement are required.

Environmentally - the Mt. Toondina/Unit 1 contact is the best example - stratigraphic tops to the ranges of marine micro-organisms (foraminifera, organic-walled microplankton) give the main facts. The sometimes startling buildup in fossils during the increase in marine influence (Unit 1) is blurred rather than falsified outright by downhole contamination. That is, cuttings have significant information content.

Correlation and age determination are in diametric contrast to this situation. The palyno-biostratigraphic "Stages" (8) are based on floral buildup: each successional unit contains essentially the elements of the preceding, plus new elements. Clearly, rotary cuttings will not reflect this item of historical biology with any reliability. (The Stage 3/Stage 2 boundary at Mt. Willoughby is a rare and precious exception).

Palynological work is proceeding in the pre-Mt. Toondina section at Mt. Willoughby in the hope that something can be salvaged from cuttings. In Lambina No.1., contamination is particularly bad and crucial questions could not be answered. Neither bore will improve substantially the present situation.

There are two answers to these problems. One is to

increase routine coring regardless of significant lithological changes. The second is to introduce routine sidewall coring, based on well logs, into the drilling programme.

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BMcG:MK
29.1.1971

Brian McGowran

Wayne K. Harris

COMPOSITE WELL LOG

SOUTH AUSTRALIAN DEPARTMENT OF MINES

MT. WILLOUGHBY No.1.

STATE: SOUTH AUSTRALIA

PETROLEUM TENEMENT: Out of Lease Areas 1:250000 MILE SHEET: Wintinna.

BASIN: Arckaringa

WELL STATUS: Dry and Abandoned

LOCATION: 27° 39' 46" S. 134° 18' 39" E.

ELEVATION: G.R. 789' (240·5m) A.S.L.
R.T. 792·25' (241·5m) A.S.L.

DATE SPUDDED: 5 Nov. 1970
DATE DRILLING STOPPED: 23 Nov. 1970
DATE RIG RELEASED: 26 Nov. 1970
TOTAL DEPTH: 2098·8ft (639·68m.)

HOLE SIZE:

INCHES	FROM	TO	
9¼"	0'	20'	(6·10 m.)
6¾"	20'	145'	(44·20m.)
4½"	145'	2022'	(616·31m.)
4¼"	2022'	2087'	(636·12m.)
3·907	2087'	2098·8'	(639·68m.)

CASING:

INCHES	DEPTH	CEMENTED TO	FROM
5	144·5' (44·04m)	Surface	

CEMENT PLUGS: 650' (198·12m.) – 700' (213·36m) with 5 sacks cement

DRILLED BY: S. A. DEPARTMENT OF MINES.
DRILLING METHOD: ROTARY.
LOGGED BY: S. A. DEPARTMENT OF MINES.

TYPE OF LOG	16. IN. NORMAL	64. IN. NORMAL	6 FT. LATERAL	S.P	NEUTRON	GAMMA RAY
DATE OF RUN	23 Nov. 1970	23 Nov. 1970	24 Nov. 1970	23 Nov. 1970	24 Nov. 1970	24 Nov. 1970
FIRST READING (FT)	2111	2111	2111	2111	2110	2100
LAST READING (FT)	145	140	145	145	25	20
INTERVAL MEASURED (FT)	1966	1971	1966	1966	2085	2080
CASING: LOGGER (FT)	140	140	145	145	140	145
CASING: DRILLER (FT)	144·5	144·5	144·5	144·5	144·5	144·5
DEPTH REACHED (FT)	2111	2111	2111	2111	2110	2100
BOTTOM: DRILLER (FT)	2098·8	2098·8	2098·8	2098·8	2098·8	2098·8
MUD TYPE	Water base	Water base	Water base	Water base	Water base	Water base
DENSITY/ VISCOSITY	9·7/48	9·7/48	9·7/48	9·7/48	9·7/48	9·7/48
Ph/ FLUID LOSS c.c	11/4	11/4	11/4	11/4	11/4	11/4
MUD RESISTIVITY	5·3 at 75°F	5·3 at 75°F	5·3 at 75°F	5·3 at 75°F	5·3 at 75°F	5·3 at 75°F
RECORDED BY	L.K. West	L.K. West	L.K. West	L.K. West	L.K. West	L.K. West
WITNESSED BY	R.C.N. Thornton	R.C.N. Thornton	R.C.N. Thornton	R.C.N. Thornton	R.C.N. Thornton	R.C.N. Thornton

OTHER SURVEYS:

TYPE	FROM	TO
Temperature log	0'	2103'
Point Resistivity	2111'	145'

LITHOLOGICAL REFERENCE

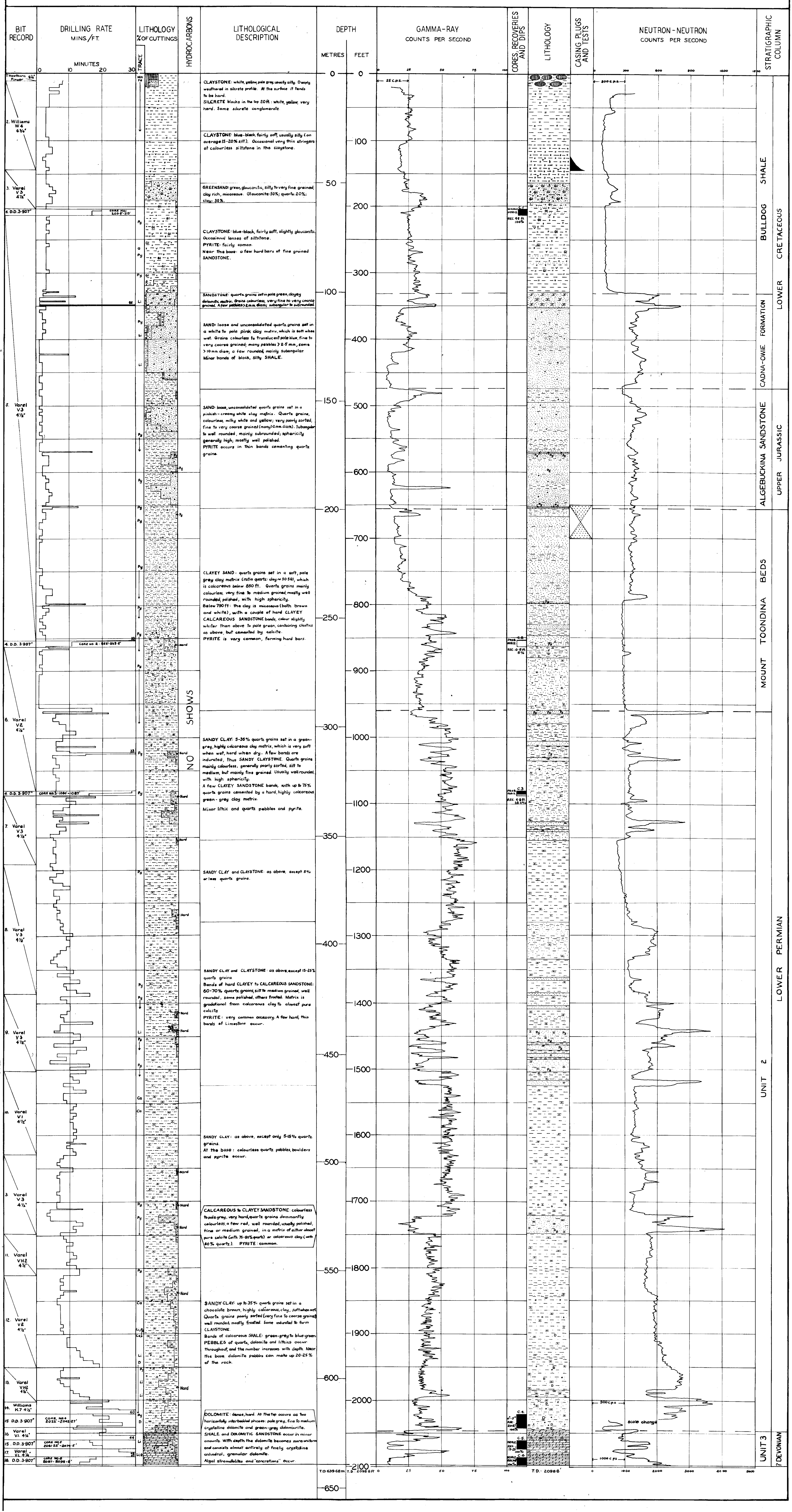
Shale claystone	Sandstone	K Kaolinitic
Sandy shale	Granular	Gl Glauconitic
Silty shale	Pebble	G Garnet
Siltstone	Li Lithic	Calcareous
Argillaceous siltstone	Anhydrite	Dolomitic
Sandy siltstone	Py Pyrite	Oolitic
Limestone	V Micaceous	F Fossiliferous Fragmental or Indeterminate
Dolomite	Carbonaceous	f Feldspathic
Coal	Fe Ferruginous	Gy Gypsum Gypsiferous
Silcrete	Ca Calcite Fragments Limestone Pebbles	Mn Manganese
Q Quartz grains	D Dolomite pebbles	

WELL SYMBOLS

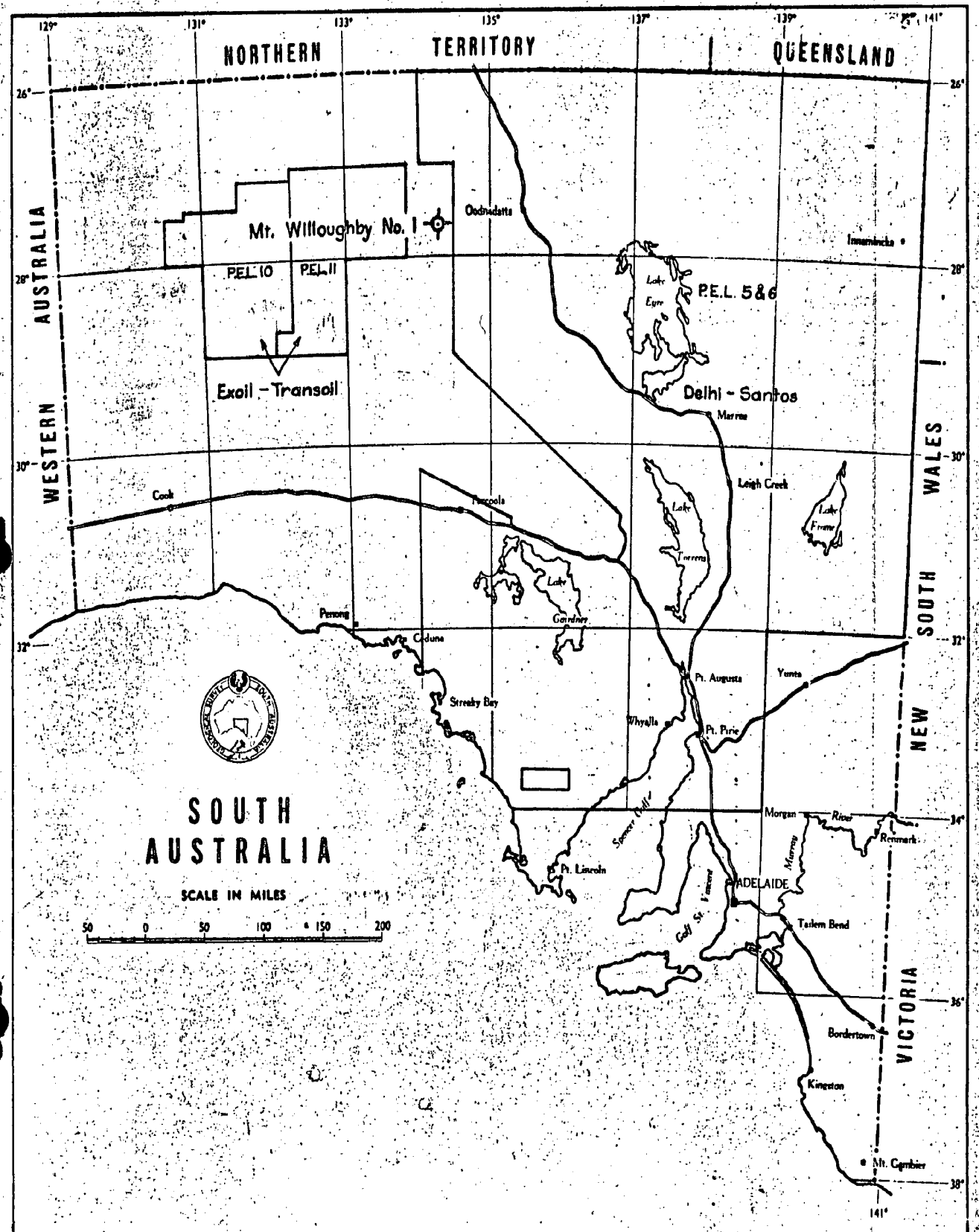
CORE INTERVAL AND NUMBER	CASING SHOE
PLUGGED INTERVAL	Fl FLUORESCENCE
	* CUT WITH CCl_4

LITHOLOGY BY: R.C.N.THORNTON.
COMPILED BY: R.C.N.THORNTON.
DRAFTED BY: J.M.BRADFORD.
DRAWING NUMBER: L 71–3.

DEPARTMENT OF MINES – SOUTH AUSTRALIA		
MT. WILLOUGHBY No. 1. COMPOSITE WELL LOG		
PETROLEUM SECTION	DRN R.C.N.T.	SCALE: 1 inch = 50 feet
GEOLOGIST	TCD. J.M.B.	L 71–3 8a
	CKD. L.V.W.	
SEN. GEOLOGIST	EXD.	DATE: 26 February 1971.



BIT RECORD
DRILLING RATE MINS./FT.
MINUTES
LITHOLOGY % OF CUTTINGS
HYDROCARBONS
LITHOLOGICAL DESCRIPTION
DEPTH
METRES
FEET
GAMMA-RAY COUNTS PER SECOND
CORES, RECOVERIES AND DIPS
LITHOLOGY
CASING PLUGS AND TESTS
NEUTRON-NEUTRON COUNTS PER SECOND
STRATIGRAPHIC COLUMN
CLAYSTONE: white, yellow, pale grey, usually silty. Deeply weathered in silcrete profile. At the surface it tends to be hard.
SILCRETE blocks in the top 20ft.: white, yellow, very hard. Some silcrete conglomerate.
CLAYSTONE: blue-black, fairly soft, usually silty (on average 15-20% silt). Occasional very thin stringers of colourless siltstone in the claystone.
GREENSAND: green, glauconitic, silty to very fine grained, clay rich, micaceous. Glauconite: 50%; quartz: 20%; clay: 30%.
CLAYSTONE: blue-black, fairly soft, slightly glauconitic. Occasional lenses of siltstone.
PYRITE: fairly comon.
Near the base: a few hard bars of fine grained SANDSTONE.
SANDSTONE: quartz grains set in pale green, clayey dolomitic matrix. Grains colourless, very fine to very coarse grained. A few pebbles > 2mm. diam; subangular to subrounded.
SAND: loose and unconsolidated quartz grains set in a white to pale pink clay matrix, which is soft when wet. Grains colourless to translucent pale blue, fine to very coarse grained; many pebbles > 2·5 mm., some > 10 mm. diam; a few rounded, mainly subangular. Minor bands of black, silty SHALE.
SAND: loose, unconsolidated quartz grains set in a pinkish-creamy white clay matrix. Quartz grains, colourless, milky white and yellow; very poorly sorted, fine to very coarse grained (many > 2mm. diam). Subangular to well rounded, mainly subrounded; sphericity generally high; mostly well polished.
PYRITE occurs in thin bands cementing quartz grains.
CLAYEY SAND: quartz grains set in a soft, pale grey clay matrix (ratio quartz: clay ~ 50:50), which is calcareous below 850 ft. Quartz grains mainly colourless, very fine to medium grained, mostly well rounded, polished, with high sphericity.
Below 790 ft: the clay is micaceous (both brown and white), with a couple of hard CLAYEY CALCAREOUS SANDSTONE bands, colour slightly whiter than above to pale green, containing clastics as above, but cemented by calcite.
PYRITE is very common, forming hard bars.
NO SHOWS
SANDY CLAY: 5-35% quartz grains set in a green-grey, highly calcareous clay matrix, which is very soft when wet, hard when dry. A few bands are indurated, thus SANDY CLAYSTONE. Quartz grains mainly colourless, generally poorly sorted, silt to medium, but mainly fine grained. Usually well rounded, with high sphericity.
A few CLAYEY SANDSTONE bands, with up to 75% quartz grains cemented by a hard, highly calcareous green-grey clay matrix.
Minor lithic and quartz pebbles and pyrite.
SANDY CLAY and CLAYSTONE: as above, except 5% or less quartz grains.
SANDY CLAY and CLAYSTONE: as above, except 15-25% quartz grains.
Bands of hard CLAYEY to CALCAREOUS SANDSTONE: 60-70% quartz grains, silt to medium grained, well rounded, some polished, others frosted. Matrix is gradational from calcareous clay to almost pure calcite
PYRITE: very common accessory. A few hard, thin bands of Limestone occur.
SANDY CLAY: as above, except only 5-15% quartz grains.
At the base: colourless quartz pebbles, boulders and pyrite occur.
CALCAREOUS to CLAYEY SANDSTONE: colourless to pale grey, very hard, quartz grains dominantly colourless, a few red, well rounded, usually polished, fine or medium grained, in a matrix of either almost pure calcite (with 75-80% quartz) or calcareous clay (with 60% quartz). PYRITE: common.
SANDY CLAY: up to 35% quartz grains set in a chocolate brown, highly calcareous, clay, soft when wet. Quartz grains poorly sorted (very fine to coarse grained) well rounded, mostly frosted. Some indurated to form CLAYSTONE.
Bands of calcareous SHALE: green-grey to blue-green.
PEBBLES of quartz, dolomite and lithics occur throughout, and the number increases with depth. Near the base dolomite pebbles can make up 20-25% of the rock.
DOLOMITE: dense, hard. At the top occurs as two horizontally interbedded phases: pale grey, fine to medium crystalline dolomite and green-grey dolomicrite.
SHALE and DOLOMITIC SANDSTONE occur in minor amounts. With depth the dolomite becomes more uniform and consists almost entirely of finely crystalline anhedral, granular dolomite.
Algal stromatolites and "concretions" occur.
BULLDOG SHALE
LOWER CRETACEOUS
CADNA-OWIE FORMATION
ALGEBUCKINA SANDSTONE
UPPER JURASSIC
MOUNT TOONDINA BEDS
LOWER PERMIAN
UNIT 2
UNIT 3
DEVONIAN



	DEPARTMENT OF MINES — SOUTH AUSTRALIA	Scale: As shown
Compiled: R. Thornton	MOUNT WILLOUGHBY No. 1	Date: 11th Jan. 1971
Drn: S.J.C. Ckd: L.V.W.	LOCALITY MAP	Drg. No. S9135 Ba

P.F. No S5850 994-2

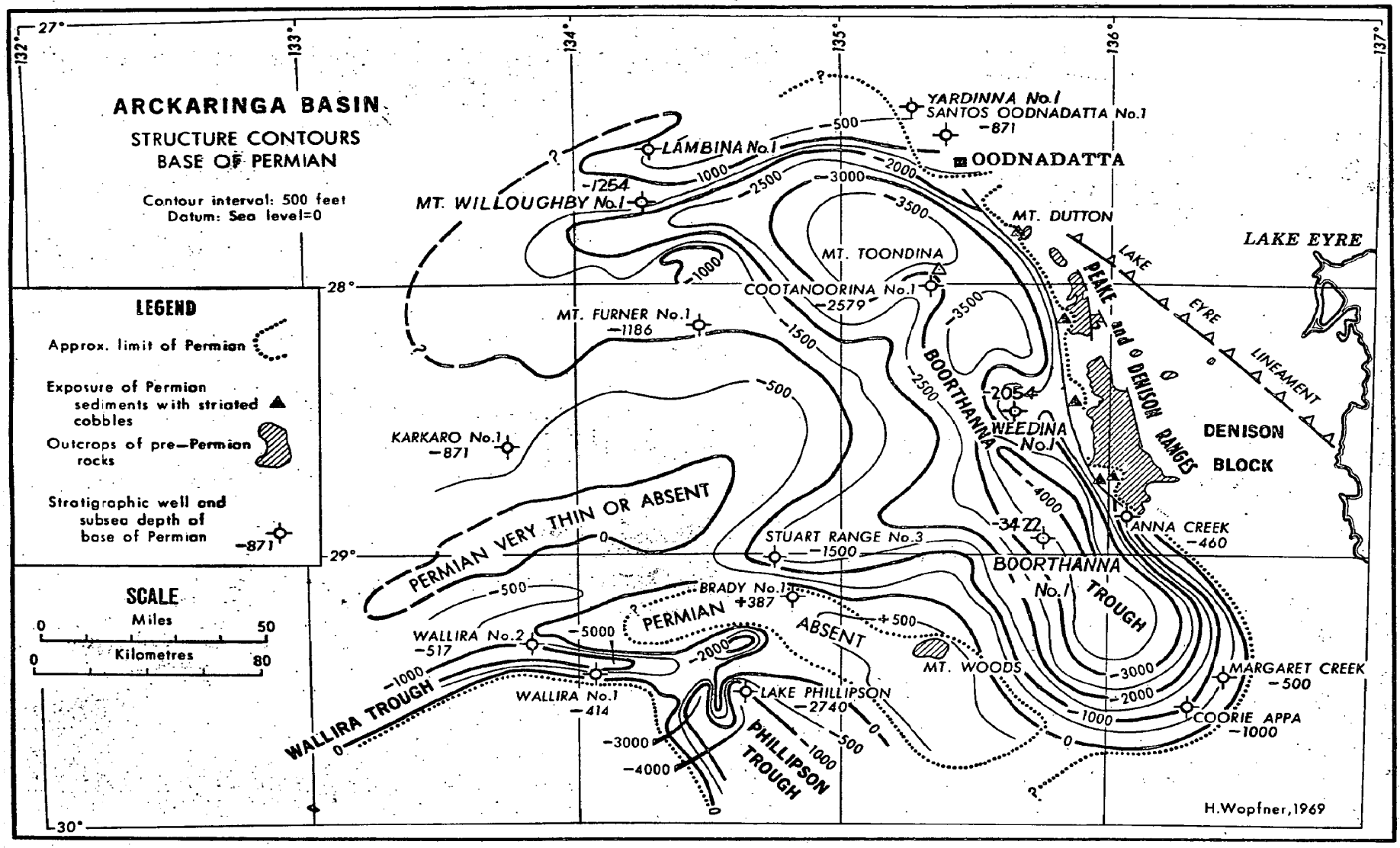
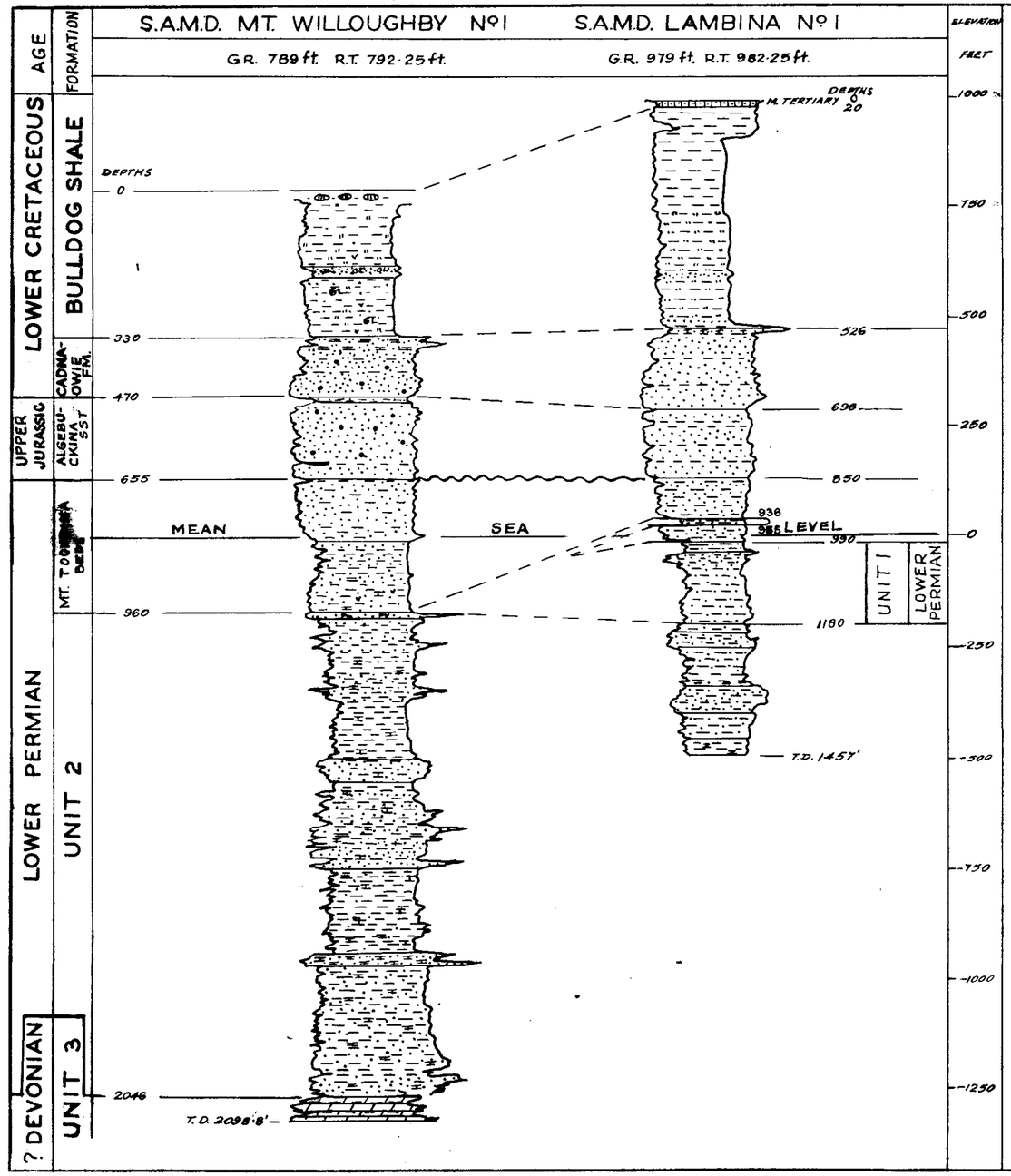
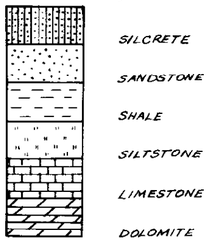


Fig.2 Arckaringa Basin, Structure Contours on Base of Permian



IM-2,70 A1811



Py: Pyrite Gl: Glauconite

o: pebble v: mica

LOCALITY PLAN

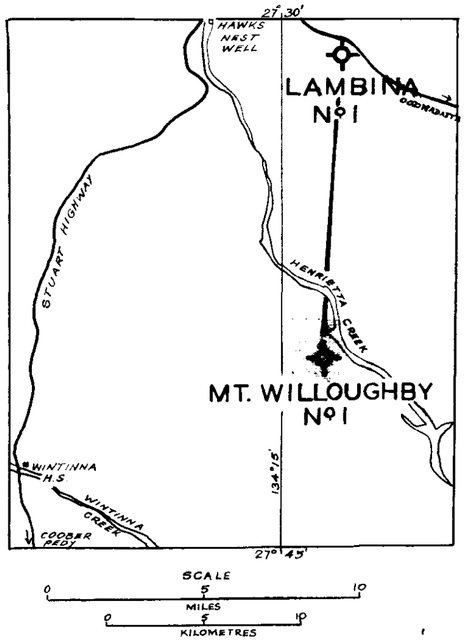
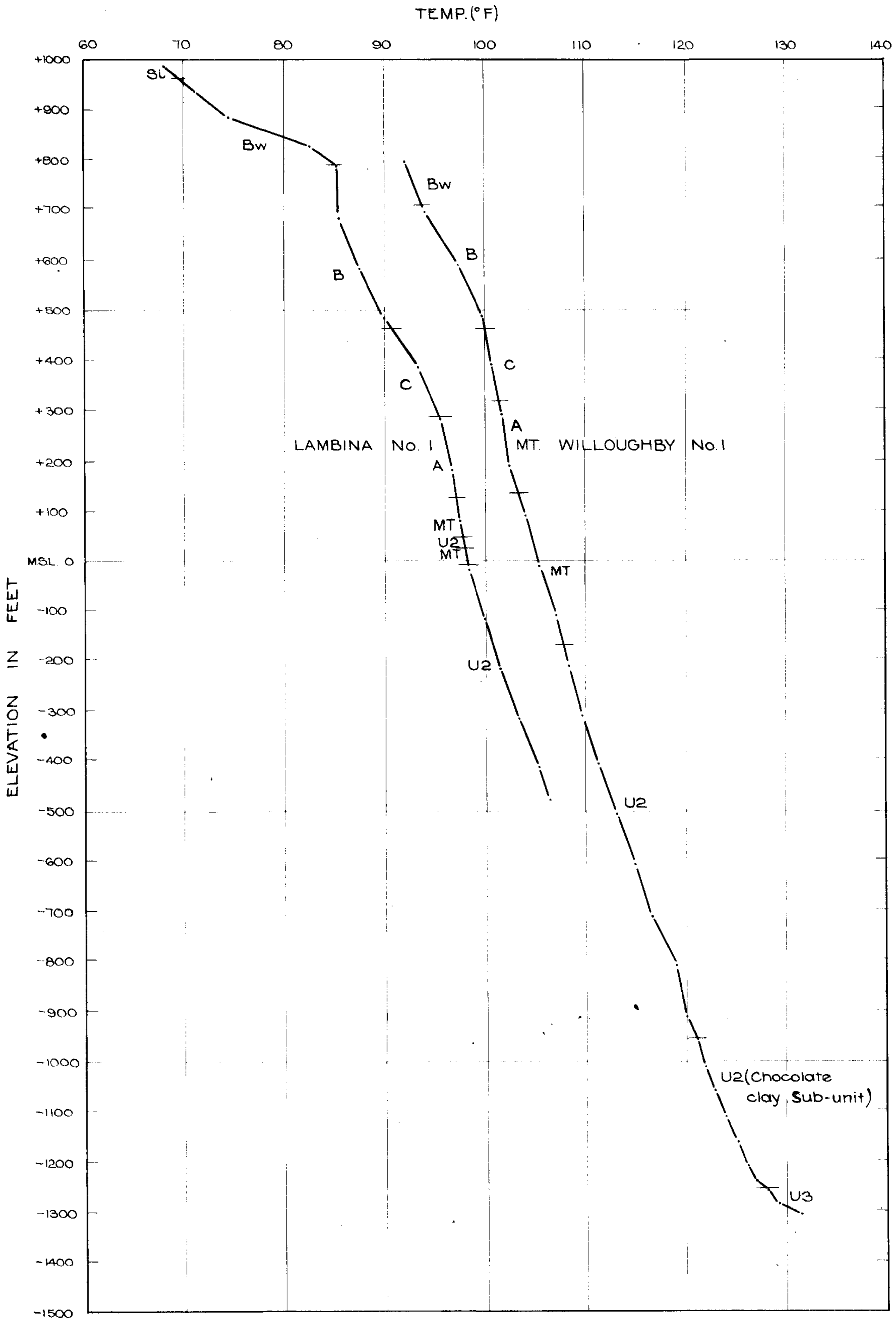


FIG. 3.

	DEPARTMENT OF MINES — SOUTH AUSTRALIA	Scale:
Compiled: R.C.M.T.	MT. WILLOUGHBY Nº1 & LAMBINA Nº1	Date: 11 Feb. '71
Drn. D.W.W. Ckd. L.V.W.	GAMMA RAY-NEUTRON CORRELATION DIAGRAM	Drg. No. 71.118 Ba



SL : Silcrete
Bw : Weathered Bulldog Fm.
B : Bulldog Fm.
C : Cadna-Owie Fm.
A : Algebuckina Sst.
MT : Mt. Toondina Beds
U2 : Unit 2
U3 : Unit 3

Note : MT. WILLOUGHBY No. 1 Curve.
1. Increase in temperature gradient below -956 ft. chocolate clay Sub-unit of Unit 2
2. Increase in temperature gradient below -1254 ft. Unit 3

DEPARTMENT OF MINES – SOUTH AUSTRALIA

MT. WILLOUGHBY No. 1 & LAMBINA No. 1
DEPTH-TEMPERATURE CURVES

Compiled: RT
Drn. SLT Ckd. LVW
Scale: As shown
Date: 23 Feb. '71
Drg. No. 71-171
Ba

FIG. 4.

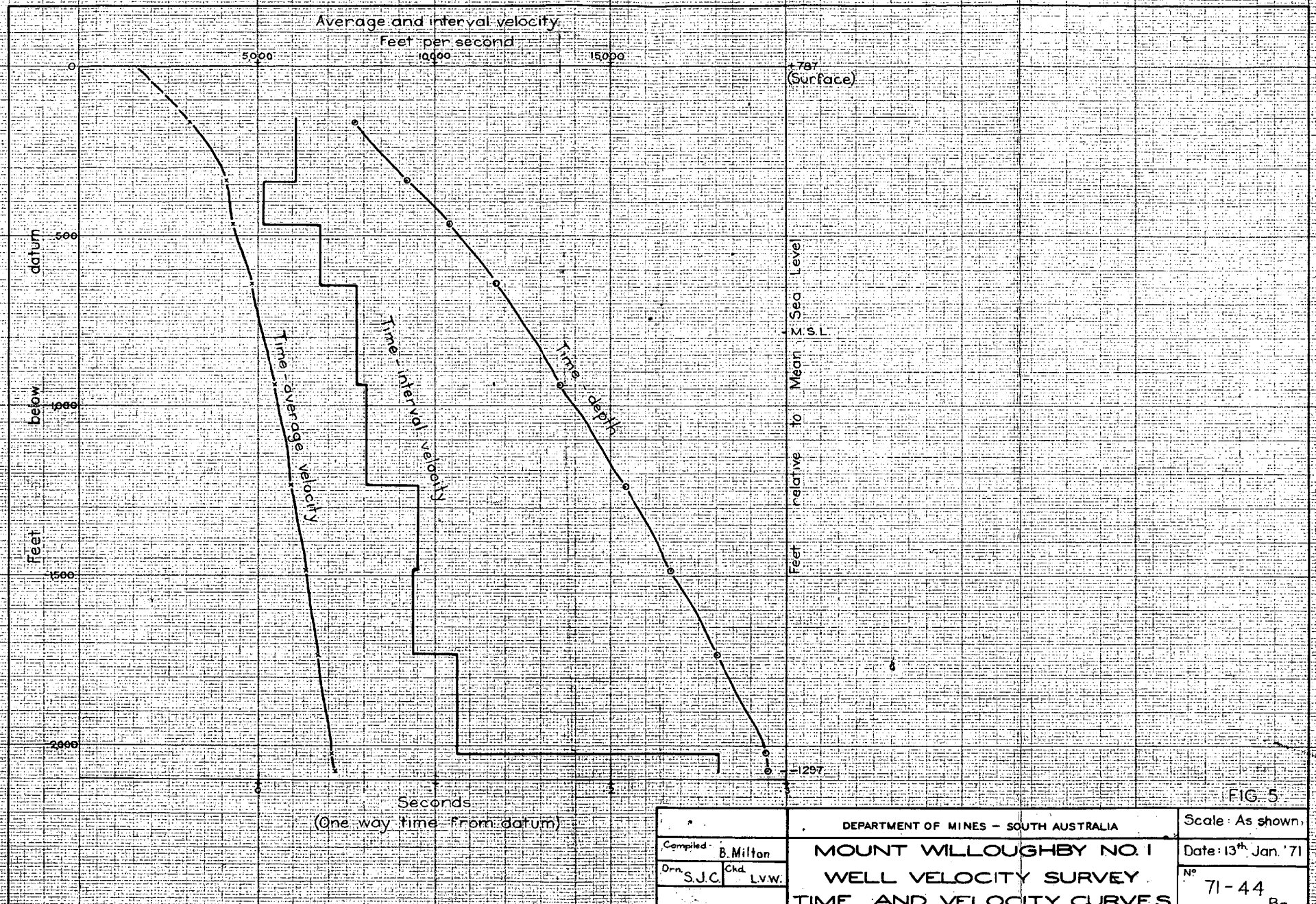


FIG. 5

Compiled B. Milton Drn. S.J.C. Ckd. L.V.W.	DEPARTMENT OF MINES – SOUTH AUSTRALIA MOUNT WILLOUGHBY NO. 1 WELL VELOCITY SURVEY TIME AND VELOCITY CURVES	Scale: As shown. Date: 13th Jan. '71 No 71-44 Ba