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STRATIGRAPHY OF THE MURRAY BASIN IN SOUTH AUSTRALIA

by

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CONTENTS

Page

ABSTRACT

The Murray Basin is an area of Mesozoic and Tertiary sedimentation divided into two main units the Murray Basin proper separated by structural highs, the Padthaway "Horst", from the Gambier Embayment.

Knowledge of the Mesozoic in the Murray Basin proper is limited to two bores in the Lameroo area which entered siltstones and mudstones below 1350 feet. In the Gambier Embayment an undetermined thickness of siltstones, mudstones and arkosic sandstones mainly of Lower Cretaceous age occurs.

Older rocks are everywhere overlain by a Tertiary sequence rarely exceeding 1000 feet in thickness in the Basin proper but at least 4000 feet thick in the Gambier Embayment. Seventeen rock units are recognized in this sequence, the biostratigraphy of which is described in general terms.

INTRODUCTION:

The study of sedimentation in the Murray Basin has been carried out almost entirely from bore cuttings in connection with underground water supplies. With the exception of a limited marginal area between Lake Alexandrina and Truro, surface mapping of the Basin has not yet commenced.

Observations on the Tertiary sequence exposed as a result of down cutting by the Murray River were made by Sturt (1833) and later in 1885 Tate published stratigraphical notes on the "Murravian" Series which he measured and sampled during journeys up and down the river by boat.

In the 70 years following Tate's work in 1885, despite the economic development of the area, very little attention was paid to details of the Tertiary stratigraphy, the general tendency being to over-simplify the whole of the sedimentary series. The sections measured and described by Tate have in recent years been remeasured and sampled and the complexity of the stratigraphy developed from a preliminary study of the microfaunas of exposed sections and numerous water bores.

Detailed faunal studies have still to be undertaken.

All type material with the exception of molluscan holotypes, is housed in the S.A. Mines Department Museum Palaeontological Collection.

ACKNOWLEDGEMENTS

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SEDIMENTATION IN THE MURRAY BASIN

The Murray Basin commenced to form during the Mesozoic when sedimentation began in both the Murray Basin proper and the Gambier Sunklands in a structural setting the outline of which has been published elsewhere (Ludbrook, 1958). Lower Cretaceous shales and mudstones have been recognized both in the Gambier Sunklands and in the Loxton district; these are followed by an almost complete Tertiary sequence which is nowhere continuous. The Basin appears always to have been shallow in the South Australian portion and the resulting stratigraphic units are thin, interdigitating either as a result of local regressions and transgressions or as a result of subsequent local erosion.

The biostratigraphic units recognized in 1959 are shown in Table 1. The areas over which the units have been noted are shown in Figure 5.

PROTEROZOIC AND PALAEOZOIC BEDROCK

In the Murray Basin proper no bore has so far gone deeper than 1800 feet at which Australian Oil & Gas Corporation's Bore near Loxton bottomed in Lower Cretaceous sediments with boulders of Kanmantoo greywacke. South of the Murray River most bores reaching bedrock have entered phyllitic slates, micaceous schist, greywacke or granitised rocks of the Kanmantoo Group which extend at least as far as the Victorian border. On the western margin of the Basin Tertiary transgressions on to Kanmantoo are well exposed at many localities including the Strathalbyn district and the Marne River Valley. East of Truro in the Hundreds of Anna and Bromlow the Tertiary laps on to Adelaide System rocks in Lewi's Creek and ½ mile north on Section 229E Hundred of Anna, where on the north side of a small gully a low ridge of yellow Miocene limestone is in strong contrast to the grey rocks of the Adelaide System on the southern side.

On Bungunnia Station, 30 miles north of Morgan, a water bore bottomed in purple slates at 1275 feet.

PERMIAN

Beyond records of boulder clays in bores between Lake Alexandrina, the Coorong and Coonambook, the extent of Permian glaciation in the Basin is unknown.

MESOZOIC

Mesozoic rocks in the Murray Basin proper are known from two occurrences at depth in the Lexton area: below 1336 feet in "Company's" Bore sunk in 1930 by Engineer-in-Chief's Department for the Lexton Farming Company, 15 miles north-east of Lexton, on Section 17, Hundred of Gordon, and below 1350 feet in Australian Oil & Gas Corporation's Lexton Oil Bore put down in 1956 on Part Section 68 Hundred of Booborowong. Information on "Company's" Bore is limited to three small remnants of bore cuttings discovered at the South Australian Museum among material formerly in the possession of Professor Howchin. So far as can be deduced from the log and from microscopic examination of the cuttings the probable sequence in this bore was:

Depth	Lithology	Formation	Age	Thickness
0'- 51'	Sand, gravel and clay		Pleistocene-Recent	51'
51 - ?156	Mostly sand with some clay	Lexton Sands	?Upper Miocene	?105'
?156 - 220	Blue sand and clay with fossil shells 176'-199'	Booborowong Beds	?Upper Miocene	? 64'
220 - 330	Grey sandstone and clay	? equivalents of Pata, Morgan, Knuppa and Gambier Limestones	Middle Miocene to Oligocene	492'
330 - 712	Argillaceous limestone			
712 - 747	Fossiliferous pyritic clay	Affinities doubtful	?early Oligocene or late Eocene	35'
750 - 1102	Carbonaceous clay and sand	Paralic sediments of Knight group	Eocene	344'

Depth	Lithology	Formation	Age	Thickness
1596 - 1805	Blue shale and sandstone	Non-marine sediments	Cretaceous	209+ ft.

Australian Oil & Gas Co's. Loxton Bore entered at 1315 feet, below carbonaceous silty sands of the Knight Group, light brown coarse angular silty grit of undetermined age passing into paralic sandy plastic clay, siltstone and sandy mudstone at 1350 feet. The mudstones contain quartz, muscovite, biotite, chlorite, glauconite and carbonaceous matter but no foraminifera above 1587 feet. At 1587 feet the boring entered greenish grey carbonaceous shale with abundant glauconite and pyrite and several species of arenaceous foraminifera: Haplophragmoides sp., Ammobaculoides romaensis, Ammobaculites minimus, Textularia sp., Marssonella kummi, Trochammina minuta. The fauna is impoverished and on somewhat negative evidence the age of the sediments at this level was tentatively determined (Ludbrook unpublished report 1956 Geol. Surv. S.A. G 593, Pal. Rep. 14/56) as Upper Albian (Tambo Formation) and later supported by Cookson & Dettmann (1958a p. 40).

It seems likely that shallow waters of the Lower Cretaceous seas entered the Murray Basin from the Great Artesian Basin by way of a channel following the present course of the River Darling. Exposures of possibly Albian sediments are known to occur east of Wilcannia on the Cobar Road.

An unproved thickness of Mesozoic sediments occurs in the Gambier Sunklands but the stratigraphic picture is not clear and much evidence has been lost with the discarding of well cuttings in the past.

The relatively thick series of arkosic sandstones, greywackes, grits, carbonaceous mudstones and siltstones named the Merino Group in Victoria (Kenley, 1954) formerly regarded as Jurassic is now believed to be largely of Lower Cretaceous age. At the top of the Group is the Runnymede Formation with dicotyledonous plant remains (Medwell, 1954).

No exposures of the Group are known in South Australia. The only bore in the South East of which continuous Mesozoic core is available for study is Comaum No. 2 (1952), in which the Nelnie Group is probably represented below 650 feet. ~~Only petrographic study has been done in detail, report of which is appended.~~ Mesozoic sediments were apparently entered at 650 feet, the uppermost of which were fine soft grey mudstones. Sedimentation is fairly uniform to the bottom of the bore, a change occurring at about 700 feet where a corresponding peak occurs in the radiometric log. The upper mudstones have been correlated with the Runnymede Formation (Boutakoff & Sprigg 1953, Ludbrook 1958). No palynological study of the arkosic sandstones below 708 feet has been attempted; mudstone at 650 feet was determined as Jurassic (Cookson, 1953, p. 463) later as Cretaceous (Cookson, 1954) and Lower Cretaceous, possibly Albian (Cookson & Dettmann 1958, p. 125).

A small collection of eleven labelled and several unlabelled specimens from South Australian Oil Wells No. 1 Bore, Section 714, Hundred of Waterhouse ("Rebe Bore") was presented to the South Australian Museum by Mr. H.F. Kessal of Mount Gambier and lent by the Museum for examination. This represents the only material preserved from this important bore.

Labelled specimens comprise:

Depth	
1400 feet	Grey mudstone
1630 feet	Grey-green siltstone
1780 feet	Greenish-grey micaceous siltstone
2325 feet	" " " "
2360 feet	Greenish-grey laminated siltstone
3150 feet	Darkish greenish grey carbonaceous siltstone
3300 feet	Dark greenish grey siltstone with carbonized plant fragments
3325 feet	Greenish grey somewhat sandy siltstone
3500 feet	Greenish grey laminated carbonaceous siltstone
4300 feet	Coal
4490 feet	Light greenish grey arkosic sandstone

The specimens from above 4490 feet, so far as could be determined from the small amount of material available, were tentatively suggested (Ludbrook, 1958) as corresponding to the 690-708 feet interval in Comaum Bore and the arkosic sandstone at 4490 feet to those below 708 feet in Comaum. Cookson & Dettmann (1958, p. 97) have determined a Lower Cretaceous sequence on the trilete spores in five of the samples from the Robe material.

TERTIARY

Older rocks are everywhere unconformably overlain by Tertiary sediments which, in the Murray Basin proper, have rarely been shown to exceed 1000 feet in thickness although in the Gambier Sunklands the Nelson Bore proved them to be at least 4000 feet thick. The oldest Tertiary strata belong to the Knight Group, of Eocene age.

(1) KNIGHT GROUP

The base of the Tertiary in the Basin is marked by a relatively thick series of paralic sediments which are undifferentiated in South Australia but divided into the Dartmoor and Bahgallah Formations in Victoria. The glauconitic and lignitic grits with Palaeocene to Lower Eocene fossils belonging to the Bahgallah Formation have not yet been identified in South Australia. Correlation of any part of the Knight Group with the overlying Eocene Dartmoor Formation has not been seriously attempted.

The Knight sands and clays were named by Sprigg (1952) and later extended to a Group by Sprigg & Boutakoff (1953). The name is taken from the only known exposure in South Australia in Knight's Quarry on the upthrow side of the Tartwaup Fault near Compton on Section 718, Hundred of Blanche, 8 miles north west of Mount Gambier. In this quarry Knight gravels and clay are discordantly overlain by the Compton Conglomerate and Gambier Limestone in the following descending sequence, measured in 1956 by geologists of Frome Broken Hill Pty. Ltd. and the writer over a total thickness of 29 feet:

Fig. 1. Knight Group clay and gravels, Hundred Blanche, Section 718, view south.

Fig. 2. Close view of quarry face and machinery October 1958.

Thickness (feet)	Lithology	Formation
2'0"	Dark brown surface soil	-
3'0"	Weathered cream glauconitic bryozoal limestone	Gambier Limestone
1'6"	Rubbly limestone - concealed	
8'0"	Yellow-brown bryozoal limestone with large limonitic nodules and bands of secondary calcification	
1'6"	Basal conglomerate with dark brown limonitic pebbles in recemented matrix; pebbles up to 2" long but not necessarily flat lying.	Compton Conglomerate
	Unconformity	
3'6"	White, reddish and yellow mottled plastic clay	Knight Group
10'0"	Ferruginous quartz gravels and grits somewhat irregularly bedded.	

The ferruginous gravels at the base, composed of polished subrounded quartz grains of medium to gravel size with fine mica flakes, are quarried by the Engineering and Water Supply Department as the only source of concrete aggregate in the district.

The Group thins out over the Padthaway "Horst" where highly carbonaceous beds are developed in areas of bedrock highs.

The Moorlands Coal Measures occur in this manner at depths of 60 to 100 feet below the surface under Buccleuch and Glenelg Group limestones, sandstones, and sandy clays.

A description of the strata intersected during a drilling programme to test the economic possibilities of the coalfield was published by McGarry (1953).

A distinctive formation of the Knight Group is well developed in the Murray Basin proper where it is of the order of 500 feet thick. The sediments consist of grey brown medium quartz sands, silty sands and carbonaceous silts passing downwards into dark brown sandy silts and silty sands. A few impoverished foraminifera mainly Globigerina, Uvigerina, Cibicides and lagenidae are usually present towards the top of the sequence indicating sedimentation under conditions of partial access to the sea. The sands are commonly gritty towards the base but

otherwise uniform in grain size throughout. The total thickness of the formation was intersected in both Lexton and Pinnaroo oil bores and over 400 feet in Canopus No. 1 Bore.

Sands with abundant Turritella aldingaa intersected in the northern part of County Cardwell near Coombe railway siding possibly represent the more seaward development of the same formation.

In Coonalpyn Township Bore these beds underlie the Bucclaeuch Group into which they pass conformably. In addition to Turritella aldingaa they contain Upper Eocene foraminifera and the scaphoped Dentalium (Gadilina) tatei Sharp & Pilsbry, described from the Eocene of the Adelaide Plains and apparently restricted to that level.

(2) BUCCLEUCH GROUP

In the Upper Eocene marine conditions similar to those in the St. Vincent Basin, and, to a lesser extent, to those in the Murray Basin existed over a limited area in the south west of the Murray Basin where in a small but probably moderately deep embayment (Fig. 1) extending roughly from Milang to the Barmon Jaluk Range and down to Coonalpyn marine limestones and sands interbedded with carbonaceous clays were laid down.

These were named (Ludbrook, 1957, p. 179) the Bucclaeuch Group, divided in upward sequence for practical purposes into Bed A - highly fossiliferous bryozoal limestone with a glauconitic marl member at the base, Bed B - incoherent carbonaceous sands with thin limestone bands, and Bed C a grey brown carbonaceous clay. It is likely that the Group is represented between 180 feet and 205 feet in the Bore section at Mulgundawa described by Tate (1900, p.110-111). It cannot be said with certainty that the bore on Section 302 Hundred of Malcolm (Tate, 1882, p. 145) entered the Bucclaeuch Group.

The beds are still insufficiently described and unnamed individually. They are correlatives of the Brown's Creek Clays - Castle Cove Limestone sequence in the Aire District of Victoria described by Carter (1958).

The area they cover falls mostly within County Buccleuch, the beds being particularly well developed around Coonalpyn in the Hundred of Coneybeer where borings on Sections 56, 25 and 44 all completely penetrated the Buccleuch sequence. In the Moorlands area also most of the beds are represented, Buccleuch A occurring as a hard grey bryozoal limestone with _Australanthus longianus_ which was recovered from depths of 252 feet on Section 13 Hundred of Sherlock and 290 feet on Section 31, Hundred of Roby.

STANDARD SUBSURFACE SECTION - COONALPYN TOWNSHIP BORE
HUNDRED OF CONEYBEER SECTION 56

Engineering and Water Supply Department Bore No. 2, Coonalpyn Water Supply (Mines Department Bore Serial 304/55) is selected as standard subsurface section for the Buccleuch Group, which overlies carbonaceous silts and sands of the Knight Group and is overlain by the Compton Conglomerate at the base of the Gambier Limestone.

In upward succession, the sequence in Coonalpyn Township Bore consists of:

Knight Group sediments (Upper Eocene)

Below 382 feet and not bottomed at 490 feet paralic sediments of the Knight Group comprise 55 feet of sandy siltstone succeeded by 17 feet of dark brown glauconitic clay and 6 feet of dark grey carbonaceous silty sand. A few planktonic foraminifera are generally present, particularly in the upper levels of salt-water sedimentation. _Halkyardia_ occurs with a variety of _Globigerina linaperta_ in the uppermost 6 feet of the group.

Buccleuch Group

The base of the marine beds forming the Buccleuch Group is at 382 feet. Above this level a white bryozoal limestone 147 feet thick with a glauconitic lower member between 322 and 382 feet was penetrated. This limestone, at present unnamed and referred to as Buccleuch A is physically similar to the Gambier Limestone. It carries a rich Upper Eocene microfauna with _Halkyardia_, _Linderina_, _Asterigerina adelaidensis_ and other forms permitting correlation with the Tortachilla Limestones of the Adelaide Basin and the

Wilson Bluff Limestone of the Eucla Basin.

Above the limestone a 13-foot black pyritic clay is succeeded by a brownish-grey bryozoal sand between 210 and 222 feet referred to as Bunglcumb B. The fauna is partially derived from the underlying limestone but includes abundant Rhombopora akitaensis and associated small foraminifera of the Upper Eocene. The uppermost bed of the Group is a black limonitic clay between 208 and 210 feet with a characteristic microfauna dominated by Bolivina spissidens. The bed is at present known as Bunglcumb C.

Oligocene Group

A stratigraphical break occurs at 208 feet in the bore and the base of the Oligocene Group is represented by the Compton Conglomerate between 195 and 208 feet. The Compton Conglomerate passes upwards into the Gambier Limestone of Oligocene age, which in this bore is pinkish-buff in colour and recrystallized at 100 feet.

Pleistocene sandy limestones

The top of the Gambier Limestone is indicated only by the presence above 100 feet of Pleistocene - Recent foraminifera occurring with Victoriella "plants" and other "Janjukian" species. Above 100 feet quartz grains are mixed with recurbed limestone, but the exact boundary is obscured by possible contamination in percussion drilling.

Sludge samples were taken every 5 feet, a description of which follows together with the micropalaeontological log and the columnar section.

Pleistocene

0 -	5 feet	Cream sandy limestone with secondary calcification (kunker)
5 -	10 feet	Cream sandy limestone and kunker
10 -	15 feet	Cream calcareous sandstone with a few warm shallow-water foraminifera, species of Siphonina and Elphidium
15 -	20 feet	Cream calcareous sandstone with abundant foraminifera, mostly Globigerina bulloides, and one derived species of Rotalia.
20 -	25 feet	Similar to previous sample, with Globigerina bulloides dominant.

25 - 55 feet Cream white sandy recrystallized and reworked bryozoal limestone with Globigerina bulloides and derived species

55 - 75 feet Cream white sandy reworked bryozoal limestone with Elphidium crispum, Rotalia howchini, Notorotalia sp. and derived small brachiopods.

75 - 80 feet Cream white sandy reworked glauconitic limestone with Victoriella plecte and other species derived from underlying Gambier Limestone.

80 - 95 feet Similar to 75 - 80 feet.

95 - 100 feet Similar to 75 - 80 feet with Elphidium crispum and derived Victoriella plecte

Glenelg Group
Gambier Limestone

100 - 115 feet Pink crystalline limestone with a few glauconite grains and a microfauna consisting principally of Cibicides pseudoungerianus, Anomalina glabrata, Cassidulina subglobosa and species of Notorotalia, Gyroidina, Globigerina and Lenticulina

115 - 145 feet Pink recrystallized limestone with the echinoids Scutellina and Fibularia and a poor microfauna

145 - 150 feet Similar to 115-145 feet with shark's tooth

150 - 155 feet Similar to 115-145 feet, with Scutellina, small brachiopods and Chlamys sp.

155 - 195 feet Recrystallized limestone with small brachiopods and a poor microfauna consisting mainly of species of Cibicides, Gyroidina and Cassidulina

Compton Conglomerate

195 - 200 feet Crystalline limestone and ferruginous sandstone with fragments of brachiopod shells, bryozoa and a few foraminiferal species: Cibicides sp., Globigerina sp., Cassidulina subglobosa

200 - 208 feet Ferruginized crystalline limestone with small brachiopods.

Knight Group
[illegible] C

208 - 210 feet Black limonitic clay. Washings consist of abundant limonite, large subrounded smoky quartz grains and quartz grains with pitted surfaces. Few worn foraminifera.

[illegible] B

210 - 215 feet Dirty brown grey bryozoal clayey sand with abundant pyrite aggregates, carbonaceous matter, and Sherbornina atkinsoni. The sand is richly foraminiferal with Notorotalia, Sigmomorphina concentrica, Bulimina [illegible] and small species

215 - 218 feet — Dirty brown grey clayey bryozoal sand with Sherborning atkinsoni and the same, but less abundant, microfauna as 210-215 feet.

218 - 222 feet — Dirty brown-grey bryozoal sand, typical of this formation rich in worn fragments of bryozoa probably derived from the underlying limestone. Numerous Sherborning atkinsoni are present.

222 - 227 feet — Black pyritic clay with Turritella "aldingae" Tate, Sherborning atkinsoni, Bulimina rupoides.

227 - 232 feet — Black pyritic clay with Sherborning atkinsoni, Gümbelina rugosa, Bulimina rupoides, and species of Anomalina, Globigerina, Angulogerina and Cassidulina.

232 - 235 feet — Black pyritic mudstone with Turritella, sharks' teeth and a microfauna similar to that of 232-235 feet.

Buccleuch A

235 - 237 feet — Dirty brown hard limestone partially recrystallized. Microfauna in the sample is that of the overlying clay.

237 - 242 feet — White bryozoal limestone with numerous examples of a species of Rotalia.

242 - 262 feet — White bryozoal limestone with Ditrupa and the foraminifera Carpenteria rotaliformis and Cibicides pseudoungerianus

262 - 277 feet — White bryozoal limestone with Carpenteria rotaliformis, Maslinella chapmani and an associated microfauna occurring in Eocene rocks in South Australia

277 - 297 feet — White bryozoal limestone with Carpenteria rotaliformis, Maslinella chapmani., a genus close to Linderina and an apparently undescribed genus related to Bolivinella

297 - 307 feet — White bryozoal limestone with Halkyardia, cf. Linderina, cf. Bolivinella, Crespinina kingscotensis, Maslinella chapmani

307 - 312 feet — White bryozoal limestone with Halkyardia, Globigerina linaperta, Gümbelina rugosa, Lamarckina sirgasia, and associated species of the Upper Eocene.

312 - 317 feet — White bryozoal limestone with Asterigerina adelaidensis, Cataspardrax sp., Globigerapsis index

317 - 322 feet — White bryozoal limestone becoming glauconitic with Globigerapsis index, Crespinina kingscotensis, cf. Linderina etc.

322 - 330 feet — White glauconitic limestone with planktonic fauna including Globigerapsis index. Asterigina adelaidensis are present.

330 - 360 feet — Greenish glauconitic and pyritic marly limestone with Gümbelina, species of Cerobertina, Lamarckina, Hermanellaia, a large Lenticulina and cf. Bolivinella

TABLE 2

MICROPALAEONTOLOGICAL LOG
COONALPYN TOWNSHIP BORE,
SECTION 56, HD, CONEYBEER

	PLEISTOCENE								GAMBIER LIMESTONE																			BUCCLEU
												C		B														
DEPTH (in feet)	10–15	15–20	20–25	25–30	30–35	35–40	55–60	75–80	95–100	100–195	195–208	208–210	210–215	215–218	218–222	222–227	227–232	232–235	235–237	237–242	242–247	247–252	252–257	257–262	262–267	267–272	272–277
Cibicides pseudoungerianus (Cushman)	v	-	-	f	f	v	-	-	-	f	-	-	r	f	f	-	-	-	-	-	-	c	r	v	r	f	f
Cibicides refulgens Montfort	v																										
Elphidium sp.	v																										
Elphidium macellum (Fichtel & Moll)	v																										
Uvigerina sp.	-	v	v																								
Angulogerina sp.	-	v	v																								
Eponides repandus (Fichtel & Moll)	-	v	-	v	-	-	-	v	-	-	-	-	r	-	r												
Cibicides lobatulus Walker & Jacob	-	v	v	-	-	-	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	-	-	-	f	f
Globigerina bulloides d'Orbigny	-	a	a	-	-	a																					
Textularia sp.				v	v	-	-	-	-	-	-	v	-	-	-	r	v	v	-	r	v	r	v	-	v	v	c
Gaudryina sp.				v	v	-	-	-	-	-	-	-	-	-	-	r	-	-	-	r	r	r	f	v	v	r	c
Cassidulina subglobosa Brady				v	v	-	-	v	-	c	-	v	-	-	-	v	v	-	-	-	-	-	-	-	-	-	-
"Discorbis" bousanus (d'Orbigny)				v	v	v	-	v	-	v																	
Notorotalia cf. howchini (C. P & C.)				r	r																						
Notorotalia sp. A				f	f	f	v	-	-	r																	
Guttulina problema d'Orbigny						r	-	-	-	-	-	-	v	-	-	-	-	-	-	-	-	-	v	-	v	v	-	v	-
Guttulina crassicostata Cushman & Ozawa						r																					
Sigmomorphina subregularis Howchin & Parr						r	-	-	-	-	-	-	-	-	-	v	-	f									
Sigmoidella elegantissima (Parker & Jones)						r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	v	-	-	-
Calcarina spackayi (Karrer)						v	-	v																			
Elphidium rotatum Howchin & Parr							r																				
"Rotalia" beccarii (Linné)							r																				
Victoriella pleota (Chapman)								v																			
Lenticulina (Robulus) sp.										v	-	-	-	-	-	-	v	v	-	v	-	-	-	-	v	-	
Cyroidina sp. A.										v	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	f	
Anomalina glabrata Cushman										v																	
Anomalinoides procolligera Carter										v	-	-	f														
Bulimina pupoides d'Orbigny													a	r	r	a	a	v	-	-	-	-	-	-	-	-	-
Cassidulina sp. A													f	v	-	v	r	-	-	-	-	v	-	-	-	v	
Guttulina irregularis d'Orbigny													v	-	v	v	v	v	-	r	-	-	v	v	r	v	
Globulina gibba d'Orbigny													v	-	v	-	-	-	-	-	-	-	-	-	-	-	
Spirillina sp. 1													v	v	v	-	v	-	-	-	-	-	-	-	-	-	
Stomatorbina concentrica (Parker & Jones)													f	v	f	-	-	-	-	v	-	-	v	v	-	-	
Lamarckina glengoensis Chapman & Crespin													v														
Notorotalia crassimura Carter													p	-	-	-	v	r	-	-	-	-	-	-	-	-	
Cibicides pseudoconvexus Parr													v	-	f	-	-	r	-	o	o	o	o	o	f	o	
Sherbornina atkinsoni Chapman													a	r	o	r	v	v	-	-	-	-	-	-	-	-	
Anomalina perthensis Parr													f	f	r	o	a	r	-	-	-	-	v	-	-	-	
Dorothia sp.															r	-	-	-	-	r	-	-	-	-	v	v	

ABLE 2

LAEONTOLOGICAL LOG

TN TOWNSHIP BORE,

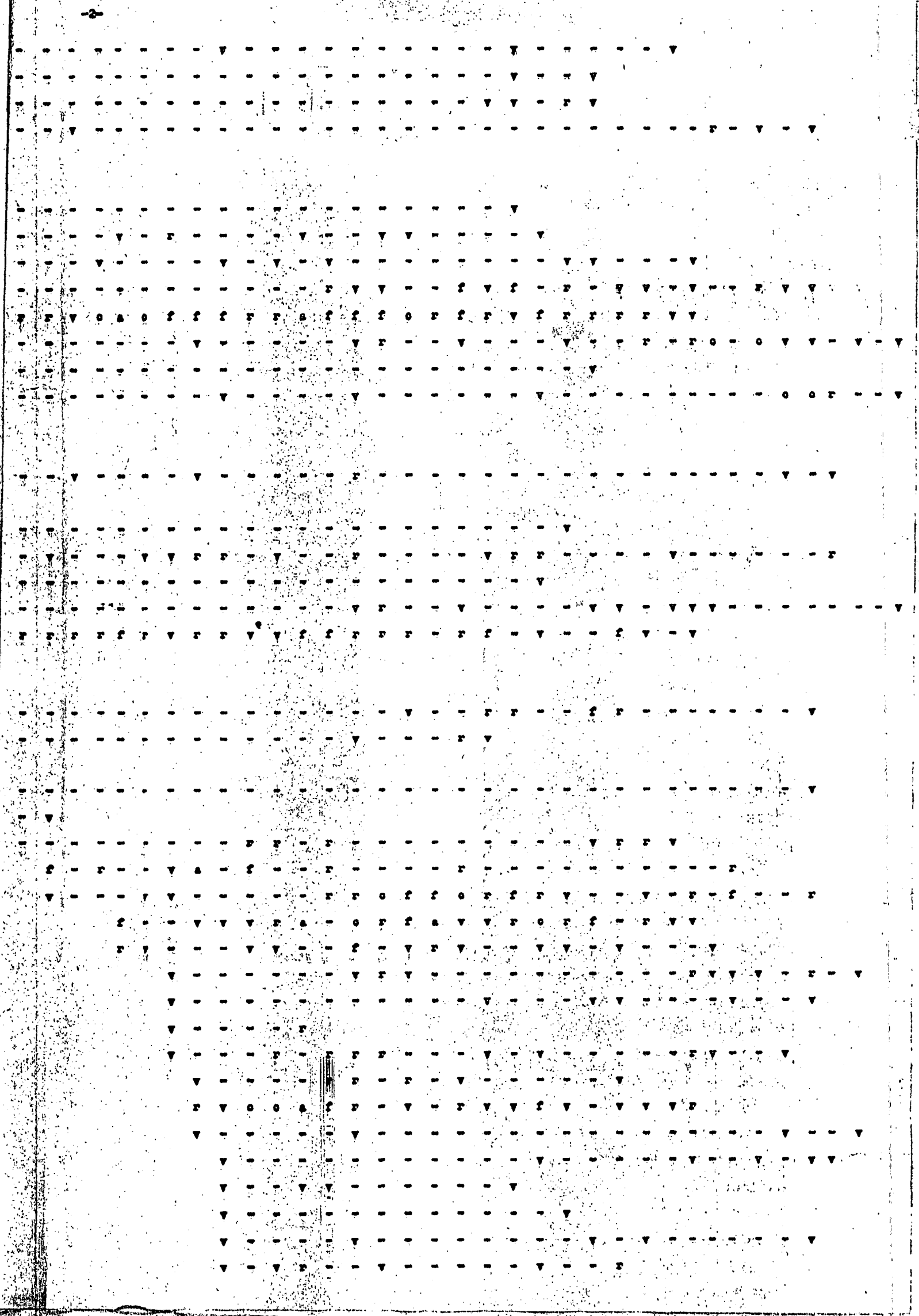
56, HD, CONKYBEER

BUCCLEUCH GROUP

KNIGHT GROUP

242-247	247-252	252-257	257-262	262-267	267-272	272-277	277-282	282-287	287-292	292-297	297-302	302-307	307-312	312-317	317-322	322-327	327-330	330-335	335-340	340-345	345-350	355-360	360-365	365-370	370-375	375-378	378-380	382-388	388-391	391-401	401-405	405-430	430-435	440-475	475-490

Quinqueloculina spp.	f	-	-	f	-	-	-	-	-	-	-	-
Pyrgo sp.	v	v	-	v	-	-	-	-	-	-	-	-
Sigmoilina victoriensis Cushman	f	v	-	-	-	-	-	-	-	-	-	-
Guttulina cf. yamasukii Cushman & Ozawa	v	-	-	v	-	-	-	-	v	-	-	-
Guttulina jarvisi Cushman & Ozawa	v											
Pseudopolymorphina rutila var. parri C. & O.	v											
Sigmoidella sp.	v	-	-	-	-	-	-	-	-	-	-	-
Glabratella sp. A	v	-	-	r	-	v	-	-	-	-	v	-
Osangularia sp.	v	-	-	-	-	-	-	-	-	v	-	-
Discorbis sp.	v	-	-	-	-	-	-	-	-	-	-	-
Carpenteria rotaliformis Chapman & Crespin	v	-	-	-	-	-	r	r	v	c	a	c
Cibicides umbonifer Parr	v	v	-	v	-	-	-	-	-	-	-	-
Nonion sp.	v	-	-	-	-	-	-	-	-	-	-	-
Angulogerina spp.			c	-	-	-	-	-	-	-	-	-
Bulimina sp.		v										
Sphaeroidina sp.		v	v									
Lagena hexagona Williamson		v	v	-	-	-	-	-	v	-	-	-
Lagena striata d'Orbigny		v										
Cyclammina sp.			v	-	-	-	-	-	-	-	-	-
Triforina bradyi Cushman			r	-	-	-	-	v	-	-	-	v
Sigmoidella kugaensis Cushman & Ozawa			v	-	-	-	-	-	-	-	-	-
Nodosaria spp.			v	-	-	-	-	-	-	-	-	-
Spondias lornensis Finlay			r	r	-	c	r	r	r	r	f	r
Globigerina linaperta Finlay var.			r									
Globigerina aff. parvi Bolli			f									
Gümbelina rugosa Parr			r	-	-	-	-	-	-	-	-	-
Cornuspira sp.				v	-	-	-	-	-	-	-	-
Triloculina sp.				v								
Marginula sp.				v	-	-	-	-	-	-	-	-
"Rotalia" sp. A						a	-	v				
Guttulina sp.						v	-	-	-	-	-	-
Cibicides vortex Dorreen								f	-	r	-	-
Globigerina linaperta Finlay								v	-	-	-	
"Crespinella sp. nov. B."											f	
Sigmomorphina sp.											r	
Alabamina westraliensis Parr												
Pullenia bulloides d'Orbigny												
Cryptina globulus Reuss												
Guttulina sp.												
Gen. aff. Linderina												
Gen. aff. Bolivinella												
Lagena sulcata Walker & Jacob												
Astrononion sp. A												
Alabamina sp.												
Reussella sp.												
Glabratella crassa Dorreen												
Sigmoidella sp.												



Fissurina sp.

Gen?

Karreriella sp.

Sherbornina crassata Wade

Eponides cf. dorsopustulatus Dorreen

Astericerina sp. A.

Astericerina cf. lornensis Finlay

Crespinina kingscotensis Wade

Melvardia sp.

Planorbulina sp.

Patellina corrugata Williamson

Pseudopolymorphina sp. nov.

Heronallenia pusilla Parr

Gen. B

Globigerinoides index Finlay

Lamarckina sirensis Carter

Sigmoidella bertonica Finlay

Astericerina adelaidensis (Howchin)

"Catapsydrax" sp.

Frondicularia sp.

Elphidium sp.

Angulogerina subangularis Parr

Spirillina decorata Brady

Glabratella sp. B

Notorotalia sp. B

Massilina sp.

Cornuspirina spp.

Heronallenia lingulata Burrows & Holland

Hoglundina elegans (d'Orbigny)

Robulus cyrtocolprum Stache

Globulina sp.

Frondicularia sp.

Pyrulina cylindroides (Roemer)

Vaginulina sp.

Bolivinopsis crespinae Parr

Fullenia quinqueloba (Reuss)

Sherbornina sp.

Tubulogenerina sp.

Carpenteria sp.

Plectofrondicularia sp.

Globigerina sp.

Hastigerina micra (Cole)

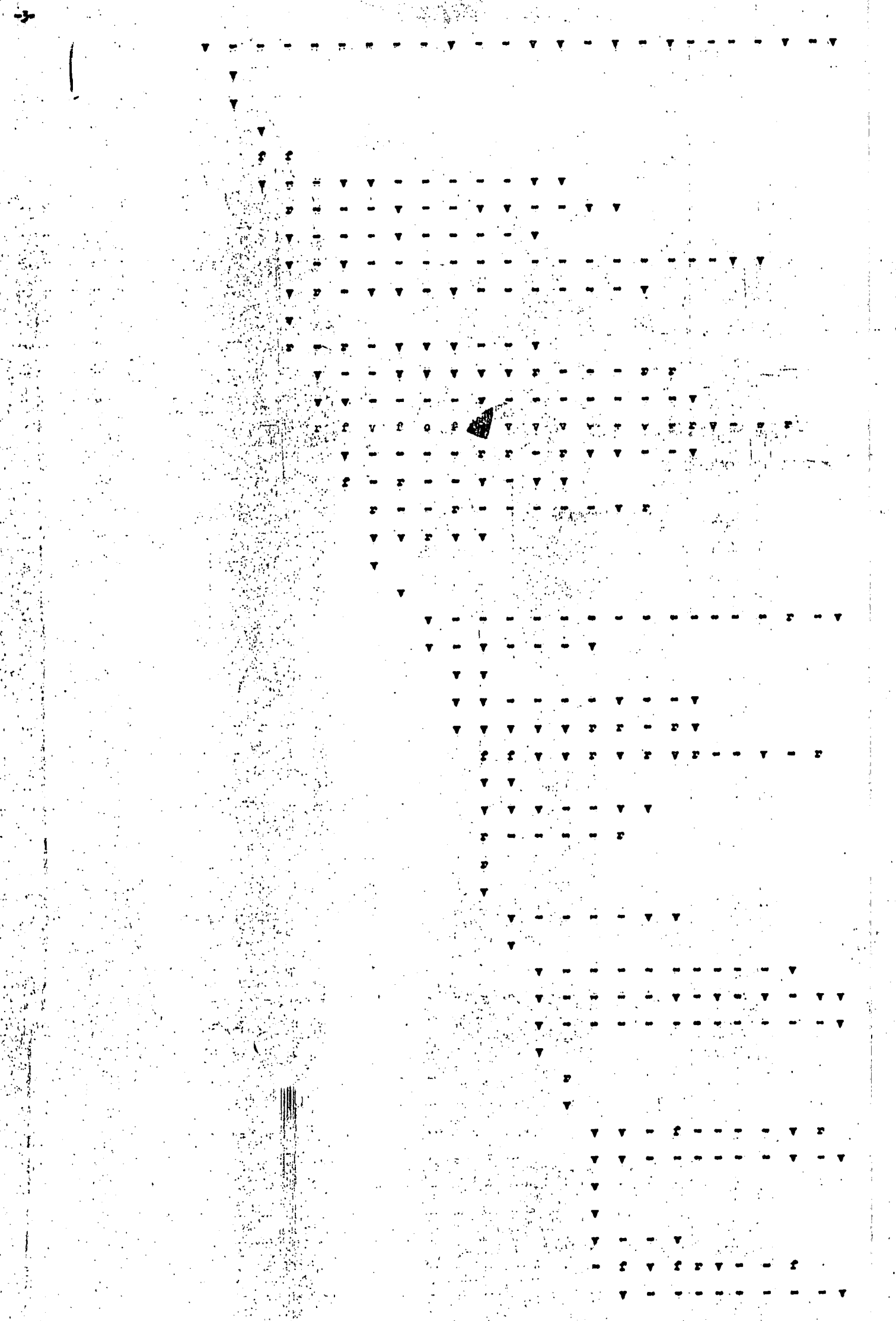
Remanella finlayi Dorreen

Guttulina cf. lehneri Cushman & Ozawa

Biloculinella globula (Bornemann)

Cyroidina sp. B.

Glabratella sp. B.



Spirillina unilatera Chapman

cf. Pseudoglandulina clarkei Parr

Globigerina cf. linaperta Finlay

Asterigerina sp. B.

Globigerina cf. ampliapertura Bolli

Lagena spp.

Bolivina sp.

Lagena terrilli Parr

Siphotextularia sp.

cf. Discorbis assulatus Cushman

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v = very rare (1-2)

r = rare (3-5)

f = frequent (6-10)

c = common (11-25)

a = abundant (25 +)

360 - 365 feet — Glauconitic marly limestone with cf. Linderina, [illegible] Hastigerina micra, [illegible] [illegible], Asterigerina adelaidensis, Maslinella chapmani and cf. Bolivinella.

365 - 378 feet — Glauconitic marl with bright green glauconite, pyrite and abundant sponge spicules and foraminifera including Asterigerina adelaidensis [illegible].

378 - 382 feet — Glauconitic carbonaceous and pyritic marl with species of Asterigerina, Gyroidina, Cibicides, Globigerinoides and Alabamina.

Knight Group

382 - 388 feet — Dark grey carbonaceous silty sand with Halkyardia, Globigerina linaperta, Cibicides [illegible]

388 - 391 feet — Dark brown pyritic carbonaceous and glauconitic clay with rounded quartz pebbles up to ¼ inch diameter. Fauna includes Turritella, the restricted scaphopod Dentalium (Gadilina) tatei Sharp and Pilsbry, fish teeth and a microfauna with Halkyardia and species of Asterigerina, Carpenteria, Cibicides, Alabamina continuing from the overlying formation.

391 - 401 feet — Dark brown highly carbonaceous gritty clay with coarse angular to subrounded quartz grains, carbonized plant remains and small foraminifera with Hastigerina micra and Globigerinoides index

401 - 405 feet — Dark brown pyritic lignitic clay with a microfauna similar to 391-401 feet

405 - 435 feet — Grey medium fine carbonaceous silty sand with Anomalinoides, Gyroidina, Cassidulina and less abundant forms.

435 - 490 feet — Grey carbonaceous pyritic sandy siltstone with Bolivinopsis [illegible], Cassidulina, Anomalina, Lagena, Cibicides

Samples below 445 feet are contaminated with species from the overlying limestone.

BORE FOR C. O. KLITSCHER, COONALPYN

HD. STRAWBRIDGE, SECTION 10

Bore 41/58 put down for C. O. Klitscher on Section 10, Hundred of Strawbridge is of more than usual palaeontological interest as a rich Eocene foraminiferal assemblage was recovered from limestone overlying bedrock between 98 and 203 feet depth.

Before entering bedrock schist at 203 feet, the boring passed through bryozoal limestone of uniform character throughout except for a change of colour from cream to pink - cream between 45 and 88 feet. Faunal examination shows that at least 2

limestones are present, the limestone of Buccleuch A between 98 and 203 feet and the Gambier Limestone between 5 and 75 feet. The 23-feet interval between 75 and 98 feet has a microfauna with both Eocene and Oligocene elements. It is at present not possible to determine whether the limestone of this interval belongs to either the overlying or the underlying formation or whether it is in fact the lateral equivalent of the upper beds of the Buccleuch Group.

The thin calcareous sand cover may be of Pleistocene age.

Buccleuch A in this bore is an autochthonous marine limestone with a rich shallow-water benthic microfauna of larger foraminiferal species. Restricted Eocene genera such as _Halkyardia_ and _Linderina_ are abundantly represented in association with _Crespinina kingscotensis_, _Maslinella chapmani_ and, at the lowest depths below 170 feet, _Asterigerina adelaidensis_. An apparently undescribed genus related to _Bolivinella_ is also generally present.

The faunal composition indicates marginal sedimentation in an area of bedrock highs.

The faunal stage is considered to be probably equivalent to the New Zealand Kaiatan.

The fauna of the upper limestone between 5 and 75 feet is typical of the Gambier Limestone, with _Victoriella plecte_ at 15 - 25 feet. This is of "Janjukian" (Oligocene) age.

Sludge samples, taken every 5 feet, were as follows:

0 - 2 ft.	Brown fine surface sand
2 - 5 ft.	Light brown calcareous sandstone with a few small species of foraminifera, probably representing a thin Pleistocene cover on Gambier Limestone.
5 - 15 ft.	Cream bryozoal limestone with an abundant "Janjukian" microfauna of the Gambier Limestone.
15 - 25 ft.	Cream bryozoal limestone with _Victoriella plecte_ and associated Janjukian foraminiferal species.
25 - 38 ft.	Cream bryozoal limestone with abundant _Amphistegina lessonii_.
38 - 45 ft.	Cream hard bryozoal limestone.
45 - 55 ft.	Pink-cream bryozoal limestone with small foraminiferal species mainly _Rotaliidae_.

TABLE 3

MICROPALAEONTOLOGICAL LOG

HD. STRAWBRIDGE SECTION 10.

	PLEISTO-CENE	GAMBIER LIMESTONE												BO
DEPTHS	0-2	2-5	5-15	15-25	25-35	45-55	55-65	65-75	75-85	85-95	95-105	105-115	115-125	125
Bolivina spp.		v	f	-	-	-	-	v						
Cibicides sp.		r	r	r	-	r	-	f	v	r	-	-	-	
Textularina sp.		f	-	-	-	-	-	-	-	-	-	-	-	
Dentalina sp.			v	v	-	-	-	-	-	-	-	-	-	
Lagena spp.			r											
Lenticulina sp.			v											
Cristellina irregularis d'Orbigny			v	-	-	-	-	v						
Cristellina cf. Jarvisi Cushman & Bermudez			r											
Discorbella discorbinaea Parker & Jones			f											
Discorbinella subcircularis Howchin & Parr			v	f										
Cassidulina subglobosa Brady			a	-	v	-	-	c	r	-	-	-	-	v
Eponidina bulloides d'Orbigny			r	v										
Discorbis sp.			v											
Stomatorbina concentrica (Parker & Jones)			v	-	-	f	v	v	-	-	-	-	-	r
Cymbidina goldfussi d'Orbigny			r	-	-	-	-	r						
Nonionina pauciloba (Fichtel & Moll)			v	v	-	r	r	v	f					
Cibicides pseudoungerianus (Cushman)			a	v	-	c	-	v	r	-	-	-	v	
"Acervulina" bonarensa (d'Orbigny)			f	v										
Cibicides wuellerstorfi Parr			f	-	-	-	-	-	r					
Cibicides refulgens (Montfort)			v	-	-	c	-	c	a					
Angulina glabrata Cushman			c	r	-	v	-	v						
Globigerina bulloides d'Orbigny			f	f										
Carpenteria sp.			v	-	-	-	-	-	-	-	-	-	-	-
Nonionella sp.			v											
Astrononion australe Cushman & Edwards			r	r										
Elphidium hannai Cushman			r	-	-	r	-	v						
Amphistegina "lessoni d'Orbigny"			r	f	a	-	-	v						
Heterostegina howchini (C. P & C)			c	-	-	r								
Heterostegina spenceiana Carter			f	-	-	r	v	r	r	f				
Astrononion centrocylax Carter			r	v	-	-	-	-	-	v				
Globorina watsoni (Karrer)			f	r	f	v	-	-	v					
Cristellina irregularis d'Orbigny				v	-	-	-	-	-	-	-	-	-	-
Amphistegina sp.				v										
Eponidina howchini Cushman				v	-	v								
Marginulinia parri Carter				v	-	-	-	-	v					
Vaginulinella plecta Chapman				v	-									
Dentalina parri Cushman				-	r									
Frondicularia sp.					v									
Bagginella simplex Cushman					v									
Cristellina sp.						v	-	-	v					
Cibicides perforatus (Karrer)								c	a					
Eponidina stelligera Chapman									v	a	r	-	r	
Cibicides lobatulus Walker & Jacob									v					

TABLE 3

MICROPALAEONTOLOGICAL LOG

MR. STRAWBRIDGE SECTION 20.

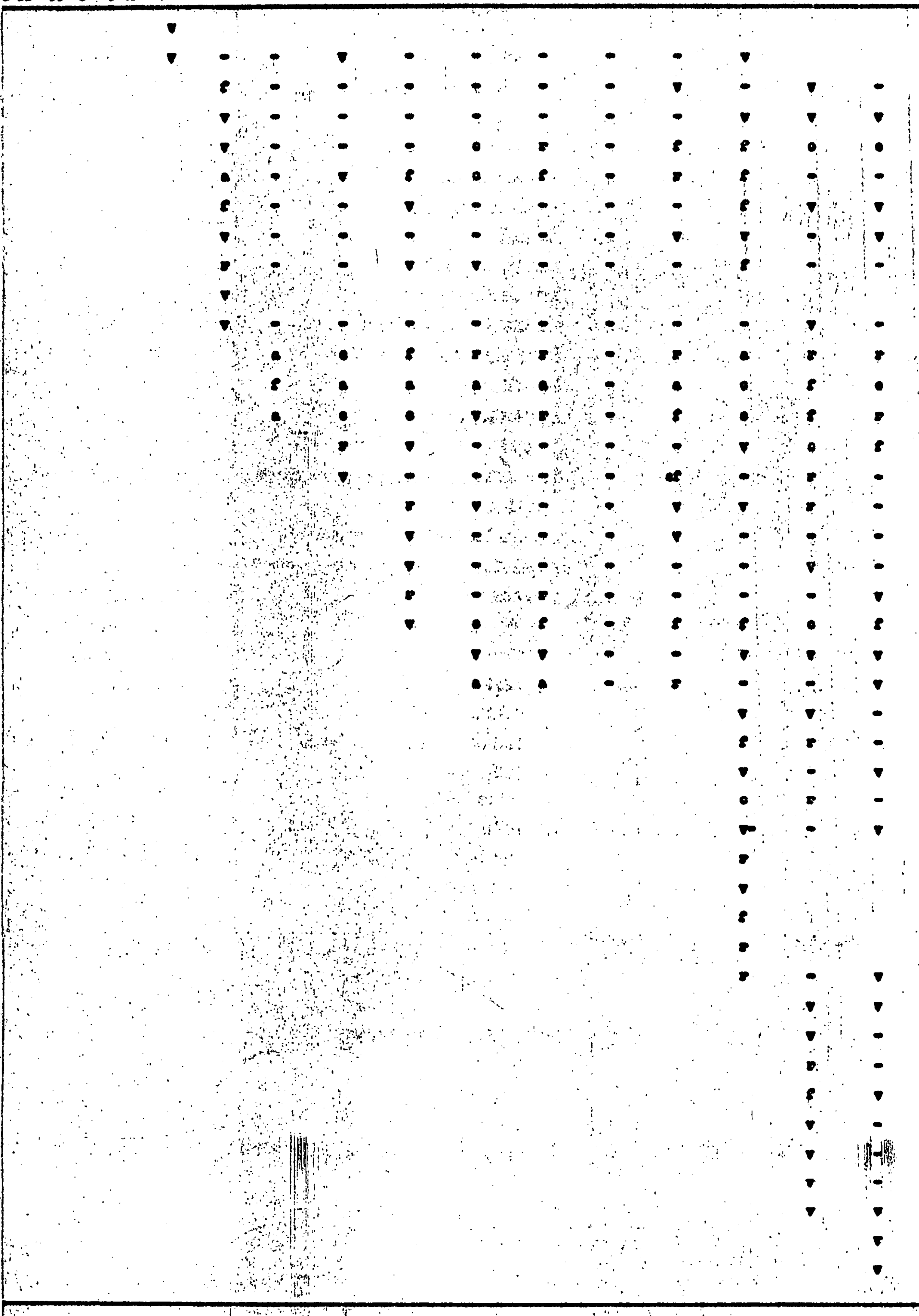
GAMBIER LIMESTONE — BUCCLEUCH A

35-45	45-55	55-65	65-75	75-85	85-95	95-105	105-115	115-125	125-135	135-145	145-155	155-165	165-175	175-185	185-195	195-205

	PLEISTOCENE				GAMBIER LIMESTONE									DU[…]
DEPTHS	0-2	2-5	5-15	15-25	25-35	45-55	55-65	65-75	75-83	83-98	98-108	108-118	118-128	12[…]
Crespinella sp.									v					
Guttulina sp.									v	-	-	v	-	
[illegible] finlayi Dorreen										f	-	-	-	
Eponides lornensis Finlay										v	-	-	-	
Cibicides pseudoconvexus Parr										v	-	-	-	
Cibicides vortex Dorreen										a	-	v	f	
Anomalina perthensis Parr										f	-	-	v	
Heronallenia pusilla Parr										v	-	-	-	
Elphidium sp.										r	-	-	v	
Valvulineria sp.										v				
Glabratella crassa Dorreen										v	-	-	-	
Crespinina kingscotensis Wade											a	c	f	
Lamarckina sp.											f	a	a	
Crespinella sp. nov. B											a	c	c	
Halkyardia sp.												r	v	
Carpenteria rotaliformis Chapman & Crespin												v	-	
Rotorbinella sp.													r	
Eponides [illegible]pustulatus Dorreen													v	
Textularia sp.													v	
Gaudryina sp.													r	
sp. aff. Bolivinella													v	
Planorbulina johannae Carter														
Amphistegina sp.														
Lagena hexagona Williamson														
Asterigerina adelaidensis (Howchin)														
Sigmomorphina sp.														
Cassidulina sp.														
Astrononion sp.														
Gyroidina sp.														
Elphidium sp. 1														
Elphidium sp. 2														
Gyroidina sp.														
Gypsina cf. howchini Chapman														
Alabamina westraliensis Parr														
Globigerina linaperta Finlay														
Calcarina sp. ? nov.														
Elphidium parri Cushman														
Elphidium chapmani Cushman														
Asterigerina cf. cyclops Dorreen														
Bolivina sp.														
Bulimina cf. semicostata Nuttall														
Glabratella sp.														
Gyroidina sp. B														

v = very rare (1-2)
r = rare (3-5)
f = frequent (6-10)
c = common (11-25
a = abundant (25 +)

0-55	55-65	65-75	75-88	88-98	98-108	108-118	118-128	128-138	138-148	148-158	158-170	170-180	180-190	190-203



55 - 65 ft. Pink-cream bryozoal limestone with small brachiopods, Eponides and Notorotalia.

65 - 75 ft. Pink cream bryozoal limestone with Rotaliidea. The boring is still in the Gambier Limestone at this level.

75 - 88 ft. Pink cream bryozoal limestone with Sherbornina atkinsoni and an associated microfauna mainly Rotaliidea.

88 - 98 ft. Cream bryozoal limestone with Sherbornina atkinsoni and a microfauna with Eocene and Oligocene elements.

98 - 108 ft. Cream bryozoal limestone (Buccleuch A) with Crespinina kingscotensis, Linderina, Maslinella chapmani and Sherbornina atkinsoni

108 - 118 ft. Cream bryozoal limestone with Halkyardia, Crespinina kingscotensis, Linderina and associated species occurring in the Upper Eocene in South Australia.

118 - 128 ft. Cream bryozoal limestone with genera of Bolivinella, Halkyardia, Linderina, Maslinella chapmani.

128 - 138 ft. Cream bryozoal limestone with abundant larger foraminifera dominated by Linderina and cf. Planorbulina.

138 - 158 ft. Similar to 128-138 feet.

158 - 170 ft. Cream sandy bryozoal limestone with abundant larger foraminifera dominated by Linderina, cf. Planorbulina and cf. Bolivinella.

170 - 180 ft. Cream sandy bryozoal limestone with quartz grains. Foraminifera dominated by Crespinina kingscotensis, Linderina, Maslinella chapmani and cf. Bolivinella, with Halkyardia and Asterigerina adelaidensis.

190 - 203 ft. Cream sandy bryozoal limestone with Halkyardia and larger foraminifera as at 170 - 180 feet.

203 - 252 ft. At 203 feet the boring entered grey sericitic schist.

(3) GLENELG GROUP

Buccleuch Group is succeeded by the Glenelg Group named by Boutakoff and Sprigg (1953, p. 46). The magnitude of the discontinuity between the two groups increases towards the south where the lowest formation of the Glenelg Group unconformably overlies the Knight Group. The contact is exposed in Knight's Quarry section described above (p. 8).

The Glenelg Group is a normal marine sequence of limestones, marls and sandy marls. The base is marked by the Compton Conglomerate 1½ feet thick under the Gambier Limestone in the type section at Knight's Quarry. The conglomerate contains abundant rounded ironstone pebbles and grit in a limonitic matrix. There is a poor microfauna with species of Bombycina (Pseudobombycina), Dorothia, Rosalina, Cassidulina, Globigerina, and Cibicides.

The formation and its equivalents have been recognised in borings over a wide area, both in the Gambier Sunklands and in the Murray Basin proper.

The Compton Conglomerate passes upwards into the Gambier Limestone.

GAMBIER LIMESTONE

This economically important limestone was described by Tenison Woods in 1860 and again in 1862. The name Mount Gambier stone was introduced in 1862 (p. 72) and Mount Gambier limestone(s) first used by Tenison Woods in 1865 (pp. 392, 393). An historical review of the literature was later published by Tate (1894) and recently by Teesdale-Smith (1958).

In South Australia the formation is now known in industry and recorded in the literature as Gambier Limestone (Sprigg 1952, p. 27; Sprigg and Boutakoff 1953, Correlation Chart p. 52).

In 1867 Tenison Woods applied the name Mount Gambier limestone to the limestone occurring at Portland in Victoria and the correlation has been maintained in literature to the present (Sprigg and Boutakoff 1953, p. 52; Ludbrook, 1957, p. 177). According to A.N. Carter of the Geological Survey of Victoria (verbal communication) the limestone exposed at Portland contains Orbulina universa and is therefore younger than the Gambier Limestone. The presence of Orbulina universa would place the upper part of the Portland sequence at the level of the Pata Limestone occurring at the top of the mid-Tertiary normal marine sequence in the Murray Basin proper.

With the approval of the South Australian members of the

Fig. 1. Gambier Limestone with Compton Conglomerate at base over Knight Group, Hundred Blanche, Section 718.

Fig. 2. Close view of base of Gambier Limestone and Compton Conglomerate.

Subcommittee on Stratigraphic Nomenclature the name Gambier Limestone is confirmed for that partly exposed at Mount Gambier and the sinkhole in the public gardens at the Town Hall designated as the type locality. This is the original section described by Tenison Woods (1860, p. 256; 1862, p. 75). Although notes on the Polyzoa (Busk, 1860) Foraminifera (Parker & Jones 1860) and macrofossils (Woods 1862, 1867) were published, the faunas have not yet been described.

The microfauna at the type locality includes Textularia corrugata, Gaudryina (Pseudogaudryina) crespinae, Dorothia parri, Clavulinoides victoriensis, Bdelloidina aggregata, Nodosaria salsis, Lenticulina sp., Guttulina irregularis, Sigmomorphina subregularis, Cassidulina subglobosa, Pullenia quinqueloba, Eponides spp., Eponides repandus, Vagocibicides cf. maoria, Globigerina bulloides (abundant), Globigerinoides rubra, Carpenteria rotaliformis, Astrononion centroplax.

The full sequence of the Gambier Limestone is nowhere clearly exposed and faunal zoning has not yet been achieved. To the north of Mount Gambier, the upper boundary of the Gambier Limestone is determined at its contact with the Naracoorte Limestone. To the east and south its upper limit is not defined.

The foraminifera contained in the upper part of the Gambier Limestone below the Naracoorte Limestone on the north side of A. James and Sons' Quarry include Textularia australis, Cibicides brevoralis, C. pseudoungerianus, Dyocibicides biserialis, Anomalina glabrata, Globigerina angustiumbilicata, G. bulloides, Astrononion centroplax, Operculina victoriensis.

The Gambier Limestone is represented in the uppermost 12 feet 6 inches under the surface soil in the type section measured at the Quarry on Section 718, Hundred of Blanche (page 6).

The lowest 8 feet over the Compton Conglomerate consists of yellow brown limonitic bryozoal limestone with occasional quartz grains up to 2 to 5 mm. diameter with a poorly preserved fauna mainly as casts and moulds of molluscs and small brachiopods. The uppermost 3 feet of weathered cream glauconitic bryozoal limestone has Fibularia gregata, small brachiopods and the foraminifera

Textularia sp., Dorothia sp., Gaudryina (Pseudogaudryina) crespinae, Massilina torquayensis, Lenticulina sp., Guttulina irregularis, Guttulina problema, and Globulina gibba, Glandulina laevigata, Cassidulina laevigata, Pullenia sphaeroides, Eponides repandus, Cibicides pseudoungerianus, Stomatorbina concentrica and Victoriella plecte.

The upper member is sawn for building stone and consists of a white aggregate of bryozoa with echinoids, brachiopods, a large asteroid, Chlamys gambierensis and Liothyrella [illegible], penguin bones, and a microfauna similar to that of the type section. The lower member known to quarrymen as "greenbacks" becomes progressively more glauconitic downwards, and in the northern part of County Robe grades into a richly glauconitic marl with abundant small foraminifera including Gümbelina, Bolivinopsis crespinae and Globigerina. The same glauconitic marl is present in parts of the Murray Basin proper. The member, which has not been named or described, is probably a correlative of the "Lower Glen Aire Clays" of the Aire Coast of Victoria (Carter, 1958).

The Gambier Limestone reaches a maximum thickness of 533 feet in the Mount Gambier area, thins out against bedrock on the Padthaway "Horst", and is represented by marly equivalents in the Murray Basin proper. It is exposed at the surface in the Mount Burr area. 1 mile north of Mount Graham chalky Gambier Limestone with abundant Globigerina bulloides outcrops in a field on the west of the roadway; a small quarry in the same limestone was opened on Section 106, Hundred of Riddoch, 1 mile east of Mount Burr. At both of these exposures Globoquadrina dehiscens occurs with the same microfauna as that of the type section.

In contrast with the limestones of the Murray Group, the Gambier Limestone is rich in planktonic foraminifera as are the mid-Tertiary sediments of southern Victoria. Deposition took place in the open sea.

Fig. 1. Gambier Limestone, Kain & Shelton's Quarry, 1956.

Fig. 2. Solution cavities in Gambier Limestone, Kain & Shelton's Quarry.

Fig. 1. Dolomite quarry, Up and Down Rocks near Tantanoola Cave. 80-foot face of dolomite, October 1958.

NARACOORTE LIMESTONE

This limestone disconformably overlies the Gambier Limestone on the upthrow side of the Kanawinka Fault Scarp east of Naracoorte. The contact is well exposed on the north side of the quarry operated by A. James and Sons, where there has been some collapse of the Naracoorte Limestone forming the roof of a cave in the Gambier Limestone. Ten feet of the Gambier Limestone are exposed, overlain by 20 feet of Naracoorte Limestone capped by 2 feet of aeolianite. The quarry face in Naracoorte Limestone is 40 feet high. The Limestone is texturally distinct from the even grained Gambier Limestone. It is a rubbly, highly fossiliferous leached coquinite, with abundant casts and moulds of molluscs and echinoids. Aturia and Eutrephoceras are common.

The molluscs are dominated by pectinidae and the large gastropods Cypraea dorsata and Alcithoe (Cottonia) heptagonalis. Chlamys gambierensis, Chlamys (Mesopeplum) incerta, Serripecten yahliensis and Limatula jeffreysiana are common. The microfaunal assemblage contains Textularia australis, Textularia carrensis, Gaudryina (Pseudogaudryina) crespinae, Dorothia parri, Sigmomorphina subregularis, Sigmoidella elegantissima, Eponides repandus, Globigerina bulloides, Globigerinoides triloba, Carpenteria rotaliformis, Elphidium crespinae, Astrononion centroplax and Operculina victoriensis.

The Naracoorte Limestone was described (Ludbrook 1957, p. 177) as a member of the Gambier Limestone of Upper Oligocene to Lower Miocene age. The presence of Globigerinoides triloba would indicate that the base of the Limestone may have been placed a little too low in the sequence and that the Naracoorte Limestone is not older than Lower Miocene.

The limestone is high in calcium carbonate. It was formerly burnt for lime but is now quarried at three places to the east of Naracoorte for road screenings.

The limestone continues northwards from Naracoorte around the eastern side of the Padthaway high and is probably represented by marly equivalents in the Murray Basin proper. Its maximum thickness observed in bores south of Bordertown is 90 feet at

Fromme.

THE ETTRICK FORMATION

On the western margin of the Murray Basin underlying the yellow limestone of the Hamman Formation is a series of grey white glauconitic marls, sandy marls grading to limestone, originally named (Ludbrook, 1957), the Ettrick Marls. The name is here changed to the Ettrick Formation to cover the general lithology of the formation as it has since been recognised.

The formation is named from A.R. Lemmer's No. 2 Bore, Section 21, Hundred of Ettrick, 20 miles east north east of Murray Bridge where it is represented by 75 feet of glauconitic marl from 210 - 285 feet.

In upward succession the sequence in Lemmer's No. 2 Bore is as follows.

Ettrick Formation 210-285 feet.

At the base of the formation from 270 to 285 feet is represented by a greenish-grey glauconitic marl stained with ferric iron and with abundant limonite. This is succeeded by a light grey marl between 240 and 270 feet and by a grey-brown marl from 210-230 feet.

Hamman Formation 130-210 feet

The Ettrick Formation passes upwards into the Hamman Formation with a gradual faunal transition. Ten feet of greenish grey limestone between 200 and 210 feet has been placed at the base of the Hamman Formation, but it could equally well be regarded as the top of the Ettrick. Above 200 feet upwards to 130 feet the yellow soft limestone of the Hamman Formation was intersected.

? Loxton Sands 10-130 feet

Between 10 and 130 feet the boring intersected yellow calcareous sandstone, calcareous grit and micaceous sandy limestones, which are assumed to be Loxton Sands. The microfauna is that of the Loxton Sands, although marginal sediments of the Bookpurnong Beds would contain a similar assemblage.

The sequence, covered by 10 feet of kunker, is logged as follows from samples taken every 10 feet:

0 - 10 feet F 143/53 Kunkar

?LOXTON SANDS

10 - 20 feet F144/53 Yellow-brown sandy and gritty limestone with a few pauperate foraminifera.

20 - 30 feet No sample

30 - 50 feet F145/53 F146/53 Red brown ferruginous and calcareous sandy clay.

50 - 60 feet F147/53 Red brown sandy clay

60 - 70 feet F148/53 Yellow calcareous sandstone, with "_Rotalia_" _beccarii_, _Crespinella umbonifera_, and small species.

70 - 80 feet F149/53 Yellow calcareous sandstone, with "_Rotalia_" _beccarii_, _Crespinella umbonifera_, and _Elphidium_ spp.

80 - 90 feet F150/53 Yellow calcareous sandstone, with medium-coarse subangular to subrounded quartz grains, calcite grains mostly limonite-stained. Microfossils are poorly preserved and scarce; species are the same as in the previous sample.

90 - 100 feet F151/53 Yellow-brown calcareous gritty sandstone with abundant mica, coarse subrounded quartz grains, echinoid fragments, bryozoa and a small microfauna similar to that of the 70-80 feet.

100 - 110 feet F152/53 Yellow, fine micaceous sandy limestone with _Crespinella umbonifera_, "_Rotalia_" _beccarii tepida_, _Elphidium pseudonodosum_.

110 - 120 feet F153/53 Brown-yellow sandy recrystallized limestone with "_Rotalia_" _beccarii tepida_, _Elphidium crassatum_, _Valvulineria_ sp.

120 - 130 feet F154/53 Yellow-brown gritty limestone, with rounded to subrounded polished quartz grains, abundant limonite and shallow water foraminifera similar to those of the previous sample.

MANNUM FORMATION

130 - 140 feet F155/53 Cream-yellow partially recrystallized limestone, with a few coarse, well-worn subrounded quartz grains, echinoid fragments,

Fig. 1. Naracoorte Limestone. A. James & Sons Quarry.

Fig. 2. North side of quarry, Naracoorte Limestone overlying Gambier Limestone.

limonitic internal casts of foraminifera, bryozoa. Amphistegina, Planorbulinella insequilateralis and Cresaniella are present.

140 - 150 feet F 156/53 Yellow, poorly fossiliferous recrystallized limestone with Cresaniella sp. nov. and Textularia vertebralis

150 - 160 feet F157/53 Cream yellow sandy limestone with fine angular quartz grains Fibularia gregaria and abundant Cresaniella and Cibicides pseudoungerianus

160 - 170 feet F158/53 Similar to F157/53, with Sherbornina atkinsoni

170 - 180 feet F159/53 Fine grained, cream sandy limestone with fine angular quartz grains, occasional glauconite and abundant foraminifera dominated by Cassidulina subglobosa, Cibicides pseudoungerianus and Cibicides umbonifer.

180 - 190 feet F160/53 Similar to F159/53 with Fibularia gregaria

190 - 200 feet F161/53 Cream sandy limestone with fine angular quartz grains and a rich microfauna similar to F159/53.

200 - 210 feet F162/53 Cream glauconitic limestone with pale rather dull green glauconite, Cassidulina subglobosa, dominates the foraminiferal assemblage with several species of Cibicides Sherbornina atkinsoni, Anomalina, Heronallenia

KETRICK FORMATION

210 - 220 feet F163/53 Grey-green glauconitic marl, with bright green fresh glauconite, abundant [illegible] and a rich associated microfauna of numerous small

220 - 230 feet F164/53 Grey-green glauconitic [illegible] to previous sample [illegible] foraminifera [illegible]

230 - 240 feet No sample.

240 - 250 feet F 165/53 Grey sticky calcareous carbonaceous clay with abundant small foraminifera, Cibicides spp. Lamarckina glencoensis, Angulogerina subangularis, and Bolivinopsis crespinae, the last two described from the Upper Eocene but extending to the lower part of the Gambier Limestone and Ettrick Formation in South Australia.

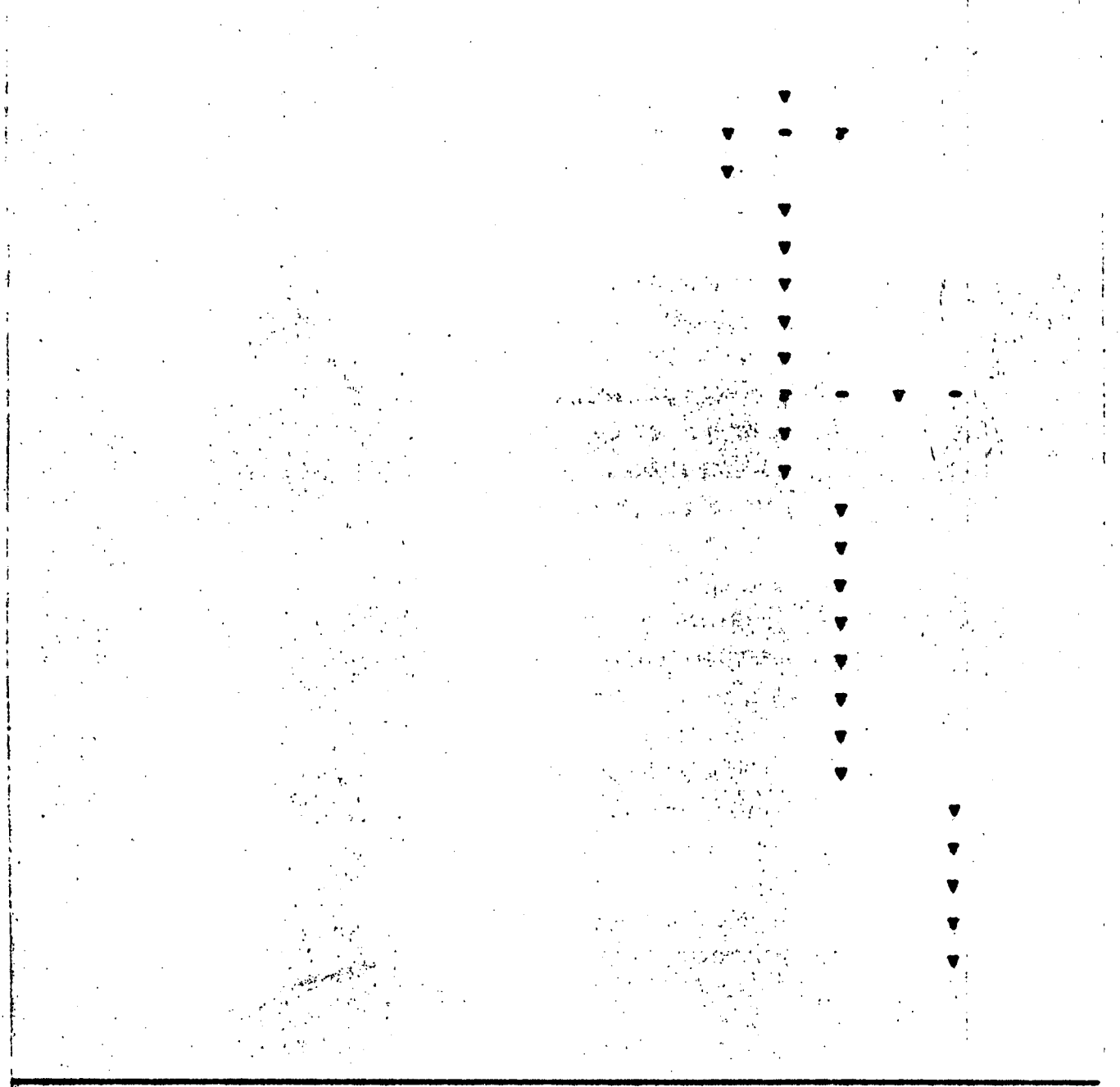
250 - 260 feet F166/53 Grey sticky calcareous carbonaceous clay with pale green glauconite. Microfauna similar to previous sample.

260 - 270 feet F167/53 Grey glauconitic marl, with pale green glauconite, fine grained with organic matter. Foraminifera dominated by Cibicides sp. nov. Massilina torquayensis, Eponides repandus and Sphaeroidina bulloides.

270 - 280 feet F168/53 Grey sandy marl, with green iron-stained clay, limonite grains, subangular fine to medium quartz grains, bryozoa, echinoid fragments; foraminifera fairly abundant.

280 - 285 feet F169/53 Greenish grey limonitic gritty clay with large angular milky quartz fragments, limonite grains, bryozoa, echinoid fragments, medium rounded quartz grains, schist fragments. There is considerable green ironstaining of clay. Microfaunal assemblage dominated by Cibicides.

The same sequence was intersected in Lanner's No. 1 Bore, correlation of the two bores being shown on the stratigraphic columns. Some details of the correlation are probably faulty on account of the wide sampling intervals in Bore No. 1. For this reason it was not selected as standard subsurface section, although it is 142 feet deeper than Bore No. 2. and entered below 325 feet a white clay-like rock composed largely of fine silica particles. This siliceous rock contains a microfaunal assemblage similar to that of the overlying marls, with abundant Cassidulina subglobosa.



▼ = very rare (1–2)
▼ = rare (3–5)
▼ = frequent (6–10)
▼ = common (11–25)
▼ = abundant (25 +)

Gavelinopsis sp.

Genus A.

Dyocibicides biserialis Cushman & Valentine

Siphotextularia sp.

Cornuspira involvens Reuss

[illegible]frondicularia sp.

Gavelinopsis sp.

Conorbella patelliformis Brady

Globigerina ampliapertura Bolli

Globigerina linaperta Finlay

Spirillina unilatera Chapman

[illegible] crassimura Carter

Gaudryina (Pseudogaudryina) crespinae Cushman

[illegible] sp.

Planispirina sp.

Articulina cf. [illegible] Cush.

Biloculinella globula (Bornemann)

Valvulineria sp. B.

[illegible] (H.A. & E.)

[illegible]ularia sagittula Defrance

Lagena sulcata W & J.

Bolivinella folia (P & J)

Frondicularia lorifera Chapman

[illegible]loculina sp.

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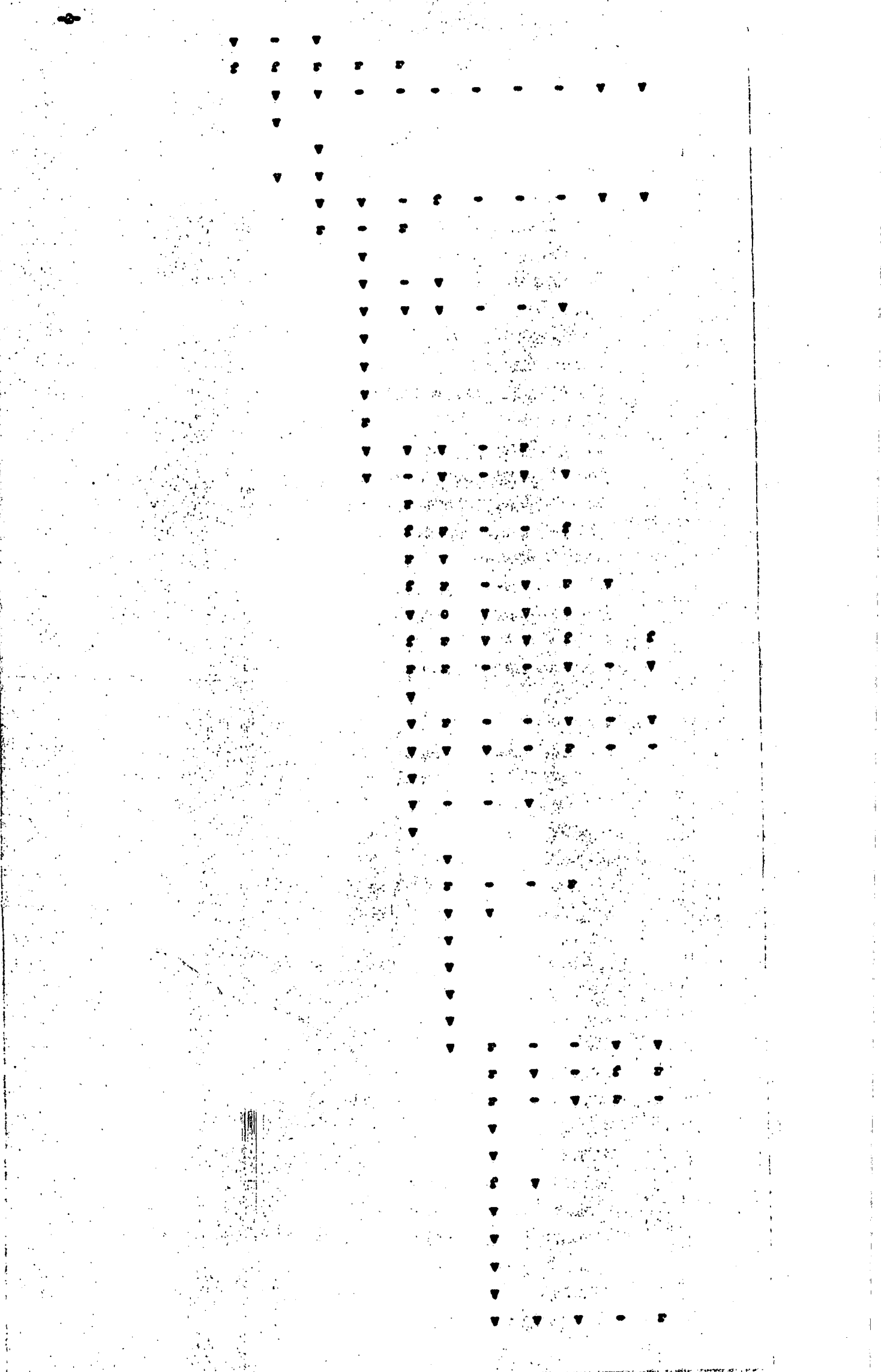
v = very rare (1-2)

r = rare (3-5)

f = frequent (6-10)

c = common (11-25)

a = abundant (25 +)



Eponides lornensis Finlay	v	-	v	
Elphidium crespinae Cushman	f	f	r	r
Lagena hexagona Williamson		v	v	-
Marginulina sp.		v		
Anomalina sp. B			v	
Globigerinoides triloba (Reuss)		v	v	
[illegible]ithia sp.			v	v
Globigerina bulloides d'Orbigny			r	-
Liebusella rudis (Costa)				v
Cornuspira sp.				v
[illegible]ulina sp.				v
Plectofrondicularia sp.				v
Sigmomorphina sp.				v
Sigmoidella elegantissima (Parker & Jones)				v
Sigmoilina sp. B.				r
Karreriella parri Carter				v
Karreriella lingulata (Burrows & Holland)				v
Ammosphaeroidina sphaeroidiniformis (Brady)				
Quinqueloculina lamarckiana d'Orbigny				
Quinqueloculina spp.				
Sigmoilopsis sp. 1				
Massilina torquayensis (Chapman)				
Massilina sp. 1				
Massilina victoriensis Cushman				
Triloculina sp.				
Pyrgo spp.				
Quinqueloculina (*Sigmoilina*) *silvestrii* C & O				
Pullenia bulloides (d'Orbigny)				
Spirillina decorata Brady				
Rotorbinella sp.				
Spirillina tuberosa Carter				
Quinqueloculina vulgaris d'Orbigny				
Quinqueloculina cuvieriana d'Orbigny				
Triloculina trigonula (Lamarck)				
Dentalina fusiformis (Roemer)				
Sigmomorphina subregularis H & P.				
Bronnella finlayi Dorreen				
Genus B				
Cibicides lobatulus (W & J)				
Bolivinopsis crespinae Parr				
Trimosina sp.				
Buccella sp.				
Angulogerina subangularis Parr				
Patellina corrugata Williamson				
Discorbis cf. *finlayi* Dorreen				
Globorotalia crassa Dorreen				
Globorotalia sp.				
Lamarckina glencoensis Chapman & Crespin				

TABLE A

AL LOG - ID. ETHRICK, SECTION 23, [illegible]

[illegible] FORMATION												ETHRICK FORMATION				
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
-	-	-	-	-	-	-	-	x	-	-	-	F	▼			
-	-	-	-	-	-	-	-	-	-	-	-	▼	-	-	-	F
-	-	-	-	-	-	F	▼	f	-	f	-	▲	f	▼	f	F
-	-	-	-	-	○	▲	▲	▲	▲	F	-	F	▼	f	▼	▼
-	-	-	-	-	-	-	-	-	▼	-	-	-	-	●	F	-
▼	F	-	-	F	▼	f	-	f	▼	-	f					
-	▼	f	-	-	-	-	f	○	f	▼	-	f	F	F	F	F
●	●															
F	▼															
-	▼	▼														
▼	▼	-	-	-	-	-	-	▼	-	-	-	-	-	▼	▼	
F	●															
	▼	-	-	-	-	-	-	F	F	▼	-	-	-	f		
f	●	▼														
	▼															
		▼														
		●	-	-	-	-	-	-	-	-	-	-	-	-	f	
		▼														
		F														
		f	-	-	-	-	▼	-	-	-	-	▼	-	-	-	▼
		F														
		▼	f	▲	F	f	▼	▼	F	F						
			▼	▼												
			▼	-	-	-	-	-	-	F	f	-	-		F	▼
			F													
			▼	-	-	-	-	-	-	▼	-	-	-	▼	-	▼
			▼													
				f	-	[illegible]	-	-	-	-	-	-	-	f	f	
				▲	F	●	○	f	○	●	▼	f	-	F	f	○
				▼	-	-	-	▼	-	-	-	▼	-	▼	▼	▼
					▼	-	▼	▼	F	F	-	F	▼	-		
						○	F	F	f	○	f	▼	f	f	▼	○
						▼	f	f	○	F	▼	F	-	●	▼	f
						F	f	f	▼	○	f	-	-	-	-	▼
						▼	-	-	F	F						
						▼	-	-	▼	-	-	-	-	-	-	▼

TABLE 4

MICROPALAEONTOLOGICAL LOG - HD. [illegible], SECTION 21, BORE 2

				LOXTON SANDS								[illegible] FORMATION				
	10-60 P144/53	60-70 P148/53	70-80 P149/53	80-90 P150/53	90-100 P151/53	100-110 P152/53	110-120 P153/53	120-130 P154/53	130-140 P155/53	140-150 P156/53	150-160 P157/53	160-170 P158/53	170-180 P159/53	180-190 P160/53	190-200 P161/53	200-210 P162/53
[illegible] spp.	▼	–	–	–	–	–	–	–	–	–	–	–	–	–	x	–
Cassidulina sp.	▼															
Heronallenia parri Carter	▼	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
"Discorbis" [illegible] (d'Orbigny)	f															
Trifarina bradyi Cushman	–	▼	–	–	–	–	–	–	–	–	–	–	r	v	f	–
Cassidulina subglobosa Brady		▼	–	–	–	–	–	–	–	–	–	c	a	a	a	a
Sphaeroidina bulloides (d'Orbigny)		▼	–	–	–	–	–	–	–	–	–	–	–	–	–	▼
Notorotalia howchini (C.P. & C.)		▼	▼	–	–	▼	▼	r	–	–	r	▼	f	–	f	▼
Anomalina glabrata Cushman		▼	–	–	–	–	–	▼	f	–	–	–	–	f	c	f
Elphidium pseudonodosum Cushman		r	▼	▼	▼											
"Rotalia" beccarii tepida Cushman		c	f	f	r	▼	c	c								
Crespinella umbonifera (Howchin & Parr)		a	f	▼	v	f										
[illegible] sp.					r	–	r	▼								
Nonion victoriense Cushman					▼											
[illegible]rotalia sp.						▼	–	v	▼							
Elphidium pseudonodosum Cushman						▼										
Guttulina problema d'Orbigny							▼	▼	–	–	–	–	–	–	▼	–
Elphidium crassatum Cushman							r	c								
Elphidium advenum Cushman								▼	–	–	–	–	–	–	r	r
Guttulina irregularis d'Orbigny							f	c	▼							
Elphidium macellum (Fichtel & Moll)								▼								
Pullenia quinqueloba (Reuss)									▼							
Cibicides refulgens Montfort									a	–	–	–	–	–	–	–
Planorbulinella inaequilateralis (H.A. & E.)									▼							
Amphistegina "lessonii d'Orbigny"									r							
Astrononion australe Cushman & Edwards									f	–	–	–	–	▼	–	–
Elphidium advenum var. depressulum Cushman									r							
Anomalina sp. A									▼	f	a	r	f	▼	▼	r
Textularia vertebralis Cushman										▼	▼					
Discorbis parri Cushman										▼	–	–	–	–	–	–
[illegible] sp.										r						
Stomatorbina concentrica (Parker & Jones)										▼	–	–	–	–	–	–
Elphidium howchini Cushman										▼						
Eponides repandus (F. & M.)											f	–	–	–	–	–
Cibicides pseudoungerianus (Cushman)											a	r	c	c	f	c
Gyroidina sp. A.											▼	–	–	–	▼	–
Sherbornina atkinsoni Chapman												▼	–	▼	▼	r
Cibicides umbonifer Parr													c	r	r	f
Cibicides brevoralis Carter													▼	r	f	c
Cibicides vortex Dorreen													r	f	f	▼
Cibicides concentricus Cushman													▼	–	–	r
Baggina philippinensis (Cushman)													▼	–	–	▼

Sherbornina atkinsoni, Cibicides spp. and other small species are abundant.

Outcrops of the Ettrick Formation

The Formation was first described from the subsurface section and was not at that time known to outcrop. Outcrops have since been recognised but the exposures are poor and no good sequence is known.

Between Tailem Bend and Wellington a shelf of hard cellular grey limestone is exposed at water level on the east bank of the Murray River. This appears to be the top of the Ettrick Formation, the Mannum Formation having been removed by erosion and Pliocene calcareous sandstones deposited directly on the Ettrick.

The formation appears to be widespread in the Coonalpyn area. Seven to eight miles west of Coonalpyn green bryozoal limestone entered at shallow depth on Section 2 and 14 Hundred of Strawbridge probably also belongs to the upper part of the formation. On Section 14 a sample collected from a quarry at a depth of 6 feet contains Sherbornina atkinsoni, Cassidulina subglobosa, Stomatorbina concentrica and Notorotalia crassimura.

The formation also occurs near the surface at Elwomple where a sample collected from a well at the gate leading to the Elwomple water supply on Section 405 Hundred of Seymour consists of green sandy marl, stained with ferric iron, with "Lovenia forbesi" and numerous molluscan casts. The microfauna, which is poorly preserved, contains Sherbornina atkinsoni, Cibicides umbonifer, Gyroidina sp. and many other small species. The rock appears to be lithologically and faunally comparable with the lower part of the formation, from 280-285 feet in the standard section.

Stratigraphical Relationships of the Ettrick Formation

The Ettrick Formation is believed to be partly equivalent to the Gambier Limestone. So little is known of the subsurface stratigraphy of the area between Millicent and Coonalpyn that it has not yet been possible to trace the northerly extension of the

Gambier Limestone and its probable lateral transition to the marls of the Ettrick Formation. The lenticular habit of limestones and faunal differences between most of the Gambier Limestone and the limestone at the top of the Ettrick Formation would appear to favour only partial correlation as was suggested originally (Ludbrook, 1957 Table I p.175).

(4) MURRAY GROUP

The limestones, clays and marls of Miocene age which are well exposed on the western margin of the Basin by down cutting of the River Murray are included in the Murray Group.

The name Murray as "the middle and lower Murray series" was first applied to these rocks in 1878 by Tate (p. 122) who in the same publication (p. 123) referred to the "Upper Murravian Series". The subsequent history of the use of the term Murravian and its subdivisions was reviewed by F.A. Singleton (1941, pp. 43-45). The Murray Group as defined by the present writer includes the limestones of Tate's Lower and middle Murravian but not the oyster beds of the Upper Murravian, most of which are now included in the Norwest Bend Formation.

The sections exposed at several accessible places in the river cliffs between Norwest Bend and Blanchetown which were measured and described by Tate (1885) have recently been re-sampled for their microfaunas.

Type sections have been defined at 4 miles below Morgan, at Norwest Bend and also at Mannum.

The limestones of the Murray Group overlap progressively onto bedrock along the western margin of the Basin and represent the maximum marine transgression in the Murray Basin proper. The Group is entirely of marine origin.

Local diastems are visible in exposures at Mannum and in the river cliffs between Blanchetown and Morgan, but the succession from the beginning of normal marine sedimentation in the Oligocene to the Middle Miocene represented by the Pata Limestone appears to be continuous in the deeper parts of the Basin near the Victorian Border between Pinnaroo and Renmark.

The Mid-Tertiary Sequence at Monnum, South Australia

In 1953, the Tertiary section was clearly exposed at Monnum on Section 519, Hundred of Finniss, during excavations for the pumping station to supply River Murray water to Adelaide. Although outcropping strata are readily accessible in river cliff sections and road cuttings in the township and surrounding districts, very little was known of their precise relationships apart from the fact that they carried a distinctive marine fauna, mostly echinoids and brachiopods, of presumed Miocene age.

In December of that year R.C. Sprigg, E.P.D. O'Driscoll, and N.H. Ludbrook measured and sampled the section at a time when the maximum vertical distance was exposed and while convenient scaffoldings were in place on the batter behind the pumping station and below the floor level of the main building. Since then, the large scaffolding has been removed, the lowest exposures in the foundation excavations are no longer accessible, and much of the section has been covered in cleaning up and levelling off the area generally.

Using as a reference the floor of the station R.L. 130 feet (datum level - Port Adelaide L.W.O.S.T. = 100 feet) measurements were taken by tape below, and by Highway Level above the floor to ground level at the top of the excavation. Sampling was initially done from the scaffoldings at 5-feet intervals or at noticeable changes in lithology.

Further collections, chiefly of megafossils, were subsequently made as opportunity offered. Collecting was always done horizontally parallel to the bedding at significant levels based on lithological and microfaunal changes. Stations from which they were taken are marked with sample numbers on Plan I.

All material is in the collection of the South Australian Mines Department.

Stratigraphic Units

The general succession in the Monnum area is divided into 4 stratigraphical units, measured at the type section at the pumping station:

Formation (in downward sequence)	Thickness (feet)
Lorton Sands	16
Morgan Limestone	8½
Finniss Clay	6
Mannum Formation	62+
	92½

The Mannum Formation is exposed in river cliffs in Mannum Township and northwards to beyond Swan Reach. It is penetrated in bores in the southwestern portion of the Murray Basin and has equivalents elsewhere which have not as yet been adequately studied. Its total thickness may be of the order of 100 feet. Basal beds, where they have been seen, are coarse calcareous quartz grits followed by calcareous quartz sandstones with some sandy limestones. The Formation is generally richly fossiliferous throughout, with a shallow-water, shoreline marine fauna. Most of the fossils, particularly the foraminifera, are poorly preserved.

The Finniss Clay succeeds the Mannum Formation with pronounced lithological change after a cessation of deposition thought to indicate a diastem rather than a disconformity. It is named for the Hundred of Finniss in which Mannum is situated.

The Morgan Limestone conformably follows the Finniss Clay with which it is interbedded near the top of the Clay. It has been considerably removed by erosion and survives as a thin remnant only in the Mannum area; elsewhere to the north it probably represents with its equivalents the maximum Lower Miocene transgression.

Fossils collected from the Miocene limestones were first figured by Captain Sturt, the explorer, in his geological observations on the Murray River (Sturt, 1833, pp. 253-255, pl. 3)

Cross bedded gritty sands are well exposed at the top of the cuttings around the pumping station and in the roadway leading down to the main buildings. They are considered to be Lorton Sands.

With the exception of the Loxton Sands, the attitude of the formations is nearly horizontal. The beds are thin and of marginal facies. Deposition in the Murray Basin has been slow and strata a few feet thick may represent appreciable time-intervals.

The most striking feature of the freshly exposed section was a previously unobserved by conspicuous break in sedimentation above the Mannum Formation. At R.L. 174 feet the Mannum calcareous sandstones are separated abruptly from the overlying blue Finniss Clay. At first glance the break in sedimentation suggests an old erosion surface, particularly as there is some secondary calcification of the top of the sandstone simulating a thin kunkar which shows up well, though over-emphasized, in photographs. The surface is, however, flat, apparently smooth, and horizontal over a wide area. It can be traced on the south-eastern side of the river where it forms a conspicuous physiographical feature. About 200 yards beyond the Pende turn-off and 0.8 miles from the punt along the Pompoota road on the western boundary of Section 19, Hundred of Younghusband, it is recognised covered with kunkar, the overlying Finniss Clay forming a gentle slope above and the younger Morgan Limestone outcropping at the road level. Looking towards the south the break is marked on the other side of a small gully a hundred yards or so distant by a line of kunkar showing conspicuously through the sand cover. This has the appearance of a fossil kunkar, but may merely represent availability of calcium carbonate in the underlying sandstones in contrast with a deficiency in the overlying clays.

An unconformity separates the Morgan Limestone from the cross-bedded Loxton Sands which have been deposited on a channelled surface of the Limestone under scour-and-fill conditions.

Superficial clays and kunkar form the surface cover over most of the area.

MANNUM FORMATION

Lower Member

Lithology. The lowest beds exposed in the excavation are dominantly medium to coarse-grained light cream to yellow-brown fossiliferous calcareous sandstones rich in limonite and with abundant tests or fragments of the echinoid known as Lovenia forbesi. From the base at R.L. 112.4 feet upwards the member consists of 15 feet of fine-grained soft calcareous sandstone with a few megafossils, grading into hard medium light yellow-brown calcareous sandstone with bands of broken megafossils, mostly Lovenia, and brown marly pockets. This is followed by 10 feet of irregularly banded hard medium coarse-grained light yellow-brown calcareous sandstone with abundant Lovenia distributed fairly consistently throughout the mass. There are occasional clayey pockets.

After elutriation the sediments consist microscopically of rounded to subangular quartz grains, calcite fragments and pellets, frequently heavily stained with limonite, grains of limonite, fragments of bryosoa and echinoid spines. Microfossils are poorly preserved, foraminifera and ostracoda being frequently infilled or replaced by limonite or calcified to the extent that identification is difficult.

Thickness. Thickness of the member exceeds 25 feet, the bottom of the Formation not having been exposed when measurements were taken. Officers of the Engineering and Water Supply Department have stated that at R.L. 85.5 feet, the underside of the floor for "A" suction sump, the same formation persisted.

Megafauna. (Samples F273/53 to F278/53, F15/53, F43/55, F46/55).

Bryozoa

Not determined specifically, and including species of Cellaria, Selenaria, Petralia, Porina, Cellepora, and Cabarea.

Brachiopoda

Magadina compta (Sowerby)

Magadina lunata (Tate)

Murravia catinuliformis (Tate)

Fig. 1. Mannum Formation as exposed before levelling, Mannum Pumping Station.

Fig. 2. Mannum Formation; air hammers in foreground.

Echinoidea

Psammechinus woodsi (Laube)

Fibularia gregata Tate

Lovenia "forbesi T. Woods"

Scutellina patella Tate

Monostychia australis (Laube)

cf. Echinolampas posterocrassa Gregory

[illegible] [illegible] Wright

[illegible] sp.

Eupatagus rotundus Duncan

Eupatagus murrayensis Laube

Pelecypoda

Lentipecten sp.

Serripecten yahliensis (T. Woods)

Chlamys foulcheri (T. Woods)

Ostrea sp.

Scaphopoda

Dentalium aratum Tate

Gastropoda

Cypraea [illegible] Tate

Microfauna (Samples F273/53 to F278/53).

The microfauna is characterised by an assemblage of small foraminifera rather than by any recognizable zone fossil. The assemblage is dominated by Astrononion centroplax, Calcarina mackayi, Cibicides pseudoungerianus, C. refulgens, Crespinella sp. nov. 1, Elphidium crassatum, Rotalia cf. calcar, Sherbornina cuneimarginata, with less plentiful Cassidulina subglobosa, Frondicularia [illegible], Gaudryina (Siphogaudryina) victoriana, Heronallenia lingulata, Planorbulinella inaequilateralis, Sigmoidella elegantissima. Textularia vertebralis occurs in abundance in the lowest sample and Operculina victoriensis comes in some 6 feet from the top of the member. Other species less commonly appearing are listed in Table II.

Upper Member

Lithology. At R.L. 137 feet there is a slight change in lithology accompanied by a change in the fauna, and marked by an irregular contact. There is a reduced tendency to banding and a change in the general texture. The calcareous sandstone becomes less dense and more numerous small clayey pockets occur. Megafossils are extremely abundant in places, loosely consolidated masses of Lovenia suggesting a coquinite. In the cliffs near the river's edge on the southeast side of the excavation, where the sediments have been exposed to natural weathering, the difference in texture is emphasized. The upper member weathers to a "raggy limestone" (Tate, 1885, p. 39) with numerous cavities.

Microscopically, washings are composed of angular to sub-angular quartz grains, calcite fragments with much limonite staining, and limonite pellets. Foraminifera, as with the lower member, are badly preserved.

Thickness of the member is 37 feet.

Megafauna. (Samples F279/53 to F284/53, F40/55 to F42/55).

Brachiopoda

Magadina compta (Sowerby)

Magadina lunata (Tate)

Murravia catinuliformis (Tate)

Echinoidea

Lovenia "forbesi T. Woods"

Fibularia gregata Tate

Monostychia australis (Laube)

Rupatagus murrayanus Laube

cf. Echinobrissus vincentinus Tate

Cephalopoda

Aturia australis McCoy

"Nautilus" altifrons Chapman

"Nautilus" geelongensis Foord

Pelecypoda

Nuculana woodsi (Tate)

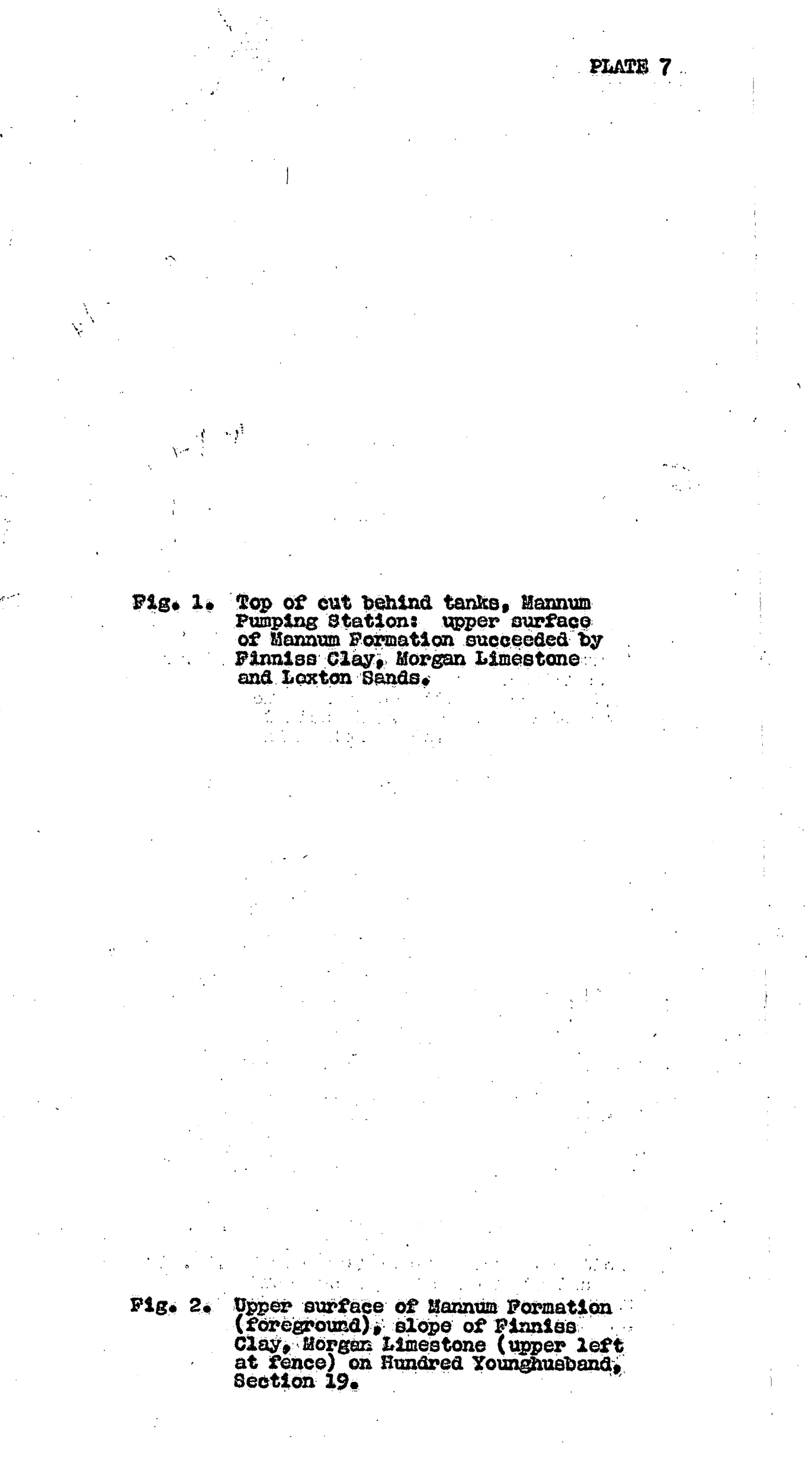


Fig. 1. Top of cut behind tanks, Mannum Pumping Station: upper surface of Mannum Formation succeeded by Finniss Clay, Morgan Limestone and Loxton Sands.

Fig. 2. Upper surface of Mannum Formation (foreground), slope of Finniss Clay, Morgan Limestone (upper left at fence) on Hundred Younghusband, Section 19.

Fig. 1. Line of kunkar marking top of Mannum Formation, Hundred Younghusband, Section 19.

Fig. 2. Thin Tertiary cover on granite Hundred Younghusband, Section 156.

Glycymeris sp. indet.

Chlamys sturtianus (Tate)

Serripecten yahliensis (T. Woods)

Spondylus pseudoradula McCoy

Ostrea sp.

Gastropoda

Cassis cf. textilis Tate

Microfauna (Samples F279/53 to F284/53).

The foraminiferal assemblage is marked by the appearance of Austrotrillina howchini and Planorbulinella plana at the base of the member. It is dominated by Anomalina glabrata, Austrotrillina howchini, Calcarina verriculata, Cassidulina subglobosa, Cibicides pseudoungerianus, Cibicides refulgens, "Crespinella" sp. nov. [illegible]thia perri, Elphidium crassatum, Elphidium crespinae, Guttulina irregularis, Notorotalia howchini, Planorbulinella inaequilateralis, Rotalia cf. calcar, Sigmoidella elegantissima. Species spasmodically occurring are listed in the palaeontological log Table II.

Section 156, Hundred of Younghusband

An interesting outcrop of the upper member occurs on the east side of the river in the Public Works Reserve at the granite quarry on Section 156, Hd. Younghusband. Here the smooth surface of a granite inlier is thinly covered with a few feet of coarse rubbly crinoidal calcareous sandstone.

Probably an island at the beginning of the transgression, the granite was submerged to shallow depth at the end of the deposition of the Mannum Formation. Optimum conditions for the establishment of a crinoid colony must have existed, for crinoid remains are very abundant. Megafossils identified (F249/53) are Mopsea tenisoni Chapman, Scutellina patella Tate, Lovenia "forbesi T. Woods" (abundant), Magadina lunata (Tate), Murravia catinuliformis (Tate), Chlamys sturtianus (Tate), Chlamys murrayanus (Tate), Ostrea sp.

Fig. 1. Marne River Valley, exposures of Mannum Formation. View north east.

Fig. 2. Marne River Valley. Hundred Ridley, Section 345. Mannum Formation transgressive on steeply dipping Kanmantoo rocks.

Foraminifera (F249/53)

Textularia vertebralis Cushman

Textularia sagittula Difrance

Textularia pseudogramen Chapman & Parr

Frondicularia lorifera Chapman

Sigmomorphina subreticularis Howchin & Parr

Sigmoidella elegantissima (Parker & Jones)

Elphidium crespinae Cushman

Notorotalia howchini (Chapman, Parr & Collins)

Operculina victoriensis (Chapman & Parr)

Stomatorbina concentrica Brady

Eponides sp. indet.

Crespinella sp. nov.

Amphistegina sp. indet.

Globigerina sp.

Sherborniana cancisarrinata Wade (common)

Astrononion centroplax Carter

Cibicides pseudoungerianus Cushman (abundant)

Cibicides refulgens Montfort

Planorbulina mediterranensis d'Orbigny

Planorbulinella plana (Heron Allen & Earland)

The Mannum formation is well developed in the south west of the Murray Basin proper. It is transgressive on Kanmantoo bedrock around Strathalbyn, and on to Monarto granite in railway cuttings on the Mobilong-Monarto boundary.

The formation is well exposed at Murray Bridge where it has been worked for building "freestone", and is now quarried for road screenings.

In the Horne River valley, on Section 345 Hundred of Ridley 4 miles east of Black Hill an exposure occurs in the road cutting on the west side of the road to Swan Reach. Here a basal breccia, 1 foot thick and sandstone unconformably overlie steeply dipping rocks of the Kanmantoo Group. Maximum thickness of the sandstone is 25 feet. It contains Sherborniana atkinsoni. Above

the sandstone 5 to 10 feet of greenish grey glauconitic clay are visible. The clay contains ovoid glauconite pellets, calcite fragments and a microfauna with Cassidulina subglobosa, Cibicides pseudoungerianus, and Cibicides umbonifer.

Contacts with Kanmantoo bedrock may be seen also at Rocky Point, 8 miles upstream from Mannum and near Teal Flat on Section 14, Hundred of Ridley.

FINNISS CLAY

Lithology. Overlying the Mannum Formation with the marked break in sedimentation at R.L. 174 feet at the type section at the pumping station are 15 feet of mottled light blue-grey, green and brown marine clays with large nodules of radiating gypsum about 6 inches in diameter in a band about 2 feet from the base of the clay on the cutting around the tanks in the upper part of the excavation. The Clay, which is named for the Hundred of Finniss, forms gentle slopes for a short distance above the top of the Mannum beds elsewhere in the district. It is locally poorly fossiliferous. In the upper two thirds of the formation, at R.L. 176 feet, the clay is interbedded with hard sandy yellow limestone into which it passes conformably.

Microscopically the washings of the clay samples differ little from those of the calcareous sandstones, with fine angular quartz grains, calcite fragments and limonite. Microfossils are scarce and poorly preserved; foraminifera are often in the form of internal casts in limonite only.

Thickness: 15 feet

Fauna (Samples F285/53 to F287/53). No megafossils were collected. The microfaunal assemblage is dominated by Amphistegina lessonii, Cibicides pseudoungerianus, and Operculina victoriensis, with Austrotrillina howchini, Calcarina verriculata, Dorothia parri, Guttulina irregularis, Quinqueloculina vulgaris, Sigmoilina cf. chapmani. Others are indicated on the log.

MORGAN LIMESTONE

Lithology. At first interbedded with and then replacing the clays is a massive nodular, medium to coarse-grained hard yellow sandy limestone with coarse banding, about 18" wide, carrying a few Lovenia (no longer dominant) abundant Cellepora, Operculina and Amphistegina showing on weathered surfaces in consolidated masses, gastropod moulds, Calliostoma, Spondylus, and echinoid spines.

Thickness. The formation has a measured thickness of 8 feet 6 inches above the uppermost clay band in the Mannum section.

Samples F 28A/55, F44/55, F45/55

Bryozoa

Cellepora etc. very abundant

Brachiopoda

Magellania garibaldiana (Davidson)

Magadina lunata (Tate)

Murravia catinuliformis (Tate)

Echinoidea

Fibularia gregata Tate

Pelecypoda

Chlamys [illegible] (T. Woods)

Chlamys murrayana (Tate)

Foraminifera

Textularia [illegible], Dorothia cf. davi, Dorothia karreri, Sigmoidella kagaensis, Parrellina craticulatiformis, Elphidium macellum var. [illegible] and Crespinella umbonifera enter and the assemblage is dominated by Operculina victoriensis, Amphistegina lessoni, Dorothia parri, Dorothia karreri and Quinqueloculina vulgaris.

On microfaunal evidence, in the absence of known restricted zone fossils, correlation must be based upon assemblages. The presence of Austrotrillina howchini in the upper member of the Mannum Formation, the Finniss Clay and the Morgan Limestone would suggest a Lower Miocene age for those beds since outside Australia Austrotrillina is not known to occur earlier than the

Upper Oligocene or later than Lower Miocene (Glaessner, 1951, p. 277).

Ranges of the megafossils are tabulated in Table I. *Aturia australis* enters at the base of the upper member of the Mannum Formation and the two *nautiloids* occur in thismember. *Chlamys murrayana* is rare.

In the absence of any accurate definition of the Oligocene - Miocene boundary, the Mannum Formation probably straddles the boundary, the approximate base of the Miocene (assuming Aquitanian to be Lower Miocene) being indicated by the entry of *Austrotrillina howchini* and *Planorbulinella plana* in the upper member.

TABLE 5

Vertical Range of Megafossils, Mannum Pumping Station

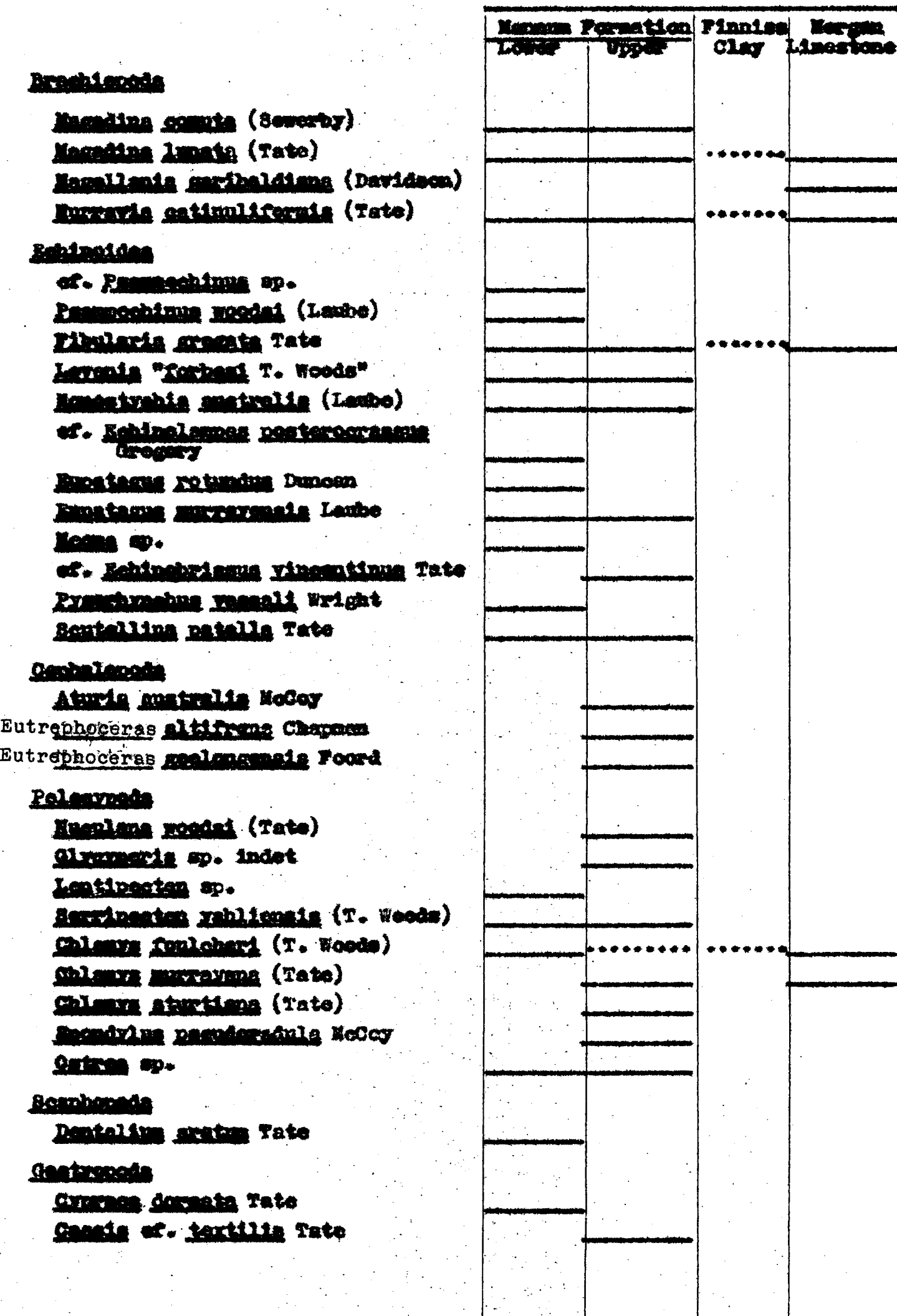


TABLE 6

DISTRIBUTION TABLE - FORAMINIFERA

MEASURED SECTION, MANNUM PUMPING STATION, [illegible]

	MANNUM FORMATION								
	LOWER MEMBER								UPPER M
Sample Number	273/53	274/53	275/53	276/53	277/53	278/53	279/53	280/53	281/53
R.L. (feet)	112'4" 117'4"	117'4" 122'4"	122'4" 127'4"	127'4" 132'	132' 135'	136' 138'	139' 143'	144' 145'6"	146' 149'6"
Textularia australis Parr	v	-	-	-	-	-	-	-	-
Textularia pseudogramen Ch. & Parr	f	v	v	f	r		v	v	f
Textularia vertebralis Cushman	a								
Gaudryina (Pseudogaudryina) crespinae C.	v	v	-	v	r	-	-	-	v
Dorothia parri Cushman	r	-	v	f	v	-	-	-	o
Nodosaria spp.	v								
Lagena spp.	v	-	-	r	-	-	-	-	-
Frondicularia lorifera Chapman	f	r	r	r	v	-	v	-	-
Guttulina irregularis d'Orbigny	r	-	v	r	-	-	-	v	r
Sigmomorphina subregularis H. & P.	v	-	-	-	-	-	-	-	-
Reussella simplex Cushman	v	v	-	v	r	r	r	v	r
Angulogerina australis (H. A. & E.)	r								
Trifarina bradyi Cushman	v								
Loxostomum sp.	v	-	v	-	-	v	-	v	-
Cassidulina subglobosa Brady	f	r	-	v	v	-	-	r	r
Pullenia quinqueloba (Reuss)	v	v	-	v					
Spirillina sp.	v	v	-	-	-	-	-	-	v
"Discorbis" bonsanus (d'Orbigny)	f	f	-	o	-	v	-	-	v
Planulinaria sp.	f	r	-	v	v	-	-	-	-
Rosalina lornensis Finlay	r	v	-	v	r	-	-	-	-
Baggina philippinensis (Cushman)	f	v	r	r					
Siphonina australis Cushman	o	v	r	f	r	-	r	-	r
Cibicides lobatulus W. & J.	f	r	v	v	v	-	v	v	r
Cibicides pseudoungerianus Cushman	a	a	o	a	o	o	o	f	a
Cibicides refulgens Montfort	o	f	c	f	r	-	r	f	f
Cibicides brevoralis Carter	r	-	v						
Planulina spp.	f	v	-	v	-	-	-	-	-
Anomalina sp. 1	f	f	-	-	-	-	-	v	
Globigerina bulloides d'Orbigny	v	v	-	-	-	-	-	-	-
Planorbulina mediterranensis d'Orbigny	r	-	v	f					
Planorbulinella inaequilateralis (H A & E.)	r	v	-	-	v	v	v	r	v
Astrononion centroplax Carter	f	f	r	f	v	r	f	-	v
Astrononion australe Cushman & Edwards	r								
Elphidium sp.	v	-	-	-	-	-	-	-	v
Sherbornina cuneimarginata Wade	r	r	r	o	v	-	v	-	r
Notorotalia howchini (C. P. & C.)	a	f	r	o	o	r	r	f	r
Notorotalia crassimura Carter	v	r	r	r	r	v	-	-	r
Heronallenia lingulata (Burrows & Holland)	r								
Heronallenia parri Carter	r	-	-	-	-	-	-	-	-
Ceratobulimina dehiscens H A & E.	v	v							
Rotalia cf. calcar d'Orbigny	v	-	v	o	-	-	v	r	a

TABLE 6

DISTRIBUTION TABLE - FORAMINIFERA

MEASURED SECTION, MANNUM PUMPING STATION, IN UPWARD SEQUENCE

MANNUM FORMATION – LOWER MEMBER				MANNUM FORMATION – UPPER MEMBER						FINNISS CLAY			MORGAN LIME-STONE	LOXTON SANDS
875/53 122'4" 127'4"	876/53 127'4" 132'	877/53 132' 135'	878/53 136' 138'	879/53 139' 143'	880/53 144' 145'6"	281/53 146' 149'6"	282/53 150' 155'6"	283/53 155'9" 163'6"	284/53 163'6" 174'	285/53 174' 176'	286/53 176' 180'	287/53 176' 180'	288/53 180' 188'6"	289/53 190'
-	-	-	-	-	-	-	-	f	r					
▼	f	r		▼	▼	f	-	-	f					
-	▼	r	-	-	-	▼	-	▼	-	-	▼			
▼	f	▼	-	-	-	o	▼	r	f	-	▼	▼	f	-
-	r	-	-	-	-	-	-	-	▼					
r	r	▼	-	▼	-	-	-	▼						
▼	r	-	-	-	▼	r	r	r	f					
-	-	-	-	-	-	-	-	-	-	-	-	-	▼	-
-	▼	r	r	r	▼	r	-	▼						
▼	-	-	▼	-	▼	-	-	-	f					
-	▼	▼	-	-	r	r	▼	r	r					
-	▼													
-	-	-	-	-	-	▼	▼	-	▼					
-	●	-	▼	-	-	▼								
-	▼	▼	-	-	-	-	-	-	-	-	▼			
-	▼	r	-	-	-	-	-	▼	▼					
r	▼													
r	f	r	-	r	-	r	r	▼	r					
▼	▼	▼	-	▼	▼	r	-	-	r	-	-	-	▼	-
●	▲	●	o	o	f	▲	▲	o	o	o	f	r	f	-
●	f	r	-	r	f	f	f	-	o					
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r	●	▼	-	▼	-	r								
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	MANNUM FORMATION									
	LOWER MEMBER								UPPER MEMBER	
Sample Number	273/53	274/53	275/53	276/53	277/53	278/53	279/53	280/53	281/53	282
R.L. (feet)	112'4" 117'4"	117'4" 122'4"	122'4" 127'4"	127'4" 132'	132' 135'	136' 138'	139' 143'	144' 145'6"	146' 149'6"	150 15[illegible]
Calcarina mackayi (Karrer)	r	v	f	r	f	c	a	-	-	
"Crespinella" sp. nov.	f	r	r	c	c	r	f	-	v	
[illegible]udryina (Siphogaudryina) victoriana C.		r	r	c	f	v	v	v		
Bolivinella folia (P. & J.)		v	-	-	-	-	-	-	v	
Guttulina lactea (W. & J.)		v	v	f	-	-	-	v	-	
Guttulina regina B., P. & J.		v	-	v						
Cibicidella variabilis d'Orbigny		v	v	r						
Amion victoriensis Cushman		v	-	-	-	-	-	-	-	
Elphidium crassatum Cushman		v	r	f	r	r	-	v	r	
Rotalia beccarii (Linne)		v	-	v	-	-	-	-	c	
Stomatorbina concentrica (Parker & Jones)			v	v	v	v	v	-	-	
Conorbella pateliformis Brady			v	f	r	v	v	-	r	
Glabratella cruciformis (Howchin)			v	f						
Planulinoides biconcava (Jones & Parker)			v	v	-	-	-	-	v	
Valvulineria cf. porifera (Parr)			v	-	-	-				
Spirillina unilatera Chapman			r	-	-	-	-	-	v	
Globigerina sp.			v	r	-	-	-	f	v	
Elphidium crespinae Cushman			f	r	-	-	-	r	r	
Elphidium parri Cushman			r	-	r	-	v	v	-	
Nodosaria vertebralis Batsch				v	-	-	-	-	-	
[illegible]alenia sp.				v						
Sigmoidella kagaensis C. & O.				v	v	-	-	-	-	
Reussella spinulosa (Reuss)				f	v	v	-	f	a	
Angulogerina spp.				r	-	-	-	-	-	
Buliminella madagascariensis var. spicata Cushman				v	-	v	-	-	-	
Bolivina crespinae Cushman				v						
Bolivina hebes var. victoriensis Cushman				v						
Bolivinella cf. australis Cushman				v	-	-	-	-	v	
Bolivinella folia var. ornata Cushman				v						
Discorbis floridana Cushman				v	-	-	-	v	-	
Calcarina verriculata (Howchin & Parr)				r	-	r	r	f	f	
Carpenteria rotaliformis Chapman & Crespin				v						
Textularia cf. sagittula Defrance					v	-	-	v	-	
Quinqueloculina spp.						v	-	v	r	
Pyrgo sp.					v	v	-	-	-	
Sigmoilina sp.					v	-	v	-	-	
Buliminella elegantissima d'Orbigny					v					
Bolivina victoriana Cushman					v	-	-	v	-	
Rotorbinella [illegible] (Howchin & Parr)					r	v	v	-	c	
Cibicides concentricus Cushman					v	-	-	v	v	
Cibicides floridanus Cushman					f					
Operculina victoriensis Chapman & Parr					r	f	f	a	a	
Bolivina dilatata Reuss						v	-	-	-	

Mannum Formation											Finniss Clay			Morgan Limestone	Loxton Sands
[illegible]er Member				Upper Member											
/53	276/53	277/53	278/53	279/53	280/53	281/53	282/53	283/53	284/53	285/53	286/53	287/53	288/53	289/53
4"	127'4"	132'	136'	139'	144'	146'	150'	155'9"	163'6"	174'	176'	176'	180'	
4"	132'	135'	138'	143'	145'6"	149'6"	155'6"	163'6"	174'	176'	180'	180'	188'6"	190'
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Sample Number R.L. (feet)	MANNUM FORMATION — LOWER MEMBER								UPP[ER MEMBER]
	273/53 112'4" 117'4"	274/53 117'4" 122'4"	275/53 122'4" 127'4"	276/53 127'4" 132'	277/53 132' 135'	278/53 136' 138'	279/53 139' 143'	280/53 144' 145'6"	281/ 146' 149'
Annulopatellina annularis (P. & J.)						v			
Discorbis mira Cushman						v	-	v	
[illegible] trilocularis d'Orbigny						v	-	-	-
Quinqueloculina seminulum (Linné)							v	-	-
Triloculina trigonula Lamarck							v	-	-
Austrotrillina howchini (Schlumberger)							r	v	r
Hauerinella? plana (Heron-Allen & Earland)							r	f	
Marginopora vertebralis Blainville								v	
Guttulina problema d'Orbigny								v	-
Bolivina cf. robusta Brady								v	-
Bolivina scalprata var. retiformis (Cushman)								v	
Eponides spp.								v	
Parvicarinina altocamerata (Heron-Allen & Earland)								v	-
Cancris auritus Cushman & Todd								v	
Dyocibicides biserialis C. & W.								f	
Acervulina inhaerens Schultze								r	
Triloculina tricarinata d'Orbigny									v
Pyrgo sarsi (Schlumberger)									v
Biloculinella globula (Bornemann)									v
Globigerina sp.									v
Elphidium chapmani Cushman									r
Quinqueloculina vulgaris d'Orbigny									
Textularia corrugata (Heron-Allen & Earland)									
Bulimina fusiformis Roemer									
Cornuspira howchini Chapman									
Lagena acuticostata Reuss									
Lagenonodosaria scalaris (Batsch)									
Nodosaria comata (Batsch)									
Bolivina tortuosa Brady									
Globigerina angustiumbilicata Bolli									
Gaudryina intermedia C. & T.									
Cibicides [illegible] Parr									
Amphistegina lessonii d'Orbigny									
Clavulinoides sp.									
Bigenerina cf. chapmani (Cushman)									
Parrellina craticulatiformis Wade									
Crespinella umbonifera Howchin & Parr									

v = very rare (1-2)
r = rare (3-5)
f = frequent (6-10)
c = common (11-25)
a = abundant (25 +)

[illegible] MEMBER			UPPER MEMBER (MANNUM FORMATION)						FINNISS CLAY			MORGAN LIME-STONE	LOXTON SANDS
276/53 127'4" 132'	277/53 132' 135'	278/53 136' 138'	279/53 139' 143'	280/53 144' 145'6"	281/53 146' 149'6"	282/53 150' 155'6"	283/53 155'9" 163'6"	284/53 163'6" 174'	285/53 174' 176'	286/53 176' 180'	287/53 176' 180'	288/53 180' 188'6"	289/53 190'
		▼											
		▼	●	▼									
		◆	●	●	●	◆	▼						
			▼	●	●	◆	▼	◆					
			▼	●	●	●	●	●	▼	▼			
			◆	▼	◆	◆	▲	●	●	▼			
			◆	◆									
				▼									
				▼	●	●	▼	▼					
				▼	●	●	●	▼					
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						◆	◆	●	●	●	◆		
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(1-2)
(3-5)
(6-10)
(11-25)
(25 +)

The Type Section of the Morgan Limestone and Cadell Marl Lens, 4 Miles South of Morgan

The Section described by Tate in 1885 is selected as type section for the Morgan Limestone and Cadell Marl Lens. The formation is of Lower Miocene (Batesfordian) age.

In 1885 Tate published a description of a section measured in the cliffs of the Murray River at a point 4 miles downstream from Morgan. This section is of particular importance as the type locality from which many of Tate's molluscan species were collected. It was recorded by Tate in downward as follows:

		ft.	in.
	Lacustrine		
1.	Reddish coloured calciferous clays	54	0
	Upper Murravian		
2.	Oyster bank	12	0
	Middle Murravian		
3.	Hard, lumpy, yellow sandstone	10	0
4.	Yellowish-grey limestone with clayey sand layers	10	10
5.	Yellowish-brown clayey sand with *Cellepora gambier-ensis*	5	4
6.	Id. with hard lumps and imperfectly stony bands. Very fossiliferous, particularly rich in gastropods	16	5
7.	Shell sand with streak of stiff blue clay	0	3
8.	As No. 6	5	0
9.	Yellow soft calciferous sandstone	43	6
	Total to river level	157	4

The section was remeasured and sampled by the writer in March, 1956. It is located about 4 miles downstream from Morgan on the east bank of the River Murray on Section C, Hundred of Cadell. It is readily accessible from the Morgan - Blanchetown road by driving off the road to the head of a small gully which cuts through the cliffs at this point. The section measured in the gully confirmed Tate's measurements and description.

Samples were taken at every five feet from the base of the section at river level or at changes in lithology, corresponding to Tate's numbered beds as follows:

Tate's Bed	Sample Number	
3	F 93/56	Hard limestone with Pecten.
	F 92/56	Top of limestone.
4	F 91/56	Bottom of 10 foot limestone bed.
5	F 90/56	Clayey sand with Collemora - north side of gully.
	F 89/56	South side of gully.
6	F 88/56	Top of marl lens.
	F 87/56	15 feet from bottom of marl lens.
	F 86/56	10' from bottom of marl lens.
7	3" shell sand	not observed.
8	F 85/56	5 feet from bottom of marl lens.
9	F 84/56	Hard band at top of lower member.
	F 83/56	third marly band.
	F 82/56	third Collemora band.
	F 81/56	second marly band.
	F 80/56	second Collemora band.
	F 79/56	first marly band.
	F 78/56	first Collemora band.
	F 77/56	10 feet above river level.
	F 76/56	5 feet above river level.
	base of section.	

MORGAN LIMESTONE

From river level upwards for 91 feet the cliffs consist of a light creamy yellow bryozoal limestone named the Morgan Limestone, with a marly lens from 21 feet thick and 300 yards long named the Cadell Marl Lens in the upper half commencing at 43'6" from the base of the Section.

The lower member 45 feet thick (Tate's bed 9) is a fairly uniform soft bryozoal limestone, cavernous near the river and becoming banded in the upper 30 feet. The hard bands each about 5 feet thick consist of masses of Collemora and alternate

into soft somewhat marly bands. The upper member (Tate's beds 5, 4, 3) above the Cadell Marl Lens is a hard yellow limestone with Cellepora.

The Morgan Limestone carries a rich microfauna similar to that of the Batesford Limestone in Victoria, although Lepidocyclina has not so far been discovered at or near Morgan. The typical assemblage of the lower member is dominated by Operculina victoriensis, Amphistegina lessonii, Cryosina howchini, Perelling craticulatiformis, Globigerinoides bimbacrica and Globigerinoides triloba.

The upper member is weathered and probably regressive, with a relatively sparse fauna.

CADELL MARL LENS

Within the Morgan Limestone at the type section a marl lens occurs over a length of 300 feet, with a maximum thickness of 22 feet (Tate's beds 8, 7, 6). The marl carries a rich fauna of well preserved mollusca which readily weather out on the surface.

These include the following species of Tate, the nomenclature of which is unrevised for the purposes of this paper. For most of them the Cadell Marl Lens type section is the type locality.

Pelecypoda

Nucula normdiana, Leda obolella, Leda woodsii, Cucullaea coriocensis, Diava dissimilis, Nuadora tenuilirata, Corditella polita, Lucina fabaloides, Anticona dimorphophylla, Verticordia rhomboidea, Xenatiovsia angustata, Cardiatrocardia fragilis, Solecurtus elliptieus, Corbula cohamilla.

Scaphopoda

Dentalium cratum, Entalis subfissura.

Gastropoda

Turritella murravana, Turritella acricula, Triton radialis, Triton tortirostris, Murex basicinctus, Murex machyatirus, Trophon mangelioides, Nassa tatei, Fasciolaria exilis, Fasciolaria decipiens, Fusus dictyotis, Fusus simulans, Fusus clavliformis, Fusus spiniferus, Peristernia murravana, Peristernia normdiana.

TABLE 7

DISTRIBUTION OF FORAMINIFERA

MORGAN RIVER SECTION IN WIZARD BRUNCH

Morgan Limestone Lower Member				Cadell Marl Lens				Morgan Limestone Upper Member			
F78/56	F79/56	F81/56	F83/56	F85/56	F86/56	F87/56	F88/56	F89/56	F91/56	F92/56	F93/56
-	-	-	v	-	r	v	-	-	-	-	v
-	v	-	-	-	-	-	-	-	-	-	-
-	-	r	f	v	-	v	-	v	-	-	-
-	r	r	f	r	-	-	-	-	-	-	v
-	-	-	-	-	f	a	a	a	-	v	-
-	-	a	a	a	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	v	-	-	r	-	-	-	-	v	-	-
-	v	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	f	a	a	-
-	-	f	-	-	-	-	-	-	-	-	-
-	-	r	f	-	v	-	f	-	-	-	-
-	-	-	-	v	-	-	-	-	v	-	-
-	-	-	v	v	-	-	-	-	-	-	-
v	a	a	v	f	v	-	-	a	f	f	f
-	-	-	-	-	-	-	-	-	-	-	-
-	v	v	r	-	r	-	-	-	f	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	v	f	r	-	-	-	-	-	-	-
-	v	v	f	f	a	r	v	-	-	v	-
-	-	-	-	-	v	-	-	f	a	v	-
-	-	-	-	f	-	-	-	-	-	-	-
-	-	-	-	v	-	-	-	-	-	-	-
v	-	v	f	f	v	-	-	v	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	-	-	-	-	-	-	-	-	-
-	-	-	a	-	-	-	-	-	-	-	-
v	-	a	f	a	a	a	r	-	-	-	-
v	-	a	-	-	-	-	-	-	-	-	-
v	-	-	-	-	-	-	-	-	-	-	-
v	-	-	-	-	-	v	-	cf.	-	-	-
v	v	r	r	v	v	v	-	v	-	f	v
v	-	-	v	-	-	-	-	-	-	-	-
v	v	-	-	-	-	-	-	-	-	-	-
	v	-	-	-	-	-	-	-	-	-	-
	r	-	-	r	-	-	-	r	r	-	-
	v	a	-	-	v	v	-	-	f	-	-
	v	-	-	-	-	-	-	-	-	-	-
	f	v	-	-	-	-	-	-	v	r	v
	v	-	-	-	-	-	-	-	-	-	-
	v	-	-	-	-	-	-	-	-	-	-
	r	v	r	v	r	v	-	-	f	-	-

TABLE 7

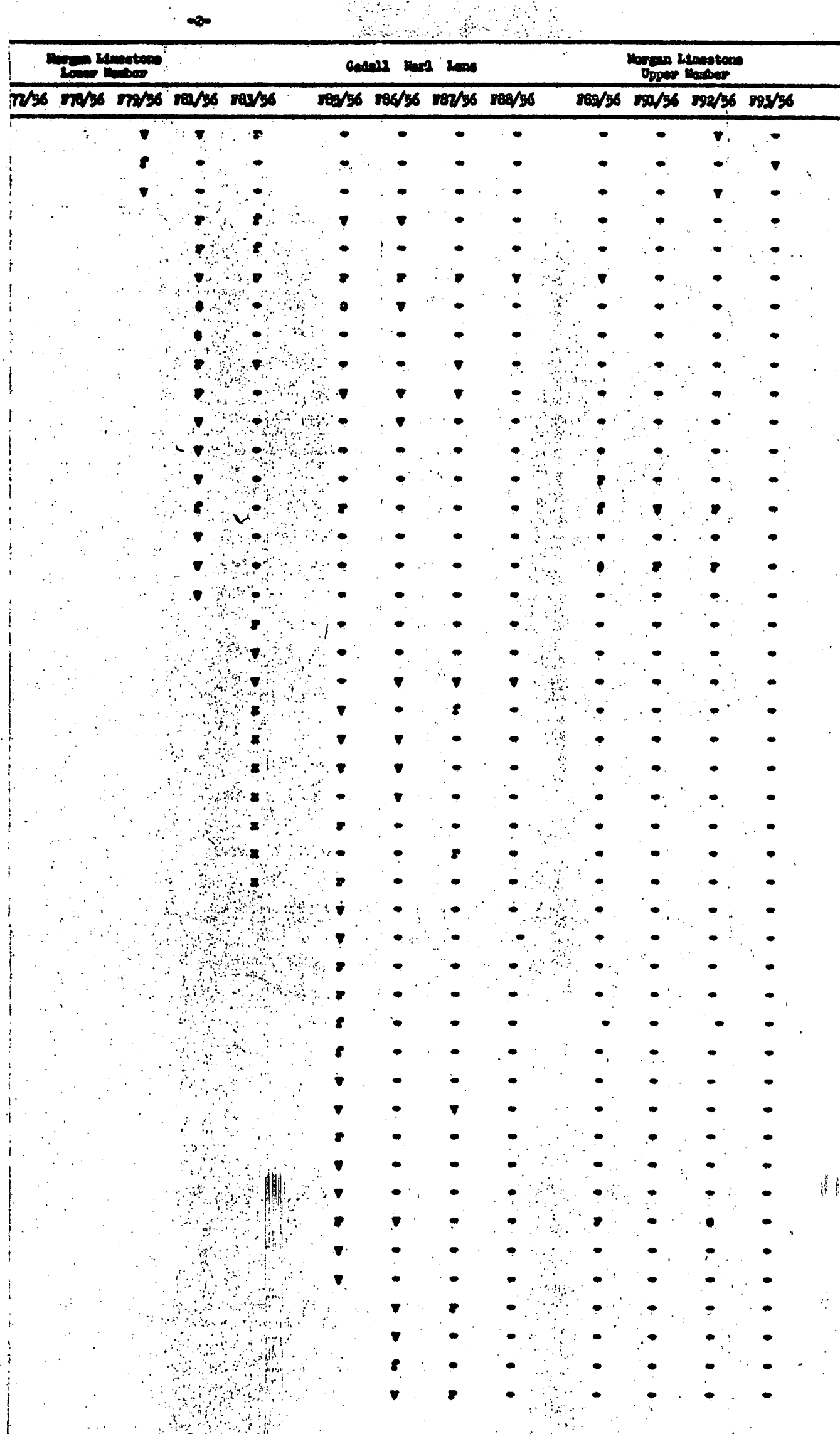
DISTRIBUTION OF FORAMINIFERA

MORGAN TYPE SECTION IN UPWARD SEQUENCE

	Morgan Limestone Lower Member						Cadell Marl	
	F76/56	F77/56	F78/56	F79/56	F81/56	F83/56	F85/56	F86/56
Textularia pseudogramen C & P	F	-	-	-	-	V	-	F
Textularia corrugata H. A. & E.	F	F	-	V	-	-	-	-
Textularia spp.	F	-	-	-	F	R	V	-
Dorothia parri Cushman	F	C	-	F	F	R	F	-
Dorothia spp.	V	-	-	-	-	-	-	R
Glandulinoides victoriensis Cushman	F	F	-	-	C	C	A	-
Sigmoilina sp.	V	-	-	-	-	-	-	-
Lagenonodosaria scalaris (Batsch)	F	-	-	V	-	-	F	-
Nodulocamerina mooraboolensis (H. A. & E.)	F	-	-	V	-	-	-	-
Uvigerina spp.	V	-	-	-	-	-	-	-
Ehrenbergina sp.	V	-	-	-	R	-	-	-
Cibicides subhaidingerii Parr	F	-	-	F	F	R	-	V
Cancris gratus Cushman & Todd	V	-	-	-	-	-	V	-
Cibicides lobatulus (Walker & Jacob)	R	-	-	-	-	V	V	-
Cibicides pseudoungerianus (Cushman)	V	-	V	C	A	V	R	V
Globigerina sp.	V	-	-	-	-	-	-	-
Globigerinoides bisphaerica Todd	V	-	-	V	V	F	-	F
Planorbulinella plana (H. A. & E.)	V	-	-	-	-	-	-	-
Gyroidina globulus (Reuss)	V	R	-	-	V	R	F	-
Gyroidina howchini Chapman	R	C	-	V	V	R	R	C
Nonion victoriense Cushman	V	-	-	-	-	-	-	V
Parrellina craticulatiformis Wade	C	C	-	-	-	-	R	-
Amphistegina lessonii d'Orbigny	R	R	-	-	-	-	V	-
Operculina victoriensis Chapman & Parr	R	R	V	-	V	R	R	V
Gaudryina (Pseudogaudryina) crespinae Cushman	-	V	-	-	-	-	-	-
Globulina gibba d'Orbigny	-	V	-	-	-	-	-	-
Saracenaria [illegible]iformis Coën	-	V	-	-	-	C	-	-
Quinqueloculina vulgaris d'Orbigny			V	-	C	R	A	A
Sigmoilopsis cf. flintii Cushman			V	-	C	-	-	-
Austrotrillina howchini (Schlumberger)			V	-	-	-	-	-
Cibicides subhaidingerii Parr			V	-	-	-	-	-
Siphonina australis Cushman			V	V	F	F	V	V
Anomalinoides procolligera Carter			V	-	-	V	-	-
Anomalina sp.			V	V	-	-	-	-
Uvigerina cf. tenuistriata Reuss				V	-	-	-	-
Bolivina spp.				F	-	-	F	-
Sphaeroidina bulloides d'Orbigny				V	C	-	-	V
Rosalinella decorata H. A. & E.				V	-	-	-	-
Cibicides refulgens Montfort				R	V	-	-	-
Globorotalia globigeriniformis (H. A. & E.)				V	-	-	-	-
Eponides repandus (F. & M.)				V	-	-	-	-
Globigerinoides triloba (Reuss)				F	V	F	V	F

	Morgan Limestone Lower Member						Cadel…	
	F76/56	F77/56	F78/56	F79/56	F81/56	F83/56	F85/56	F…
Globigerina bulloides d'Orbigny				v	v	r	-	
Elphidium howchini Cushman				f	-	-	-	
Elphidium parri Cushman				v	-	-	-	
Ammosphaeroidina sphaeroidiniformis (Brady)					f	f	v	
Gaudryina sp. cf. *collinsi* Cushman					f	f	-	
Triloculina trigonula (Lamarck)					v	f	f	
Quinqueloculina auberiana d'Orbigny					c	-	c	
Pyrgo sarsi (Schlumberger)					c	-	-	
Cornuspira involvens Reuss					f	v	-	
Cornuspira tasmanica Parr					f	-	v	
Pyrulina cylindroides (Roemer)					v	-	-	
Sigmoidella kagaensis Cush. & Ozawa					v	-	-	
Cassidulina spp.					v	-	-	
Reussella spinulosa (Reuss)					f	-	f	
Pullenia quinqueloba (Reuss)					v	-	-	
Cibicides concentricus (Cushman)					v	-	-	
Cibicidella variabilis (d'Orbigny)					v	-	-	
Liebusella rudis (Costa)						f	-	
Schenckiella howchini (Cushman)						v	-	
Pyrgo sp.						v	-	
Sigmoilina sp.						x	v	
Quinqueloculina sp.						x	v	
Articulina victoriana Cushman						x	v	
Triloculina tricarinata d'Orbigny						x	-	
Cornuspira sp.						x	f	
Cornuspiroides [illegible] (Chapman)						x	-	
Dyocibicides biserialis Cushman & Valentine						x	f	
Textularia cf. *sagittula* Defrance							v	
Siphotextularia sp.							v	
Quinqueloculina polygona d'Orbigny							f	
Quinqueloculina berthelotiana d'Orbigny							f	
Spiroloculina sp.							f	
Biloculinella globula (Bornemann)							f	
Miliolinella circularis (Bornemann)							v	
Dentalina sp.							v	
Fissurina spp.							f	
Parafissurina sp.							v	
Sigmomorphina subregularis Howchin & Parr							v	
Bolivina sublobata Cushman							f	
Planorbulina sp.							v	
Elphidium chapmani Cushman							v	
Martinottiella bradyana Cushman								
Triloculina sp.								
Massilina cf. *australis* Cushman								
Spiroloculina antillarum d'Orbigny								

Morgan Limestone Lower Member					Cedell Marl Lens				Morgan Limestone Upper Member			
77/56	778/56	779/56	781/56	783/56	785/56	786/56	787/56	788/56	789/56	791/56	792/56	793/56



	Morgan Limestone Lower Member					Cadell Marl		
	F76/56	F77/56	F78/56	F79/56	F82/56	F83/56	F85/56	F86/56	F
Nonsilina sp.								v	
Nodobaculariella sp.								v	
Parrinogerina vertebralis Blainville								v	
Planispirinoides sp.								r	
Quttulina problema d'Orbigny								v	
Remulina globulifera Brady								v	
Sagenia intermedia Cushman & Todd								r	
Salsurina recticulata (Howchin & Parr)								v	
Quttulina regina (B. P. & J.)									
Virgulina sp.									
Astrononion australe Cushman & Edwards									
Globigerinoides rubra (d'Orbigny)									
Textularia vertebralis Cushman									
Anomalina glabrata Cushman									
Elphidium advenum Cushman									
Pullenia bulloides d'Orbigny									
Cassidulina subglobosa Brady									
Fursenkoina fusiformis (Reuss)									
Nonionellina sp.									
Lagena spp.									
Uvigerina bradyi Cushman									
Guttulina irregularis (d'Orbigny)									
Discorbis cf. floridana Cushman									
Globigerinoides transitoria Blow									
Cancellinopsis sp.									

v = very rare (1-2)
r = rare (3-5)
f = frequent (6-10)
c = common (11-25)
a = abundant (25 +)

Morgan Limestone Lower Member					Cadell Marl Lens				Morgan Limestone Upper Member			
7/56	F78/56	F79/56	F81/56	F83/56	F85/56	F86/56	F87/56	F88/56	F89/56	F91/56	F92/56	F93/56
						▼	▼	-	-	-	-	-
						▼	▼	-	-	-	-	-
						▼	▼	-	-	-	-	▼
						r	-	-	-	-	-	-
						▼	-	-	-	-	-	-
						▼	-	-	-	-	-	-
						r	r	-	r	r	▼	-
						▼	-	-	-	-	-	-
							▼	-	r	-	-	-
							▼	-	-	-	-	-
							r	-	-	-	▼	-
							▼	-	-	-	-	-
								r	-	-	-	-
									r	▼	r	-
									▼	-	-	-
									▼	-	-	-
									r	r	r	f
									▼	-	-	-
										▼	-	-
										▼	-	-
										▼	-	-
										▼	-	-
										▼	-	-
										▼	-	-
											▼	-

▼ = very rare (1-2)
r = rare (3-5)
f = frequent (6-10)
c = common (11-25)
a = abundant (25 +)

Fig. 1. Type Section Morgan Limestone, Cadell Marl Lens, Hundred Cadell, Section C.

Fig. 2. Morgan Limestone. Morgan Railway Station.

The Cadell Marl Lens or its equivalents is represented in borings in County Albert by blue clays or marls rich in *Turritella murrayana* overlying the Morgan Limestone (Barnes, 1951). *Austrotrillina howchini* commonly occurs also.

OVERLYING STRATA

The Morgan Limestone is overlain disconformably by a thick oyster bed of the Norwest Bend Formation, succeeded by 54 feet of Pleistocene clays. The Loxton Sands are discontinuous in the area. They occur to the north on Section 131 Hundred of Cadell where they are quarried in a very small way as freestone and to the south in the cliffs about 6 miles south of Morgan overlying Morgan Limestone and overlain by Norwest Bend Formation oyster bed, but are missing at the type section.

Morgan Limestone Outcrops in the Hundreds of Anna and Bromley. Truro Military Sheet.

Remnants of transgressive mid-Tertiary limestones occur at 413 feet above sea level (513 above datum level Port Adelaide, relative to bench mark 20/A, Truro R.S.) in and to the north of Levi's Creek, Section 229E, Hundred of Anna, and on Section 26, Hundred of Bromley.

These are considered to be littoral deposits of the Morgan Limestone.

Two exposures of Tertiary limestones (fossiliferous calcarenite) on Section 229E, Hundred of Anna, were sampled by R.P. Coats and N.H. Ludbrook on 4th December, 1954.

In Levi's Creek, 1½ miles north-north-west of Stonefield, thirteen feet of limestone are exposed in the south bank of the creek overlain by (?) Pleistocene red clayey sands. Half a mile to the north a low scarp of yellow limonitic fossiliferous limestones lies on the northern side of a small gully with Pre-Cambrian sediments on the south. The actual contact has been obscured by erosion, but the absence of earlier Tertiary sediments in the area indicates the transgressive nature of the mid-Tertiary here as elsewhere in South Australia.

The Tertiary exposure, 5¼ miles northerly from Stonefield on Section 26, Hundred Bromley, was seen by the writer in company with R.C. Sprigg and I. Chebotarev in January, 1953. One sample was taken.

SECTION 229E, HUNDRED OF ANNA

1. Half a mile to the north of Levi's Creek a low scarp of yellow ferruginous limestone (calcarenite) crowded with casts and moulds of Turritella occurs. Most of the Turritellas are infilled with limonite and the casts have weathered out on the surface in great profusion. About 15 feet from the base, a pelecypod band with Ostrea, Chlamys murrayana (Tate) and Anticoma (Proxichione) sp. occurs. At the top the section becomes more sandy and relatively poorly fossiliferous, with a few Turritella. The section is covered by thin kunkar.

Three samples were taken:

F105/55

From south side of ridge about 100 yards from the southern end.

A ferruginous limestone crowded with moulds and casts of Turritella, probably undescribed species, with a gemmulate medial band like T. aldingae.

Lovenia "forbesi T. Woods"

sp. Psammechinus sp.

Serripecten yahliensis (T. Woods)

F106/55

Southern end of ridge about 15 feet from base. Rubbly Turritella limestone, with

Bryozoa

Cellepora gambierensis T. Woods

Pelecypoda

Cucullaea corioensis McCoy

Glycymeris subtrigonalis (Tate)

Notrigonia semiundulata (McCoy)

Spondylus pseudoradula McCoy

Serripecten yahliensis (McCoy)

Pandora sp.

Modiolus sp.

Pleuromeris (?) _delicatula_ (Tate)

Antigona (_Proxichione_) indet. but probably _dimorphophylla_ (Tate)

Venerid indet.

Tellina sp. indet cf. _albinelloides_ Tate

Gastropoda

Turritella sp.

_F107/55_

Sandy limestone at top of section.

Fauna

Foraminifera

Quinqueloculina vulgaris d'Orbigny

Quinqueloculina sp.

Triloculina sp.

Sigmomorphina flintii (Cushman)

Sigmoidella elegantissima (Parker & Jones)

Nonion victoriense Cushman

Cibicides pseudoungerianus (Cushman)

Calcarina verriculata (Howchin & Parr)

Notorotalia howchini (Chapman, Parr & Collins)

Echinoidea

Monostychia australis (Laube)

Brachiopoda

Magellania divaricata (Tate)

Pelecypoda

Serripecten yahliensis (T. Woods)

Gastropoda

Turritella sp.

2. An exposure in Levi's Creek consists of yellow arenaceous limestones with sandy bands, showing some variability in fossil content and lithology. They carry abundant megafossils.

	Sample Number	Lithology	Thickness
Top	F113/55	Calcareous sandstone	1'6"
	F112/55	Yellow ferruginous limestone with abundant _Turritella_	2'
	F111/55	Sandy limestone	1'

Sample Number	Lithology	Thickness
F110/55	Yellow ferruginous limestone with *Turritella*	2'
F109/55	Yellow rubbly calcareous sandstone with echinoids	4'
F108/55 Base	Limestone with abundant large pelecypods, *Ostrea*, *Chlamys*, *Spondylus*	3'
		13'6"

Fauna

F108/55

Pelecypod bed, base of section, 3 feet thick, with numerous large casts of *Spondylus pseudoradula* McCoy.

Echinoidea

Lovenia "*forbesi* T. Woods"

Monostychia australis (Laube)

Brachiopoda

Magellania divaricata (Tate)

Pelecypoda

Chlamys foulcheri (T. Woods)

Spondylus pseudoradula McCoy

Ostrea sp.

Chlamys sp.

Gastropoda

Turritella sp.

Semicassis (*Antephalium*) sp. cf. *radiata* Tate

F109/55

Yellow rubbly calcareous sandstone 4 feet thick with echinoids.

Bryozoa

Cellepora sp.

Echinoidea

Lovenia "*forbesi* T. Woods"

Monostychia australis (Laube)

Eupatagus murrayensis Laube

Psammechinus woodsi Laube

<u>Pelecypoda</u>

<u>Chlamys</u> cf. <u>sturtiana</u> (Tate)

<u>F110/55</u>

Yellow ferruginous limestone - <u>Turritella</u> band - 2 feet thick.

<u>Pelecypoda</u>

<u>Glycymeris</u> sp.

<u>Antigona</u> (<u>Proxichione</u>) <u>dimorphophylla</u> (Tate)

<u>Gastropoda</u>

<u>Turritella</u> sp.

<u>Turritella</u> <u>murrayana</u> Tate

<u>F111/55</u>

Sandy band 1 foot thick.

<u>Foraminifera</u>

<u>Quinqueloculina</u> <u>vulgaris</u> d'Orbigny

<u>Dorothia</u> <u>parri</u> Cushman

<u>Elphidium</u> sp.

<u>Operculina</u> <u>victoriensis</u> Chapman & Parr

<u>Cibicides</u> cf. <u>refulgens</u> Montfort

<u>Cibicides</u> <u>pseudoungerianus</u> (Cushman)

<u>Notorotalia</u> <u>howchini</u> (Chapman, Parr &Collins)

<u>Calcarina</u> <u>verriculata</u> (Howchin & Parr)

<u>Bryozoa</u>

<u>Cellepora</u> sp.

Others, not determined.

<u>Echinoidea</u>

<u>Psammechinus</u> <u>woodsi</u> Laube

<u>Pelecypoda</u>

<u>Chlamys</u> sp.

<u>Gastropoda</u>

<u>Turritella</u> <u>murrayana</u> Tate

<u>F112/55</u>

Yellow limestone with <u>Turritella</u> - 2 feet thick.

<u>Chlamys</u> <u>murrayana</u> (Tate)

<u>Turritella</u> <u>murrayana</u> Tate

F113/52

Calcareous sandstone 18" thick.

Relatively poorly fossiliferous, with Turritella sp.

SECTION 26, HUNDRED OF BROWNLOW

Material from this outcrop consisted of a ferruginous sandy limestone, washings from which are angular calcite fragments with some limonite staining, rounded to subangular clear quartz grains and a little glauconite.

F264/52

Foraminifera

Quinqueloculina cf. limbata d'Orbigny

Q. vulgaris d'Orbigny

Q. lamarckiana d'Orbigny

Triloculina trigonula Lamarck

Biloculina flinti Cushman

Biloculina chapmani Cushman

Massilina planata Cushman

Massilina sp.

Textularia sp.

Dorothia parri Cushman

Nodosaria sp.

Guttulina problema d'Orbigny

Guttulina austriaca d'Orbigny

Guttulina irregularis d'Orbigny

Cassidulina subglobosa Brady

Nonion sp.

Elphidium sp.

Elphidium crispinae Cushman

Elphidium parri Cushman

Cibicides pseudoungerianus (Cushman)

Amphistegina lessoni d'Orbigny

Calcarina verriculata (Howchin & Parr)

Heterostegina howchini (Chapman, Parr & Collins)

Pelecypoda

Ostrea sp.

Pinna sp.

venerid inlet.

Gastropods

Turritella murrayana Tate

Turritella sp.

Ostrea sp.

The deposit is littoral and very similar lithologically to those in Hundred of Anna.

PATA LIMESTONE

The Pata Limestone at the top of the Murray Group is known only from subsurface material. It has not yet been recognized in outcrop.

BOOKPURNONG BEDS

The Bookpurnong Beds which overlie limestones of the Murray Group were also first recognized in bores but are now known to outcrop downstream from Loxton

The type section for this formation is the exposure on Section 11, Hd. Pyap, 2½ miles downstream from Loxton, first described by Howchin (1929, p. 168, pl. 7, fig. 1), measured and sampled by J. Spence of Freme-Broken Hill Co. Pty. Ltd. in 1957 as follows:

Thickness	Lithology	Formation
17 feet	Kunkar and reddish aeolian sand	-
35 feet	False bedded coarse sand and gravel with fine sand.	Loxton Sands
47 feet	Unconsolidated, yellow, micaceous fine-grained sand with a few pelecypods in the lowest 1 foot.	" "
1 feet 9 inches	Buff fine calcareous sandstone with Callmoera.	Bookpurnong Beds
10 feet	Yellow-brown cohrenous incoherent shell bed with glauconite.	"

The bed continues below the Murray River.

The section was visited and sampled by E.P. O'Driscoll and the writer in April 1959.

The uppermost 1'9" contains, in addition to Callmoera,

Fig. 1. River Murray in Morgan Limestone, east of Waikerie.

Fig. 2. Quarry in Morgan Limestone, Overland Corner.

Hinnites corioensis, Serripecten yahliensis, Corbula ephamilla and Turritella (s.l.) The associated microfauna is rich in arenaceous miliolidae, and includes Textularia corrugata, Dorothia minima, Quinqueloculina vulgaris, Pyrgo elongata, Triloculina trigonula, Flintina intermedia, Siphonaperta adelaidensis, S. chapmani, Guttulina lactea, Bolivina vacuna, Discorbis dimidiatus, Discorbis globularis, Bagina philippinensis, Cancris intermedius, Cibicides pseudoungerianus, Elphidium macellum, Operculina victoriensis.

The 10 foot shell bed is marly and glauconitic, rich in foraminifera, mostly miliolidae, and chalky fragile pelecypoda. The foraminiferal assemblage contains Textularia corrugata, Gaudryina cf. collinsi, Dorothia minima, Siphonaperta spp., Siphonaperta macrophila, Sigmoilopsis lepidigera, Cornuspiroides striolatus, Guttulina irregularis, Sigmomorphina subregularis, Discorbis globularis, Cancris intermedius, C. ovatus, Cibicides pseudoungerianus, Elphidium chapmani, Elphidium macellum, Elphidium parri, Notorotalia sp., Operculina victoriensis.

Pelecypoda include Nucula morundiana, Nucula (Ennucula) atkinsoni, Nuculana (Saccella) woodsi, Nuculana (Saccella) vagans, Ledella praelonga, Ledella sp., Parvaleda sp., Cucullaea corioensis, Limopsis cf. morningtonensis, Hinnites corioensis, Serripecten yahliensis, Propeamussium atkinsoni, Crenella sp., Anomia sella, Eudora cf. carrucata, Cuspidaria subrostrata, Eucrassatella kingicoloides, Cuna pelita, Cyclocardia (Scalaricardita) subcompacta, Pleuromeris pectus, Pleuromeris subpecten, Nemocardium (Pratulum) sp., Antigona dimorphophylla, Tawera dialma, Gari hamiltonensis, Gari aequalis, Panopea sp., Gastropoda: Turritella sp. Scaphopoda: Dentalium spp.

The Bookpurnong Beds also outcrop on Section 142, Hundred of Pyap, where the following section was measured by E.P. O'Driscoll and N.H. Ludbrook on 6/8/58. River level was then about 2 feet above normal.

Thickness	Lithology	Formation
10 - 15 feet	Yellow, micaceous sands.	Loxton Sands.
11 feet	Green-grey and yellow sandy marl	Bookpurnong Beds.

<u>Thickness</u>	<u>Lithology</u>	<u>Formation</u>
3 feet	Yellow glauconitic marl	Bookpurnong Beds

The lowest three feet contain abundant <u>Marginopora vertebralis</u>, <u>Operculina victoriensis</u> and <u>Ditrupa</u>.

<u>PATA LIMESTONE AND BOOKPURNONG BEDS,</u>

<u>STANDARD SUBSURFACE SECTION</u>

<u>DRAINAGE SHAFT 18, LOXTON</u>

The drainage Bore sunk to a depth of 295 feet from the bottom of Engineering and Water Supply Department Shaft 18 on Section 377 Hundred of Gordon is selected as standard subsurface section for the Pata Limestone and Bookpurnong Beds. Both formations are known almost entirely from bore cuttings, although twelve feet of the Bookpurnong Beds are exposed 2¼ miles west of Loxton when the water level of the River Murray is low.

In upward succession, the sequence in Drainage Bore 18 consists of -

<u>Morgan Limestone</u> (Lower Miocene)

Below 192 feet and not bottomed at 295 feet the boring passed through grey white somewhat marly bryozoal limestone with a rich microfauna dominated by <u>Operculina victoriensis</u>, <u>Amphistegina lessonii</u>, and <u>Parrellina craticulatiformis</u>; <u>Lepidocyclina howchini</u> occurs between 245 and 267 feet.

Between 182 and 196 feet a greenish grey micaceous glauconitic sandy marl separates the Morgan Limestone from the overlying Pata Limestone, and represents a passage bed between the two formations, the presence of glauconite also suggesting a change in sedimentation. The microfauna also appears to be transitional, with foraminiferal elements of the overlying and underlying limestones.

The <u>Pata Limestone</u> occurs between 126 and 182 feet. It is lithologically similar to the Morgan Limestone, and is typically a pale grey partially recrystallized bryozoal limestone, marly in parts and with hard bands with abundant <u>Ditrupa</u>. The megafauna has not been described but includes species of <u>Turritella</u>, <u>Dentalium</u>, <u>Nuculana</u>, <u>Limopsis</u> and <u>Carditidae</u>.

The microfauna is distinguished by the entry of Orbulina universa and Gibicides victoriensis, the latter being restricted to the formation. Orbulina suturalis and species of the Porticulasphaera glomerosa series are also present.

Bookpurnong Beds

Above the Pata Limestone brown to greenish-grey micaceous silty sands and marls of the Bookpurnong Beds occur. These are richly fossiliferous with abundant molluscs including Lehmorra quadricingulata and shallow water foraminifera, particularly miliolid species. Flintina intermedia which has been regarded (Parr 1939, p. 70) as restricted to the Kalimnan, is usually present in some numbers. This species makes its first appearance at the top of the Pata Limestone and continues upwards to the Loxton Sands in the Murray Basin. It has been recorded by Chapman (1916, p.352) as occurring with Amphistegina and Operculina at 315 - 325 feet in Mallee Bore 9.

Loxton Sands

Above 78 feet the yellow calcareous quartz sands, fine near the base, with abundant muscovite, were intersected. The depth at which they were entered in the shaft is not accurately recorded, but they generally occur in the Loxton area within a few feet of the surface. Typical shelly grits with Donax depressa were recovered from the shaft.

The Bookpurnong Beds and Loxton Sands are believed to be, but not necessarily established as, of Upper Miocene age.

Description of the Sludges:

Loxton Sands

32 - 50 ft. Yellow calcareous medium sand with subangular to subrounded quartz grains, fairly well polished, muscovite, shell fragments and a few poorly preserved foraminifera.

50 - 63 ft. Yellow-brown calcareous fine and coarse quartz sand with subrounded polished quartz grains, muscovite, Balanus sp., and a few small foraminifera

63 - 76 ft. Yellow calcareous fine sand with fine angular quartz grains and coarse subrounded polished grains, muscovite, biotite, small foraminifera including *Elphidium pseudonodosum* and *Elphidium macellum* and ostracodes.

76 - 78 ft. Yellow fine micaceous marly sand with fine angular quartz grains, abundant small muscovite flakes, ostracodes molluscs including *Eumarcia (Eumarcella) adelaidensis*, ostracodes and foraminifera with *Flintina intermedia*, *Elphidium advenum*, *E. pseudonodosum* and *E. macellum*.

Bookpurnong Beds

78 - 105 ft. Dark green-grey carbonaceous sandy marl with glauconite and muscovite.

The sediments were laid down in shallow water into which silty and carbonaceous matter was carried. There is an abundant microfauna dominated by *Flintina intermedia*, *Elphidium pseudonodosum*, lagenids and miliolids.

Molluscs include *Leiopyrga quadricingulata*, *Placamen subroborata*, *Tawera dictyna*. *Balanus* is also present.

105 - 118 ft. Brownish green-grey micaceous silty sand and grit. Washed residues consist of light reddish-brown fine angular calcite fragments and coarse subrounded both clear and milky quartz grains conspicuously ironstained. *Leiopyrga quadricingulata* and other molluscs are present with numerous small foraminifera dominated by Bolivina spp. and lagenids.

118 - 126 ft. Greenish grey highly fossiliferous sandy glauconitic marl. Washed residues consist mainly of abundant dark green and brown glauconite, calcite, fine angular quartz grains, limonite and numerous ostracodes. Foraminiferal species of the upper part of the formation (? Upper Miocene) continue but some such as *Operculina victoriensis* and

Marginopora vertebralis usually more characteristic of the Lower Miocene appear. Molluscs include *Nuculana* sp. nov., *Turritella* sp., and *Dentalium* (*Laevidentalium*) sp.

Pata Limestone

126 - 150 ft. Grey-white partially recrystallized limestone with abundant large flat *Operculina* (? *victoriensis*), *Cibicides victoriensis*, *Marginopora vertebralis* together with *Ditrupa* spp. fish otoliths, *Nuculana* sp. nov., *Turritella* sp., *Limopsis* sp., *Carditidae* and *Nuculidae*.

150 - 165 ft. Pale grey marly bryozoal limestone with numerous *Operculina* and *Cibicides victoriensis* and *Ditrupa*

One specimen of *Flintina intermedia* in the sample would represent the earliest appearance of this species. While the possibility of contamination during the drilling process must not be overlooked it has also been noted in a sample from the same stratigraphic level in the Murrayville district of Victoria. Molluscs (*Nuculana* and *Carditidae*) and crustacea are present.

165 - 182 ft. Pale grey marly bryozoal limestone with some glauconite. The microfauna is characterised by numerous *Operculina victoriensis* and *Cibicides victoriensis* with planktonic forms including *Orbulina universa*, *Orbulina suturalis*, *Globigerinoides bisphericus*, *G. triloba* and species of the *Porticulasphaera glomerosa* series. The megafauna contains species of *Turritella*, *Dentalium*, *Nuculana*, *Limopsis* and *Carditidae*.

Transitional Bed

182 - 196 ft. Greenish grey micaceous glauconitic sandy marl. Washed residues consist of fine to medium angular quartz grains, yellow limestone fragments, dark bright green glauconite pellets, and shell fragments. The megafauna includes species of *Dentalium*,

Nuculana, Barbatia, Carditidae, and Corbula. The microfauna is dominated by Globigerinoides bisphaerica, Cibicides pseudoungerianus and Massilina anaphila. It appears to be transitional between that of the Morgan Limestone and that of the Pata Limestone.

Morgan Limestone

196 - 202 ft. Grey-white marly and partially recrystallised bryozoal limestone with Operculina victoriensis, Amphistegina lessonii and Parellina craticulatiformis, the latter restricted to the formation. Echinoids are also present.

202 - 209 ft. Grey-white marly bryozoal limestone with rich microfauna including the three species above and Planorbulinella plana, Carpenteria proteiformis, Globigerinoides bisphaerica and Globoquadrina dehiscens.

209 - 245 ft. Light grey marly bryozoal limestone, with abundant bryozoa. Microfauna similar to that of 202 - 209 feet.

245 - 267 ft. Light grey marly bryozoal limestone with Lepidocyclina howchini associated with Operculina victoriensis Amphistegina lessonii, Parellina craticulatiformis, Globigerinoides bisphaerica.

267 - 295 ft. Light grey marly bryozoal limestone, with a similar microfauna including numerous small species.

Correlation of Other Drainage Bores in the Area

	Hd. Gordon Sec. 489	Hd. Gordon Sec. 537	Hd. Gordon Block 496
	ft. Depth	Feet	Feet
Existing shaft	0 - 30'	0 - 35'	0 - 24'
Loxton Sands	30' - 76'	35' - 71'	24' - 54'
Bookpurnong Beds	76'-105'	71' - 72'6"	54' - 112'
Pata Limestone			112' - 167'
Transitional bed			? 167' - 180'
Morgan Limestone			180' - 200'

TABLE 8

MICROPALAEONTOLOGICAL LOG

SEC. 377, HUNDRED OF GORDON

DRAINAGE BORE, SHAFT 18

	LOXTON SANDS				BOOKPURNONG BEDS			PI
DEPTH (feet)	32-50	50-63	63-76	76-78	78-105	105-118	118-126	126-150
Fissurina sp.	v	-	v	v				
Cassidulina sp.	v							
?Elphidium sp.	v	v						
Rosasella sp.	-	v	-	-	-	-	r	
Bolivina spp.	-	v	v	-	-	v	r	-
Cibicides pseudoungerianus (Cushman)	-	v	-	-	-	-	o	v
Lagena spp.			v	v	v	-	f	
Guttulina irregularis (d'Orbigny)			v	-	v	-	-	-
Guttulina problema d'Orbigny			v	-	v	r	r	-
Angulogerina sp.			v					
Patellina cf. inconspicua (Brady)			v					
Elphidium pseudonodosum Cushman			v	r	a	r	v	
Elphidium macellum (Fichtel & Moll)			v	v	r	r	o	-
Elphidium sp.			r	f	f	r	-	v
Heterolepa sp.			v	v	r	v	v	
Quinqueloculina vulgaris d'Orbigny				v	f	r	o	o
Quinqueloculina spp.				v	o	o	v	-
Planispina intermedia (Howchin)				r	o	v	-	-
Lagena striata (d'Orbigny)				v				
Lagena sulcata Walker & Jacob				o	v			
Guttulina lactea (Walker & Jacob)				v	v			
Pseudopolymorphina sp.				v	-	-	-	-
Elphidium advenum Cushman				f	r	r	v	
Astrononion sp.				v	-	v	r	
Triloculina trigonula (Lamarck)					r	-	v	-
Triloculina sp.					v	-	v	
Planispina triquetra (Brady)					r			
Siphonaperta adelaidensis (Howchin & Parr)					r	-	-	v
Sigmoilopsis lapidigera (Howchin & Parr)					f			
Lenga spp.					v	-	v	-
Sigmoilina edwardsi (Schlumberger)					f			
Miliolinella sp.					v			
Guttulina regina (Brady, Parker & Jones)					v	v		
Pyrulina sp.					v			
Discorbis dimidiatus (Jones & Parker)					r			
Globigerinoides triloba (Reuss)					cf.	-	-	v
Guttulina yamasakii Cushman & Ozawa						v		
Guttulina cf. austriaca d'Orbigny						v		
Glandulina laevigata d'Orbigny						v		
Sigmoidella hannensis Cushman & Ozawa						v	-	v
Sigmomorphina semitecta (Reuss)						v		
Bolivina rugosa Parr						f	-	-

TABLE 8

MICROPALAEONTOLOGICAL LOG

SEC. 177, HUNDRED OF GORDON

DRAINAGE BORE, SHAFT 18

NDS	BOOKPURNONG BEDS			PATA LIMESTONE				MORGAN LIMESTONE					
3-76	76-78	78-105	105-118	118-126	126-150	150-165	165-182	182-196	196-202	202-209	209-245	245-267	267-295

	LOXTON SANDS				BOOKPURNONG BEDS				PATA LIMEST
DEPTH (feet)	32-50	50-63	63-76	76-78	78-105	105-118	118-126	126-150	150-165
Valvulineria sp.						r	f	-	-
Cancris interregius Cushman & Todd						v	v	-	-
Nonion victoriense Cushman						r	c	-	v
Nonion sp.						v			
Dorothia parri Cushman							r	v	-
Siphotextularia sp.							v		
Siphonaperta agnorhila (Parr)							v	-	-
Sigmoilina sp.							v	v	v
Marginopora vertebralis Blainville							v	c	r
Plectofrondicularia australis (Heron-Allen & Earland)							v		
Uvigerina schwageri Brady							v	v	v
Uvigerina subperegrina Cushman & Kleinpell							v		
Triferina bradyi Cushman							v	-	-
Lamarckina sp.							r		
Cibicides sp.							r		
Anomalina glabrata Cushman							v	-	v
Discorbis sp.							v		
Baccina philippinensis (Cushman)							v		
Elphidium parri Cushman							v	v	v
Elphidium crassatum Cushman							v	v	
Notorotalia hannai (Chapman, Parr & Collins)							r	v	-
Rotalia sp.							v		
Operculina "victoriensis" Chapman & Parr							f	c	r
Textularia spp.							v	v	v
Dorothia sp.								v	v
Articulina sp.								v	v
Massilina sp.								v	v
Cornuspira involvens Reuss								v	
Cornuspira tasmanica Parr								v	v
Cornuspira sp.								v	v
Spiroloculina sp.								v	
Cibicides victoriensis Chapman, Parr & Collins								c	a
Sigmoidella cf. elegantissima (Parker & Jones)									cf.
Spiroloculina bulloides d'Orbigny									v
Globigerina bulloides d'Orbigny									v
Siphonina australis Cushman									v
Textularia cf. sagittula Defrance									
Gaudryina (Pseudogaudryina) sp.									
Liebusella rudis (Costa)									
Schenckiella hannai (Cushman)									
Sigmoilopsis asperula (Karrer)									
Sigmoilopsis chapmani (Cushman)									
Sigmoilina victoriensis Cushman									
Cornuspiroides crespinae (Chapman)									
Lenticulina sp.									
Uvigerina spp.									

OXIDE SANDS			BOOKPURNONG BEDS		PATA LIMESTONE			MORGAN LIMESTONE					
50-63	63-76	76-78	78-105	105-118	118-126	126-150	150-165	165-182	182-196	196-202	202-209	209-245	245-267	267-295
				r	r	-	-	-	-	-	-	-	-	▼
				▼	▼	-	-	-	-	-	-	-	-	▼
				r	o	-	▼	-	r					
				▼										
					r	▼	-	f	▼	-	-	-	▼	-
					▼									
					▼	-	-	r	o	-	▼	-	▼	-
					▼	▼	▼							
					▼	o	r	▼						
					▼									
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					▼	▼	▼	-	r	-	▼			
					▼	▼								
					r	▼	-	▼	▼	-	-	-	-	a
					▼									
					f	o	r	o	r	f	f	r	r	f
					▼	▼	▼	-	▼	f	r			
					▼	▼	▼	▼	r	▼	▼			
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					▼	▼	▼	▼						
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					▼	▼	▼	▼	▼					
					▼	▼	▼	f	r					
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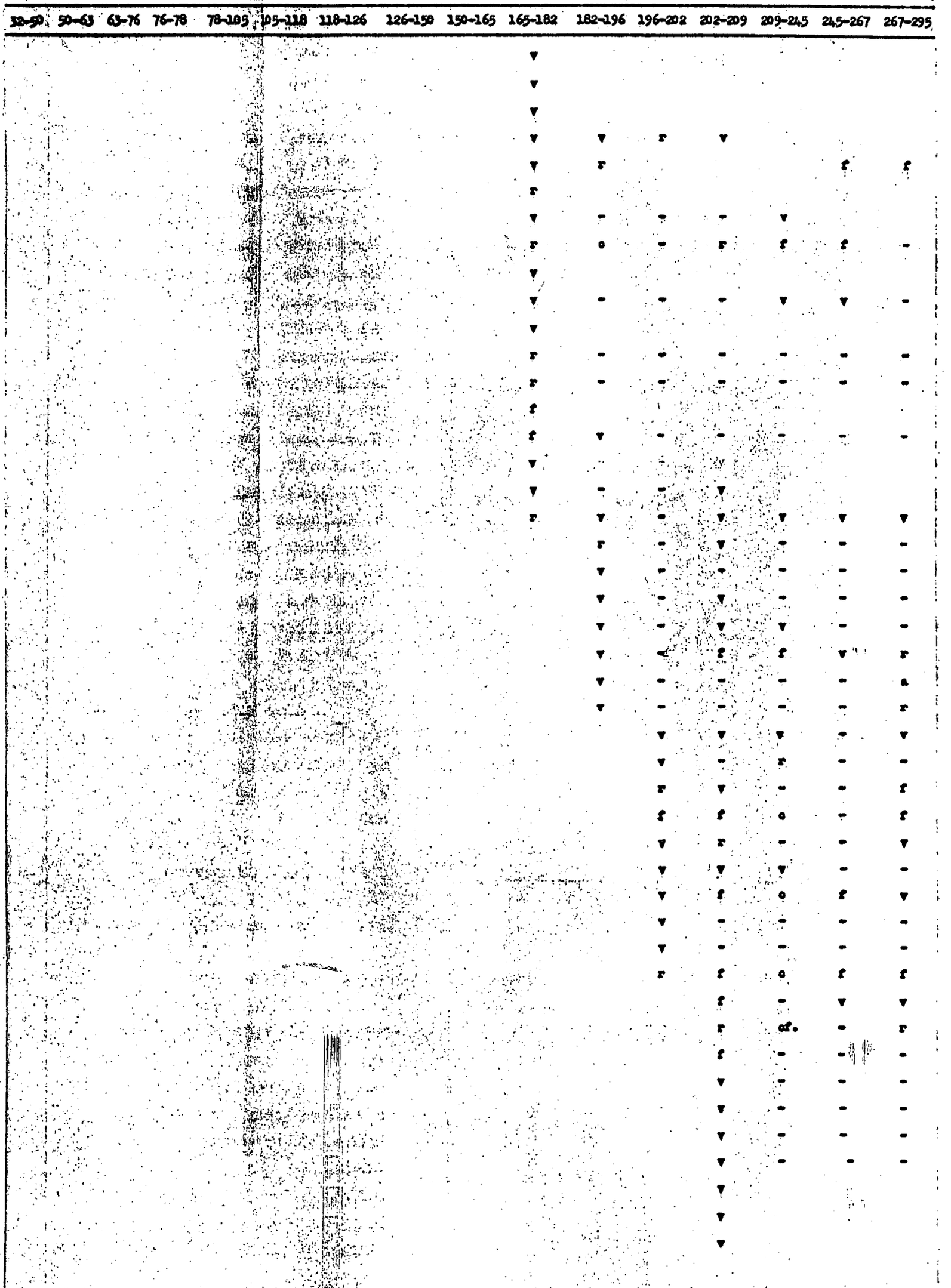
					o	a	a							
						af.	▼	r	▼	f	r	▼	-	
						▼	-	-	-	-	-	-	-	f
						▼	▼	▼						
						▼	▼	-	-	-	-	-	-	r
							▼							
						r	-	-	-	-	-	-	-	r
						f	-	-	▼	-	-	-		
						r								
						f	r							
							▼							
							▼	▼	▼					
							▼							
							▼							
							▼	-	-	▼	-	-	-	r

	LOXTON SANDS				BOOKPURNONG BEDS			PA
DEPTH (feet)	32-50	50-63	63-76	76-78	78-105	105-118	118-126	126-150
Cibicides sp.								
Dyocibicides sp.								
Cancris sp.								
Anomalinoides procolligera Carter								
Globigerina apertura Cushman								
Globigerina ciperoensis angustiumbilicata Bolli								
Globigerina trilocularis d'Orbigny								
Globigerinoides bisphaerica Todd								
Globigerinoides triloba immatura Le Roy								
Globigerinoides transitoria Blow								
Biorbulina bilobata (d'Orbigny)								
Orbulina universa d'Orbigny								
Candorbulina universa Jedlitschka								
Porticulasphaera glomerosa glomerosa (Blow)								
Porticulasphaera glomerosa curva (Blow)								
Hastigerina murrayi Thompson								
Globoquadrina dehiscens (C. P. & C.)								
Elphidium howchini Cushman (?)								
Quinqueloculina lamarckiana d'Orbigny								
Triloculina tricarinata d'Orbigny								
Sphaeroidina bulloides d'Orbigny								
Cibicides refulgens Montfort								
Cibicides subhaidingerii Parr								
Astrononion australe Cushman & Edwards								
Carpenteria rotaliformis Chapman & Crespin								
Sigmomorphina subregularis Howchin & Parr								
Chrysalidinella costata (H. A & E.)								
Cassidulina subglobosa Brady								
Ehrenbergina sp.								
Cibicides lobatulus (Walker & Jacob)								
Stomatorbina concentrica (Parker & Jones)								
Parellina craticulatiformis Wade								
Ceratobulimina (Ceratocancris) australis C. & H.								
Cerobertina sp.								
Amphistegina lessonii d'Orbigny								
Textularia corrugata H. A & E.								
Textularia pseudogramen Chapman & Parr								
Gaudryina (Pseudogaudryina) crespinae Cushman								
Clavulinoides victoriensis Cushman								
Biloculinella globula Bornemann								
Nodosaria soluta Reuss								
Dentalina sp.								
Robulus spp.								
Marginulina spp.								
Sigmomorphina chapmani (H. A & E.)								


LOXTON SANDS
ROCKPENNONG BEDS
PATA LIMESTONE
MORGAN LIMESTONE
32-50
50-63
63-76
76-78
78-105
105-118
118-126
126-150
150-165
165-182
182-196
196-202
202-209
209-245
245-267
267-295

	LOXTON SANDS				BOOKPURNONG BEDS			
DEPTH (feet)	32-50	50-63	63-76	76-78	78-105	105-118	118-126	126-
Guttulina (Sigmoidina) silvestrii C. & O.								
Guttulina (Sigmoidina) pacifica C. & O.								
Globulina gibba d'Orbigny								
Reussella simplex Cushman								
Reussella decorata H. A. & E.								
Cassidulina laevigata d'Orbigny								
Eponides repandus (Fichtel & Moll)								
Planorbulinella plana (H. A. & E.)								
Cymbalopora globulus Reuss								
Carpenteria proteiformis Goës								
Conorbella patelliformis (Brady)								
Crespinella sp.								
Reussella spatiformis Chapman								
Reussella spinulosa (Reuss)								
Tubulogenerina mooraboolensis Cushman								
Globratella "arguiformis" (H. A & E.)"								
Lenticulina howchini								
Globigerina cf. venezuelana Hedberg								
Loxostomum limbatum (Brady)								

v = very rare (1-2)
r = rare (3-5)
f = frequent (6-10)
c = common (11-25)
a = abundant (25 +)

LOXTON SANDS				ROCKFURNONG BEDS		PATA LIMESTONE				MORGAN LIMESTONE			
50	50-63	63-76	76-78	78-105	105-118	118-126	126-150	150-165	165-182	182-196	196-202	202-209	209-245	245-267	267-295
												v			
												r	v		
												v			
												v	v		
												v	-	-	r
												v	-	-	r
												v	r	r	r
												v			
												v	v	r	r
												r			
													v	-	v
													v	-	-
													v	-	-
													v	-	-
													v	-	-
													v	-	-
														r	-
															r
															r

v = very rare (1-2)
r = rare (3-5)
f = frequent (6-10)
c = common (11-25)
a = abundant (25+)

Both the Pata Limestone and Bookpurnong Beds are of limited distribution. The Pata Limestone appears to be a small lens which thins out north of the River Murray between Renmark and Canopus Station where its lateral equivalent is a dark grey carbonaceous clay. Marginal Bookpurnong Beds were intersected in a bore at Marama in the Hundred of Molineux.

LOXTON SANDS

The Loxton Sands are very widely distributed over the whole of the Murray Basin proper. They are characteristically bright yellow, cross bedded micaceous sands, grits, and silty sands. The colour varies locally from reddish to cream according to the degree of weathering. Shelly bands are commonly present near the base of the formation. The beds were rapidly deposited in estuaries or shallow water apparently following negative movements in the Basin proper at the end of the Miocene. The abundance of mica seems to indicate new source rocks in the granites of the Padthaway horst and elsewhere on the margin of the Basin.

At the type section on the southern side of the Loxton Pumping Station on Section 118 Hundred of Gordon, the Loxton Sands are 50 feet thick, consisting of shell bed 5 feet thick at the base above water level (R.L. of river 142 feet, normal pool level 139 feet) overlain by about 45 feet of cross bedded gritty sands. The fauna of the shell bed contains water worn and comminuted shells of *Nuculana* sp., *Glycymeris cainozoica*, *Pleuromeris pectens*, *Tawera disjuncta*, *Donax* (*Plebidonax*) *depressa*, *Cantharidus* (*Phasianotrochus*) sp., and *Calyptraea corrugata*. The microfauna is poor, with *Quinqueloculina*, *Notorotalia*, and *Elphidium chapmani*.

The Loxton Council operates a quarry on Section 32 Hundred of Gordon in which 50 feet of Loxton Sands are quarried for concrete aggregate.

Fig. 1. Loxton Sands. Type Section, Loxton Pumping Station.

Fig. 2. Loxton Sands. Loxton Council Quarry

Fig. 1. Great Pyap Bend, Hundred Pyap, Section 11. Loxton Sands in foreground. Type Section Bookpurnong Beds below (our of view)

Fig. 2. Quarry in thick oyster bed. Marne River valley. Hundred Ridley, Section 63.

North of the pumping station on Stanitzki's property, Section 115, Hundred of Gordon, secondary calcification has produced a partly consolidated shelly grit used for stone pitching at the pumping station. The Loxton Sands in Stanitzki's Quarry are very fossiliferous with abundant foraminifera including Quinqueloculina schreiberiana, Quinqueloculina seminulum, Flintina intermedia, Triloculina trigonula, Elphidium chapmani, Marginopora vertebralis, Rotalia cf. beccarii, with Operculina and Amphistegina probably derived from Murray Group limestones. Mollusca species include Glycymeris cainozoica, Glycymeris convexa, Cucullaea sp., Ostrea sturtiana, Neotrigonia sp., Miltha hora, Cytherea murrayana, Tawera dictea, Placunanomia sturtiana and Donax (Plebidonax) depressa. Cirripedes are numerous. There are good exposures of the Loxton Sands in road cuttings on the Loxton - Waikerie road at Moorook on Section 25, Hundred of Moorook. The Sands are fine and more silt, at this locality with abundant echinoid spines and cirripedes. The foraminiferal assemblage contains miliolids including Flintina intermedia, and abundant Notorotalia cf. clathrata.

The river cliffs at Lock 4 are cut in Loxton Sands which are varicoloured, crossbedded, and pass upwards into fine white micaceous sand. Floods during 1956 severely eroded these sands, depositing them about ½ mile downstream where they were dredged in 1958 for building sand.

In borings in the north east of the Basin the formation is generally encountered overlying the Bookpurnong Beds. The discontinuity increases in a westerly direction and in the west of the Basin the Loxton Sands generally overlie the Morgan Limestone.

The Loxton Sands - Morgan Limestone sequence may be observed on Section 131, Hundred of Cadell, where finer consolidated Loxton Sands are quarried for building stone of which the Cadell Institute is constructed. The same sequence is exposed at Caloote, downstream from Mannum.

NORWEST BEND FORMATION

The Norwest Bend Formation is characterised principally by thick oyster beds disconformably overlying the Loxton Sands. The type section was described by Tate (1885, p. 34) at Norwest Bend Station on the great bend of the River Murray east of Morgan, where 28 feet of sandy limestone with *Ostrea sturtiana*, *Glycymeris convexa*, *Neotrigonia howitti* and *Donax* (*Plebidonax*) *depressa* rest on 42 feet of Morgan Limestone. The formation may be traced on the cliffs, upstream towards Cadell where the sequence of Morgan Limestone overlain by the Loxton Sands in turn overlain by the Norwest Bend Formation is exposed in the roadway leading down to the Cadell punt landing on the north bank. The same sequence occurs on Section 131 Hundred of Cadell, south of the Morgan punt landing on the east bank, and also about 6 miles south of Morgan.

In the Waikerie district there are important exposures of the Norwest Bend Formation which have been quarried for building stone. "Waikerie Freestone" on the northern side of the river in Section J6 Hundred of Markaranka is a hard white sandy limestone showing some false bedding and abundant moulds of *Mytilus* sp., *Anodontia sphericula* and *Diastoma provisi*. On the southern side of the river on Section 451 Hundred of Waikerie half a mile north of the church, on the north west side of Ramco, "Ramco stone" was quarried before the 1939-1945 war. This is lithologically similar to Waikerie free stone with abundant pelecypod moulds in bands in false bedded sandy limestone. Anodontia sphericula casts are abundant on some bedding planes, associated with *Glycymeris convexa*, *Ostrea*, *Pinctada crassicardia*, *Mytilus linguatulus*, *Neotrigonia howitti*, *Spondylus spondyloides*, *Miltha hora*, *Placamen subroborata*, *Dentalium*, *Leiopyrga quadricingulata*, *Diastoma provisi*.

At one time these exposures were thought to be a calcareous phase of the Loxton Sands (Barnes, 1951, p. 18, Ludbrook 1957, p. 179) but they are currently considered on faunal and lithological grounds to belong to the Norwest Bend Formation. The fauna has been described elsewhere (Ludbrook, 1959) as of Pliocene age. It is found also in sandy limestones in the Hundred of Sherlock and

Fig. 1. Remco stone with moulds of Anodontia sphericula on bedding plane.

Fig. 2. Waikerie freestone. Blake's Quarry, north west of Waikerie, Hundred Markaranka.

calcareous sands of the river cliffs at Tailem Bend and southwards towards Wellington.

The formation and its equivalents have been recognized only along the western margin of the Basin. This is interpreted at present as indicating the existence of a narrow estuary roughly following the present course of the Murray River, but more detailed work may prove that some sediments at present correlated with the Loxton Sands are younger.

The thick oyster beds of the western margins of the Basin do not necessarily all belong to the Norwest Bend Formation. They may be seen in the Loxton Sands in the river cliffs between Cadell and Norwest Bend and below the main oyster bed in the cliff section at Glenforslan north of Blanchetown.

(5) STRATIGRAPHICAL AND FAUNAL SEQUENCE CANOPUS BORE NO. 1. P.L. 166h. NORTH OF RENMARK. S.A.

Canopus Bore No. 1 was drilled for water in 1952/53 by the South Australian Mines Department for Canopus Pastoral Company on P.L. 166h, 45 miles north of the River Murray and adjacent to the New South Wales border.

Rather poor 860-grain sheep water was struck at 572 feet, and below this level some significant improvement in the water was observable. 710-grain water regarded as fairly good sheep water and suitable also for beef cattle was struck between 910 and 951 feet. This was tested at 600 gallons per hour.

Stratigraphical Sequence

The boring first passed through 185 feet of Recent and Pleistocene terrestrial sands. Between 185 feet and 536 feet the mid-Tertiary sequence of Bookpurnong Beds downwards to equivalents of the Ettrick marls was intersected. At 536 feet the boring entered sands and carbonaceous clays of the Knight Group in which the boring ceased at 951 feet.

1. Pliocene to Recent terrestrial sands 0-185 feet

This formation consists of an upper 5 feet of red ferruginous sandy surface soil and subsoil with nodular kunkar;

then, in downward sequence, 20 feet of red calcareous clayey quartz sand, less ironstained when washed than the surface sands, and 160 feet of greyish and yellowish brown medium and fine quartz sands which are well-sorted, of medium size, subrounded to subangular, and frequently with etched surfaces. The sands are unfossiliferous and of terrestrial origin.

2. Bookpurnong Beds 185-195 feet

The Loxton Sands are missing in the bore which at 185 feet entered 10 feet of dark grey micaceous silty sands with pyrite and glauconite representing the Bookpurnong Beds. Molluscs included Nuculana sp., Cyclocardia (Scalaricardita) calva, Cuna polita, Laevidentalium sp., Turritella spp., Turbonilla sp., and Austrotoma spp. Rotalia beccarii and an assemblage of small foraminifera mostly lagenids species of Bolivina and Cibicides pseudoungerianus are also present.

3. Black Clay equivalent of Pata Limestone 195-285 feet

The boring passed into black very plastic pyritic clay at 195 feet. Limonite and occasional glauconitic faecal pellets are present. There is a persistent fauna of small foraminifera, mostly very thin shelled, a minute taxodont pelecypod, and a few molluscs, corals, ostracodes and bryozoa. Cibicides victoriensis occurs between 205 and 235 feet. Mollusca include Pelecypoda : Pronucula atkinsoni, Nuculana vagans, N. woodsi, Nuculana sp., Limopsis sp., Cuna polita, Cyclocardia (Scalaricardita) calva, Pleuromeris sp., Numella suborbicularis, Tellina sp. Gastropoda : Brookula singletoni, Collonia sp., Liotina sp. Turritella (Haustator) murrayana, Turritella (Colpospira) tristira, Turritella sp., Cerithiopsis sp., Syrnola sp., Hinia (Reticunassa) tatei.

4. Morgan Limestone equivalent 285-350 feet.

At 285 feet the black plastic clay is replaced by a greenish-grey calcareous sandy highly fossiliferous marl, with a clay intercalation between 300 and 335 feet. There is a fairly conspicuous faunal change and the microfauna contains

Tubulogenerina mooraboolensis, Globigerinoides triloba, Guttulina bowmani, Carpenteria proteiformis, Amphistegina lessonii, and Sigmoilina victoriensis. Mollusca include Pelecypoda : Nucula sp., Nuculana sp., Nuculana vagans, Cyclocardia (Arcturellina) sp. Scaphopoda : Dentalium (Fissidentalium) sp., Dentalium (Laevidentalium) subfissura. Gastropoda: Calliostoma sp., Brookula singletoni, [illegible] sp., Turritella (Gazameda) acricula, Turritella (Colpospira) quadrisulcatilis, T. (C.) tristira, Cerithiella trisecta, Sthenorytis (Dannevigena) sp., Cirsotrema (Tenuiscala) gemmulata, Paramella annulata, Hexaplex (Murexsul) bracheamira, Mitra (Eumitra) tatei, Marginella (Stazzania) wentworthi, Cypraea sp.

Bryozoa are common, and the fauna also includes ostracodes, sponges and worms.

5. Equivalents of Mannum Formation 350-500 feet

Below 350 feet there is a gradation downwards through equivalents of the Mannum Formation to the upper part of the Ettrick Formation. The interval is characterised by abundant glauconite. Between 350 and 400 feet the sediments consists of a grey sandy calcareous clay grading to marl at 400 feet, with Brookula singletoni, Turritella (Colpospira) tristira and abundant small foraminifera. The characteristic "Batesfordian" species of the Morgan Limestone disappear.

6. Equivalents of Gambier Limestone and Ettrick Formation 500-522 feet

In this interval the boring intersected a narrow member consisting of dark grey calcareous highly glauconitic clay rich in bryozoa and foraminifera. Victoriella "plants" occurs between 500 and 510 feet. The foraminiferal assemblage contains also Massilina torquayensis together with Clavulinoides victoriensis, Dorothia parri, Gaudryina (Siphogaudryina) victoriana.

TABLE 9

CANOPUS NO. 1 BORE - MICROPALAEONTOLOGICAL LOG

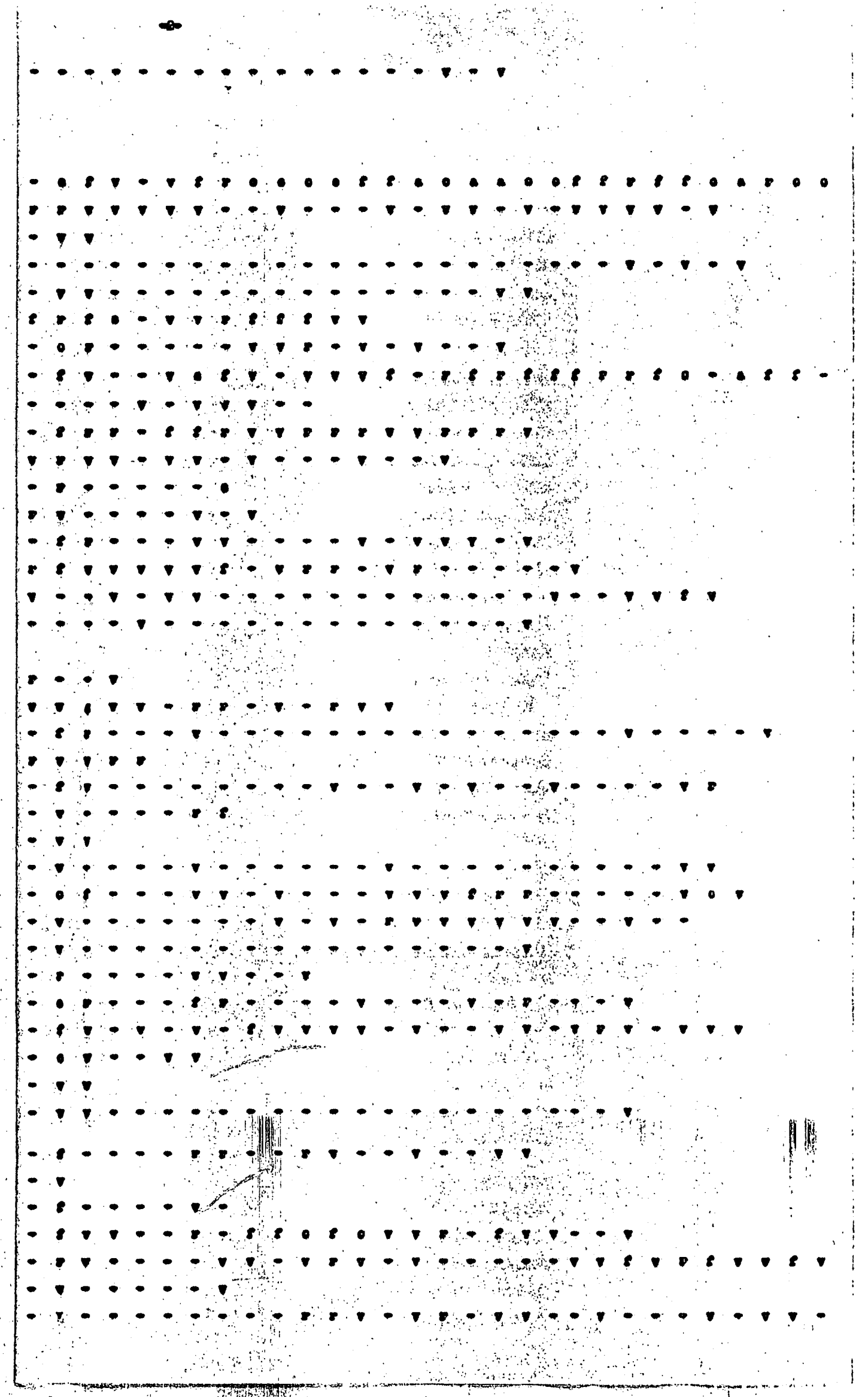
EQUIVALENTS OF	ROCK-FORMING BEDS	PATA LIMESTONE						MORGAN LIMESTONE										MANNUM					
Depth	185-195	195-205	205-215	215-225	225-235	235-245	245-255	255-265	265-275	275-285	285-295	295-305	305-315	315-325	325-335	335-345	345-350	350-360	360-370	370-380	380-390	390-400	400-410
Quinqueloculina vulgaris d'Orbigny	v	f	v	r	r	r	v	v	v	-	a	f	r	-	r	o	v	r	v	r	f	v	v
Ammosphaeroidina sphaeroidiniformis	v	-	r	v	v	f	f	f	o	r	o	r	v	-	v	f	f	v	v	v	-	r	-
Sigmoilopsis chapmani	v	o	f	r	v	f	f	v	v	v	a	f	v	v	r	f	r	f	v	f	r	r	v
Sigmoilopsis sp. 1	v	-	-	-	-	r	-	-	-	-	-	-	-	-	-	-	-	r	-	v			
Nodosaria acuta	v	v	-	v	-	-	-	-	-	-	v	-	-	-	-	-	v	-	v	-	-	v	-
[illegible]nodosaria hispida	v	-	v	-	-	-	-	-	-	-	-	-	-	-	-	-	-						
[illegible]nodosaria scalaris	v	-	-	v	-	-	-	-	v	-	f	f	-	-	v	v							
Fissurina marginata	v	r	v	v	v	v	v	v	v	-	f	-	v	-	v	f	-	v	-	f	v	r	v
Guttulina problema	f	-	v	-	-	v	-	-	-	-	v	-	-	-	-	-	v	-	-	v	v	-	-
Sigmoidella elegantissima	f	-	v	-	-	v	-	-	-	-	v	v	-	-	-	-	-	-	-	-	-	-	-
Reussella spinulosa	v	r	v	-	-	-	-	-	-	-	o	f	-	-	-	f	f	v	r	o	v	f	-
Bolivina dilatata	v	v	-	-	-	-	-	-	-	-	r	-	-	-	-	v	r	-	v	v	r	-	-
Bolivina plicatella	r	v																					
Bolivina sublobata	f	o	v	v	-	-	-	-	-	-	r	-	-	-	-	v							
Bolivina subreticulata	r	v	-	-	-	-	-	-	-	-	r	-	-	-	-	v	r	-	-	f	v	-	-
Loxostomum sp.	v	v	-	v	-	-	v	-	v	r	a	-	-	-	-	v	r	v	v	v	v	v	-
Pullenia quinqueloba	v	v	v	v	-	-	-	-	v	-	-	-	-	-	-	-	-	v	v	r	-	v	v
Sphaeroidina bulloides	v	r	v	-	f	v	a	a	o	a	r	a	f	v	f	v	-	v	-	v	-	v	v
[illegible] mira	v																						
Sherbornina australis	v	f	v	r	f	r	o	f	f	o	o	f	r	r	f	o	r	v	v	f	r	v	v
Cibicides [illegible]	r	v	-	-	v	-	-	-	-	v	r	v	-	v	r	o	v	r	f	o	f	r	r
Cibicides lobatulus	r	r	r	v	v	-	v	r	v	-	o	f	f	v	-	v	v	v	v	v	-	r	-
Cibicides pseudoungerianus	a	a	a	a	a	a	a	a	o	a	a	a	a	f	a	a	a	f	-	a	a	a	o
Anomalina glabrata	a	f	f	v	f	f	f	f	o	r	o	v	v	f	f	f	f	v	v	o	r	f	v
Hoeglundina elegans	v	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rotalia beccarii	o																						
Rotalia cf. *hamiltonensis*	v																						
Textularia pseudogramen	-	v	r	v	v	v	r	-	v	v	o	a	-	-	v	o	f	v	v	r	-	r	r
Quinqueloculina lamarckiana	-	r	v	-	f	r	v	r	v	r	o	r	v	-	r	f	v	-	v	r	v	v	v
Quinqueloculina seminulum	-	v	r	-	-	v	v	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sigmoilopsis sp. 2	-	r	r	v	f	v	r	r	v	-	f	r	-	v	v	r	-	-	v	r	v	v	v
Biloculinella globula	-	f	v	-	-	v	-	-	-	-	f	v	-	-	r	f	-	v	v	v	v	v	v
Fissurina sp.	-	f	v	-	v	v	o	f	f	f	-	-	-	-	-	-	r	-	-	-	-	-	-
Cassidulina laevigata	-	v	v	v	-	-	-	-	-	-	v	r	-	-	-	v	r						
Discorbis tuberculata australiensis	-	v	-	-	v	v	-	-	-	-	v	-	-	-	-	v	v	-	v	v	r		
[illegible] convexa	-	r	-	-	v	v	-	v	-	-	-	v	-	-	-	-	-	-	-	-	-	v	
[illegible] intermedia	-	-	-	-	-	-	-	-	-	-	-	v	-	-	-	r	-	v	-	-	-	v	
Elphidium advenum	-	r	-	v	v	-	-	-	-	-	v	v											
Gaudryina (Pseudogaudryina) crassa	-	v	v	-	-	-	-	-	-	-	o	v	-	-	-	f	f	v	v	-	-	-	v
Dorothia parri	-	-	r	-	v	v	v	-	-	-	f	r	v	v	v	o	r	v	-	v	-	v	v
Sigmoilina victoriensis	-	-	v	-	r	v	v	-	r	-	v	f	v	v	v	r	r	v	-	r	v	v	-
Triloculina trigonula	-	-	v	v	v	v	-	-	-	r	f	v	-	-	-	f	r	v	v	v	-	-	v

TABLE 9

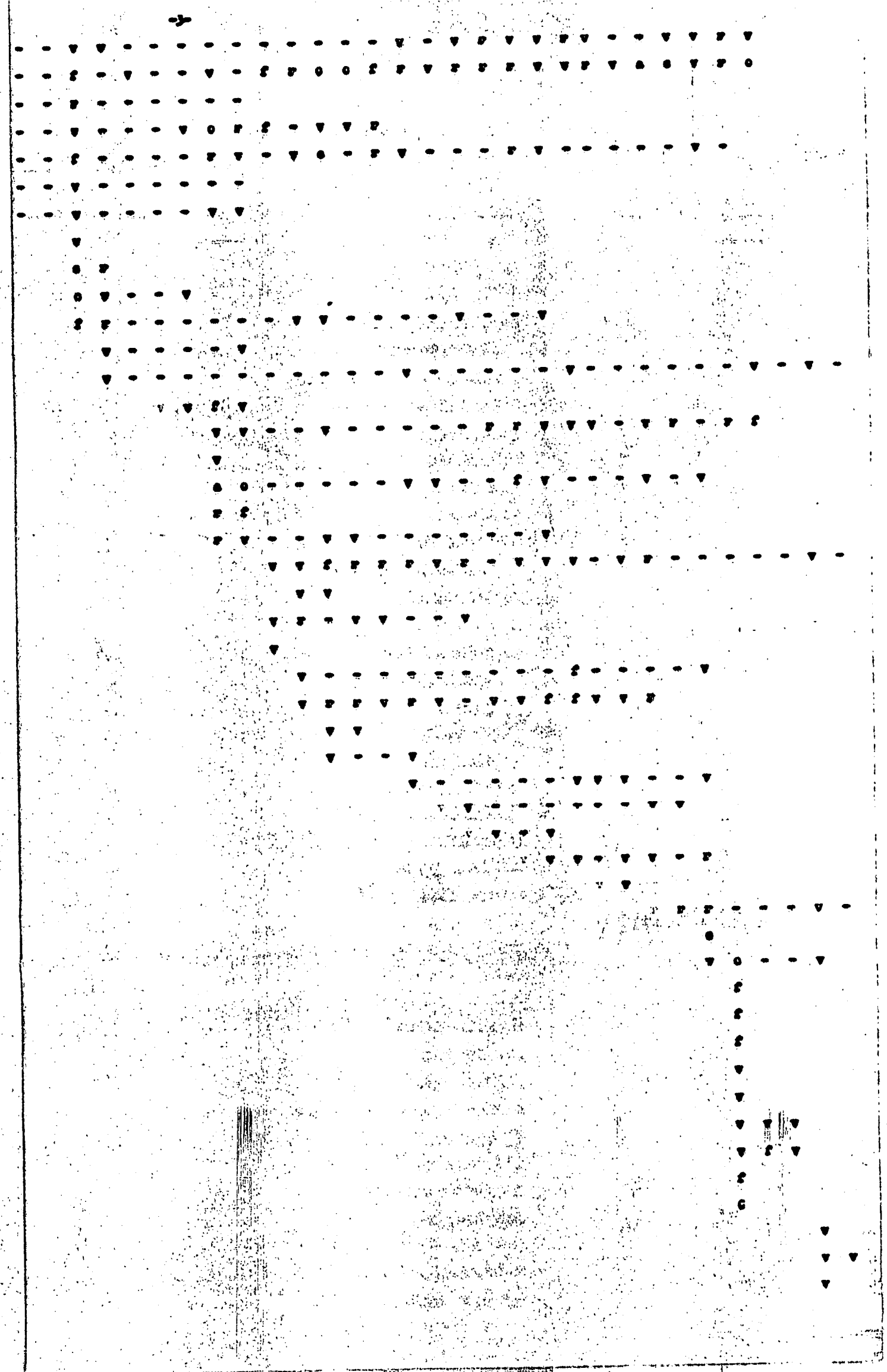
CANOPUS NO. 1 BORE - MICROPALAEONTOLOGICAL LOG

MORGAN LIMESTONE									MANNUM														GAMBIER - ETTRICK							COMPTON	
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
▼	▼	-	●	f	r	-	r	o	▼	r	▼	r	f	▼	▼	f	r	r	f	f	f	r	r	f	▼	▼	●	f	r	r	▼
f	●	r	●	r	▼	-	▼	f	f	▼	▼	▼	-	r	-	▼	r														
▼	▼	▼	●	f	▼	▼	r	f	r	f	▼	f	r	r	▼	▼	r	▼	r	▼	▼										
-	-	-	-	-	-	-	-	-	-	r	-	▼																			
-	-	-	▼	-	-	-	-	-	▼	-	▼	-	-	▼	-	-	-	-	▼	▼	▼	▼	-	-	▼	r	-	r	▼		
-	-	-	-	-	-	-	-	-	-																						
-	▼	-	f	f	-	-	▼	▼																							
▼	▼	-	f	-	▼	▼	▼	f	-	▼	-	f	▼	r	▼	▼	▼	r	r	r	-	-	▼	-	f	▼	●	r	r		
-	-	-	▼	-	-	-	-	-	▼	-	-	▼	▼	-	-	-	▼	-	▼												
-	-	-	▼	▼	-	-	-	-	-	-	-	-	-	-	-	-	▼	-	-	-	-	-	▼	▼							
-	-	-	●	f	-	-	-	f	f	▼	r	o	▼	f	-	r	r	-	▼	r	▼										
-	-	-	r	-	-	-	-	▼	r	-	▼	▼	r	-	-	-	-	-	-	▼	-	-	-	-	-	▼					
-	-	-	r	-	-	-	-	▼																							
-	-	-	r	-	-	-	-	▼	r	-	-	f	▼	-	-	▼	-	-	▼	▼											
-	▼	r	●	-	-	-	-	▼	r	▼	▼	▼	▼	▼	-	-	-	-	-	-	-	-	▼								
-	▼	-	-	-	-	-	-	-	-	▼	▼	r	-	▼	▼	-	-	▼	▼	▼	r	▼	-	r	▼	f	▼	r	▼	▼	-
●	●	●	r	●	f	▼	f	▼	-	▼	-	▼	-	▼	▼	-	-	▼	▼	▼	▼	f	-	-	r	f	r	●	f	▼	▼
f	f	o	●	f	r	r	f	o	r	▼	▼	f	r	▼	▼	r	r	o	r	r	r	r	▼	o	f	f	▼	f	r	▼	-
-	-	▼	r	▼	-	▼	r	o	▼	r	f	o	f	r	r	▼	▼	f	f	o	f	f	f	r	r	-	o	▼	▼	▼	▼
r	▼	-	●	f	f	▼	-	▼	▼	▼	▼	▼	-	r	-	-	-	-	-	▼	-	-	-	-	-	▼					
●	o	●	●	●	●	f	●	●	●	f	-	o	●	●	o	f	●	●	●	o	●	●	o	f	f	●	o	●	o	o	o
f	●	r	o	●	▼	f	f	f	f	▼	▼	o	r	f	▼	r	r	▼	r	r	r	r	-	f	f	f	-	f	r	r	-
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	▼										
r	▼	▼	o	●	-	-	▼	o	f	▼	▼	r	-	r	r	▼	-	r	▼	r	r	▼	r	▼	-	-	r	-	-		
▼	▼	r	o	r	▼	-	r	f	▼	-	▼	r	▼	▼	▼	r	r	r	r	r	r	▼	▼	-	-	-	r	r	▼	r	▼
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	▼	▼								
r	▼	-	f	r	▼	▼	▼	▼	-	-	▼	▼	▼	▼	▼	▼	-	-	▼	▼	-	-	-	-	-	▼	▼	▼			
-	-	-	f	▼	-	-	r	f	-	▼	▼	▼	▼	▼	▼	▼	-	-	▼	-	-	-	-	▼	▼	-	▼	-	-	▼	-
-	f	f	-	-	-	-	-	-	r	-	-	-	-	-	-	▼	-	-	▼												
-	-	-	▼	r	-	-	-	▼	▼																						
-	-	-	▼	-	-	-	-	▼	▼	▼	▼	-	r																		
-	-	-	▼	-	-	-	-	-	-	-	-	-	-	▼																	
-	-	-	▼	-	-	-	r	-	-	▼	-	-	-	▼																	
-	-	▼	▼																												
-	-	-	●	▼	-	-	-	f	f	▼	▼	-	-	-	▼	r	▼	-	r	▼	▼	▼	r	▼	▼	▼	r	▼	▼		
-	-	-	f	r	▼	▼	▼	o	r	▼	-	▼	-	▼	▼	r	▼	f	r	r	▼	▼	▼	▼	▼	r	-	-	-	r	r
r	-	▼	f	▼	▼	▼	r	r	▼	-	r	▼	-	▼	▼	▼	r	▼	-	▼	-	-	▼	-	▼	-	▼	-	-	-	-
-	▼	f	▼	-	-	-	f	r	▼	▼	▼	-	-	▼	▼	▼	▼	-	f	▼	▼	▼	▼	-	-	▼	f	▼	▼	▼	r

Patellina [illegible]	-	-	r	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Discorbis dimidiatus	-	-	f	v																		
Cibicides victoriensis	-	-	v	-	v																	
Elphidium chapmani	-	-	v	-	-	v																
Notorotalia howchini	-	-	r	v	-	-	v	-	-	-	o	f	v	-	v	f	r	o	o	o	o	f
Cornuspira involvens	-	-	-	v	v	v	v	v	v	r	r	v	v	v	v	v	-	-	v	-	-	-
Marginopora vertebralis	-	-	-	v	-	-	-	-	-	-	v	v										
Triloculina sp.	-	-	-	v	-	v	v	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
[illegible] irregularis	-	-	v	-	-	-	-	-	-	-	v	v	-	-	-	-	-	-	-	-	-	-
Cassidulina subglobosa	-	-	v	v	r	r	r	o	r	f	r	f	o	-	v	v	r	f	f	f	v	v
[illegible] sp.	-	-	-	v	v	-	-	-	-	-	o	r	-	-	-	-	-	v	v	r	-	v
Anomalina procolligera	-	-	-	v	-	-	v	-	-	-	f	v	-	-	v	o	f	v	-	v	v	v
Calcarina verriculata	-	-	-	v	-	-	-	-	-	-	-	-	-	v	-	v	v	v	-	-		
Quinqueloculina longirostris	-	-	-	-	v	-	-	v	-	-	f	r	r	-	f	f	r	v	v	r	r	r
Cornuspiroides [illegible]	-	-	-	-	v	v	v	-	r	v	r	v	v	-	v	v	-	v	-	-	-	v
Cibicides refulgens	-	-	-	-	v	-	-	-	-	-	r	-	-	-	-	-	o					
Triloculina tricarinata	-	-	-	-	v	v	v	v	-	r	v	-	-	-	-	v	-	v				
Sigmoilopsis [illegible]	-	-	-	-	-	v	v	-	-	-	f	r	-	-	-	v	v	-	-	-	-	v
Sigmoilina cf. edwardsi	-	-	-	-	-	r	r	r	r	r	f	v	v	v	v	v	f	-	v	r	r	-
Glandulina laevigata	-	-	-	-	-	v	v	r	v	v	-	-	v	-	v	v	-	-	-	-	-	-
[illegible] collinsi	-	-	-	-	-	v	-	-	-	-	-	-	-	v	-	-	-	-	-	-	-	-
Nonion sp.	-	-	-	-	-	v																
Dentalina cylindroides	-	-	-	-	-	-	v	v	-	r	-	-	v									
[illegible]na bulloides	-	-	-	-	-	-	v	v	v	v	v	o	v	v	-	r	r	-	v	-	r	v
Bolivina victoriana	-	-	-	-	-	-	-	v	-	-	f	r	-	-	-	v	-	-	-	-	-	-
Ceratobulimina hauerii australis	-	-	-	-	-	-	-	r	f	r	v	v	r	r								
[illegible] vertebralis	-	-	-	-	-	-	-	-	v	-	f	v	-	-	-	-	-	-	-	-	v	-
Textularia corrugata	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	r	f					
Textularia [illegible]	-	-	-	-	-	-	-	-	-	-	v	v										
[illegible]	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	v	-	-	-	-	-	-
[illegible] victoriensis	-	-	-	-	-	-	-	-	-	-	o	f	-	-	-	v	v	-	v	-	-	-
[illegible]	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	-	-	v	-	v	-
Cornuspira tasmanica	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	-	-	-	-	-	-
Quinqueloculina polygona	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	v	v	-	-	v		
Quinqueloculina undosa	-	-	-	-	-	-	-	-	-	-	o	r	-	-	-	f	v	-	-	-	-	v
Sigmoilina tenuis	-	-	-	-	-	-	-	-	-	-	f	v	-	v	-	v	-	f	v	v	v	v
Articulina [illegible]	-	-	-	-	-	-	-	-	-	-	o	v	-	-	v	v						
Articulina victoriana	-	-	-	-	-	-	-	-	-	-	v	v										
Sigmoidella kagaensis	-	-	-	-	-	-	-	-	-	-	v	v	-	-	-	-	-	-	-	-	-	-
Buliminella madagascariensis var. [illegible]	-	-	-	-	-	-	-	-	-	-	f	-	-	-	-	r	r	-	-	r	v	-
Buliminella elegantissima	-	-	-	-	-	-	-	-	-	-	v											
Uvigerina flintii	-	-	-	-	-	-	-	-	-	-	f	-	-	-	-	v	-					
Uvigerina proboscidea	-	-	-	-	-	-	-	-	-	-	f	v	v	-	-	r	-	f	f	o	f	o
Trifarina bradyi	-	-	-	-	-	-	-	-	-	-	r	v	-	-	-	-	v	v	-	v	r	v
Tubulogenerina mooraboolensis	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	v					
Pullenia bulloides	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	-	-	-	r	r	v



Eponides lornensis	-	-	-	-	-	-	-	-	-	-	v	v	-	-	-	-	-	-	-	-	-
Cibicides concentricus	-	-	-	-	-	-	-	-	-	-	f	-	v	-	-	v	-	f	r	o	o
Discorbis spp.	-	-	-	-	-	-	-	-	-	-	r	-	-	-	-	-	-				
Globigerinoides triloba	-	-	-	-	-	-	-	-	-	-	v	-	-	-	v	o	r	f	-	v	v
Globigerina bulloides	-	-	-	-	-	-	-	-	-	-	f	-	-	-	-	r	v	-	v	o	-
Globigerina angustiumbilicata	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	-	-				
Gypsina howchini	-	-	-	-	-	-	-	-	-	-	v	-	-	-	-	v	v				
Carpenteria proteiformis											v										
Elphidium crespinae											a	r									
Amphistegina lessonii											o	v	-	-	v						
Operculina victoriensis											f	r	-	-	-	-	-	-	v	v	-
[illegible] cf. collinsi												v	-	-	-	-	v				
Bolivina hebes var. victoriensis												v	-	-	-	-	-	-	-	-	-
Globigerinoides bispherica														v	v	f	v				
Robulus clericii																v	v	-	-	v	-
[illegible] collinsi																v					
Calcarina mackayi																a	o	-	-	-	-
Bolivina mucronata																r	f				
Bolivina advena																r	v	-	-	v	v
Angulogerina australis																		v	v	f	r
Bolivina vadescens																			v	v	
[illegible] sp.																		v	r	-	v
Lamarckina glencoensis																		v			
[illegible] oblonga																			v	-	-
[illegible]loculina canaliculata																			v	r	r
Reophax scorpiurus																				v	v
Heronallenia parri																				v	-
Gyroidina soldanii																					
Valvulineria pauciloculata																					
Astrononion centroplax																					
Bolivina anastomosa																					
[illegible] globula																					
[illegible]iella advena																					
Globigerina ciperoensis ciperoensis																					
Notorotalia crassimura																					
Gaudryina (Siphogaudryina) victoriana																					
[illegible] torquayensis																					
Globulina gibba																					
Bulimina pupoides																					
Bolivina scalprata var. retiformis																					
Bolivina cf. cookei																					
[illegible] australica																					
[illegible] concentrica																					
Victoriella plecte																					
[illegible]iella cf. advena																					
Quinqueloculina cf. vicksburgensis																					
Guttulina (Sigmoidina) pacifica																					



Angulogerina sp.

Angulogerina sp.

Bolivina cf. *acostaensis*

Cibicides umbonifer

Robulus sp.

---

v = very rare (1-2)

r = rare (3-5)

f = frequent (6-10)

c = common (11-25)

a = abundant (25 +)

▼ = very rare (1-2)
▼ = rare (3-5)
▼ = frequent (6-10)
● = common (11-25)
● = abundant (25 +)

7. ? Equivalents of Compton Conglomerate 522-536 Feet.

At 522 feet the basal bed of the normal marine series is represented by dark green and black sandy clay. The residues after washing consist almost entirely of ovoid siderite and glauconite pellets. Cibicidem pubomiferr is the dominant foraminifer. This bed appears to be synchronous with the Compton Conglomerate.

8. Knight Group 536-951 Feet.

There is an abrupt stratigraphical break at 536 feet where the boring entered Eocene carbonaceous sands and sandy clays of the Knight Group. These were not completely penetrated when the boring ceased.

DISTRIBUTION OF TERTIARY FORMATIONS

The series of 8 maps presented on Plan 7 ... illustrate progressively the bores in which marine Tertiary strata from Eocene to Pliocene have been identified from their microfaunas. Areas of outcropping bedrock are also plotted.

Map 1 shows the limited area over which Eocene marine limestones and bryozoal sands of the Eucalench Group have been recognised. Within the area the beds are cut off locally by bedrock highs. Eocene paralic sediments of the Knight Group occur throughout the Basin except where they are cut off by highs. Marine intercalations near the top of the Group are not uncommon but no attempts have been made to correlate them.

Map 2 shows the wide distribution of Oligocene limestones marls and sandy marls of the Gambier Limestone and Pittrick Formations. Information is limited by the fact that many water bores stop in the Miocene limestones in the Basin proper and the presence of the Oligocene at the base of the normal marine sequence can only be inferred from its occurrence in such bores as penetrate the whole sequence.

The abundance of planktonic foraminifera in the Gambier Limestone indicates open sea deposition in the Gambier Sunklands. Access to the open sea in the western portion of the Basin proper was cut off by the Highs of the Padthaway horst and planktonic forms are rare in the Ettrick formation.

Map 3 pin points bores in which the Miocene Narracoorte Limestone and Namum Formation occur, and shows the south western margin of the Basin where the Namum Formation is markedly transgressive. South of Tailem Bend it has been stripped off and it also appears to be mostly absent from the Gambier Sunklands. The Narracoorte Limestone is probably contemporaneous, at least in part, with the Namum Formation.

Maps 4 and 5 show the progressively diminishing area in which Morgan Limestone and Pata Limestone occur. The Bookpurnong Beds in Map 6 are somewhat more extensive than the Pata Limestone but still very limited locally.

Map 7 illustrates the wide cover of Loxton Sands in the Murray Basin proper.

The narrow estuarine character of the Norwest Bend Formation is indicated in Map 8.

The first conclusion to be drawn from the maps is that the Tertiary seas which had entered the Basin during the Eocene practically covered the Basin proper and Gambier Sunklands during the time when the Gambier limestone and Ettrick marls were deposited. Positive movements along the Padthaway "Horst" appear to have commenced at the end of the Oligocene and the seas started to drain away in an easterly direction. Their equivalents can be identified in the Victorian part of the Basin. Access to the open sea was probably limited to a narrow channel near the South Australia - Victoria border on the eastern side of the Gulf shown by Wills (1946, p. 273) or partially obstructed by an archipelago of the Padthaway horst. This is suggested by the general paucity of open sea foraminifera in the Miocene limestones of the Basin proper as contrasted with the Gambier Limestone.

The Loxton Sands are not only more widely distributed than the Bookpurnong Beds and Pata Limestone but are richly microfossil. They would appear to have been derived from different source rocks. This is tentatively suggested as demonstrating either the rise of the Padthaway Horst or the stripping off of mid-Tertiary sediments during the later Miocene and exposure of the granites of the Padthaway horst to erosion. In the Moorook-Loxton district the Loxton Sands carry a good deal of derived mid-Tertiary material, particularly foraminifera and echinoid fragments.

The estuary in which the Norwest Bend Formation was deposited may have post-dated faulting along the eastern margin of the Mt. Lofty Ranges which determined the present southerly course of the River Murray.

The normal absence of the Miocene in the Gambier Sunklands may be due to the emergence of the area in the middle and late Tertiary or to erosion during the Pleistocene. The whole of the Sunklands and part of the Padthaway horst are extensively covered with Pleistocene shell beds and coolianites. Although reworking of the Gambier Limestone is common in the Pleistocene reworked Miocene material has not so far been noted.

FORAMINIFERAL RANGES AND CORRELATION

Table II shows the vertical ranges so far established of the planktonic foraminifera considered to be biostratigraphically significant. Although the microfaunas of the Murray Basin proper are generally characterized by a paucity of planktonic forms, a number of the species discussed by Blow (1956, 1959) Bolli (1957), Hornibrook (1958) and Carter (1958 a,b) are represented in ranges comparable with those recorded by these authors.

Records of Globigerina ampliapertura by the writer (Ludbrook 1957, p.176 1958, p.107) are based on misidentification of a globigerinid referable to Catapsydrax, established by Bolli, Loeblich and Tappan, 1957, on characters which do not always

appear to be present. Hofker's observations (1959, pp. 5-6) are of interest in this connection.

Significant benthonic species are tabulated in Table 10. Sherbornina atkinsoni has a much more extensive range in South Australia than that stated by Carter & Wade (1957, p. 155). It occurs in both the Eocene and Oligocene with the thicker variety described as Sherbornina crassata. The writer's identification of both forms from Buccleuch B and from the Port Willunga Beds has been confirmed verbally by Dr. Wade. The occurrence of Sherbornina crassata has been recorded on Table 2 but the species is doubtfully seperable from S. atkinsoni.

Microfaunal assemblages useful for rapid determinations are shown on Table I.

The Upper Eocene Buccleuch Group may be correlated with the Brown's Creek Clays and Castle Cove Limestone in the Aire District of Victoria. Hantkenina alabamensis compressa has not so far been found in the Buccleuch Group but species such as Asterigerina adelaidensis, Maslinella chapmani, and a genus close to Bolivinella with which it is associated at Maslin Bay, are present in Buccleuch A. The Group is equivalent to the Upper part of the Arnold series (Kaiatan-Runangan) in New Zealand. A species of Halkyardia close to Halkyardia bartrumi is present in Buccleuch A [illegible].

The Gambier Limestone and Ettrick Marls are correlatives of the "Lower Glen Aire Clays" - Calder River Limestone - Upper Glen Aire Clays sequence of Carter 1958 (pp. 14-18) and of the Landon Series (Whaingaroan - Waitakian) and probably the lower part of the Pareora series of New Zealand. They appear to cover most of Oligocene time and may prove to extend into the Miocene.

The Oligocene-Miocene boundary cannot be established so long as it remains unresolved elsewhere in the world.

The Murray Group is equivalent to the Southland Series of New Zealand, time of deposition of the Morgan Limestone corresponding to the Altonian and of the Pata Limestone to the Clifdenian. A microfauna similar to that of the Morgan Limestone is recorded by Carter (1958a, p. 29) from the upper part of the

Fishing Point Marl in Victoria. The evolutionary series Globigerinoides trilobs trilobs - G. bisphaerica - Porticulasphaera transitoria - Biorbulina bilobata and Globigerinoides triloba triloba - G. bisphaerica - Porticulasphaera glomerosa - Orbulina universa are present in the upper part of Morgan Limestone and lower part of the Pata Limestone.

The two series are closely comparable with Blow's Lineage V Branch ii (1959, p. 105) and the first appearance of the several species follows a similar pattern to that of the evolutionary series (Blow, 1956, p. 69) in the Globigerinatella insueta - Globorotalia fohsi zones of the Cipero Formation of Trinidad and Tesuyo and Pozon Formations of Venezuela (Bolli, 1957; Blow 1959).

Corresponding benthonic forms which are particularly useful in rapid mid-Tertiary correlation are Parellina craticulatiformis, restricted to the Morgan Limestone, and Lepidocyclina (Trybliolepidina) howchini restricted to the lower part of the Morgan Limestone. Associated with Orbulina universa in the Pata Limestone are Cibicides victoriensis and a broad form of Operculina victoriensis.

The precise correlation beyond South Australia of the younger Tertiary Bookpurnong Beds, Loxton Sands and Norwest Bend Formations is as yet unresolved, and the position of the Miocene-Pliocene boundary is indefinite. The Loxton Sands were originally described (Ludbrook, 1957, p. 179) as "Cheltenhamian" and the Norwest Bend Formation as "Kalimnan", the Cheltenhamian stage being regarded as Upper Miocene and the Kalimnan Lower Pliocene.

There is a strong faunal affinity between the Norwest Bend Formation particularly as it occurs at Waikerie and in the Tailem Bend - Moorlands area, and the Dry Creek Sands and Hallett Cove Sandstone of the St. Vincent Basin. The Dry Creek Sands have been dated (Ludbrook, 1954, p. 54) as late Lower Pliocene or early Middle Pliocene. If this dating is correct, the Norwest Bend Formation would be Lower to Middle Pliocene and the base of the Pliocene could be drawn at the base of the Bookpurnong Beds which are richly glauconitic and mark a change in sediment-

TABLE 12

RANGES OF PLANKTONIC FORAMINIFERA OF BIOSTRATIGRAPHIC SIGNIFICANCE

AGE	EOCENE				OLIGOCENE					MIOCENE				UPPER MIOCENE PLIOCE ?L. PLIOCENE		
MURRAY BASIN PROPER	KNIGHT GROUP	BUCCLEUCH GROUP A	B	C	ETTRICK FORMATION		MANNUM FORMATION			FINNISS CLAY	MORGAN LIMESTONE	CADELL MARL	PATA LIMESTONE	BOOKPURNONG BEDS	LOXTON SANDS	NORTHEAST BEND FORMATION
GAMBIER SUBBASINS	Knight Group	? Missing			Glauconitic member	Gambier Limestone Compton Conglomerate		Nuracoorte Limestone		NOT RECOGNIZED						
Globigerina bilobata																
Globigerina universa																
Globigerina sp.																
Globigerapsis index																
Globigerina cf. ampliapertura																
Globigerina angustiumbilicata																
Globigerina apertura																
Globigerina bulloides																
Globigerina cinerocensis																
Globigerina linaperta																
Globigerina linaperta var.																
Globigerina aff. parvi																
Globigerina trilocularis																
Globigerina cf. venezuelana																
Globigerinoides bisphaerica																
Globigerinoides rubra																
Globigerinoides transitoria																
Globigerinoides triloba triloba																
Globigerinoides triloba immatura																
Globoquadrina dehiscens																
Globulina rugosa																
Hastigerina siera																
Hastigerina wyvilli																
Orbulina universa																
Pseudoemphaera glomerosa glomerosa																
Pseudoemphaera glomerosa curva																

TABLE 20

RANGES OF BENTHONIC FORAMINIFERA OF BIOSTRATIGRAPHIC SIGNIFICANCE

AGE	EOCENE			OLIGOCENE			MIOCENE				UPPER MIOCENE ?L. PLIOCENE		PLIOCENE
MURRAY BASIN PROPER	KNIGHT GROUP	BUCKLEUCH GROUP A	B	C	ETTRICK FORMATION		HAINUH FORMATION	FINNISS CLAY	MORGAN LIMESTONE	CADELL MARL	PATA LIMESTONE	BOOKPURNONG BEDS	LOXTON SANDS	NORWEST BEND FORMATION
GAMBIER EMBAYMENT	Knight Group	? Missing			Glauconitic member	Gambier Limestone Compton Conglomerate	Naracoorte Limestone	NOT RECOGNISED						
Bermina postmiliensis														
Amphistegina "lessonii"														
Anomalina pertheusis														
Asterigerina adelaidensis														
Asterigerina cf. lornensis														
Astrorotalia calloswyi														
Astrononion centrolobum														
Austrotrillina howchini														
cf. Bolivinella sp.														
Bolivinopsis crenulinae														
Calcarina mackayi														
Calcarina verriculata														
Carpenteria proteiformis														
Cibicides bryerolia														
Cibicides pseudoconvexus														
Cibicides subhaidingerii														
Cibicides umbonifer														
Cibicides victoriensis														
Crespinella umboniferu														
Crespinella sp. nov. A														
"Crespinella" sp. nov. B														
Crespinina kingscotensis														
Elphidium advenum														
Elphidium crassatum														
Elphidium pseudonodosum														
Flintina intermedia														
Gavelina howchini														
Halkyardia sp.														
Lenarotalia circensis														
Lenarotalia clanwoodensis														
Lenticulina howchini														
Linderina sp.														
Marginopora vertebralis														
Nonionella terquemiana														
Notorotalia crassimura														
Notorotalia howchini														
Operculina victoriensis														
Parrellina gratioulatiformis														
Planorbulina johannae														
Planorbulinella inaequilateralis														
Planorbulinella plana														
Rotalia cf. soldani														
Sherbornina atkinsoni														
Sherbornina crassata														
Sherbornina cumminsensis														
Siphonaperia lepidocera														
Spirillina tubercosa														
Victoriella pisota														

ation. The Bookpurnong Beds have many elements in common with the Grange Burn Coquina of Muddy Creek near Hamilton in Western Victoria. If the present dating of the Bookpurnong Beds and Loxton Sands as Upper Miocene is correct, the age of the Grange Burn Coquina might have to be revised if fossil studies confirm its correlation with the Bookpurnong Beds. If, on the other hand, they are all of Pliocene age, the absence of the late Miocene will be unexplained.

QUATERNARY

Practically the whole of the south east of South Australia, including the Gambier Sunklands, was under marine influence during the Pleistocene and a notable series of coastal dune ranges are thought to represent 16 strand lines related to Pleistocene high sea levels.

The Quaternary sequence has been described principally by Sprigg (1952 a, b), Hossfeld (1950) Tindale (1933, 1947) and Crocker (1941, 1946).

Faunas probably equivalent to the Werrikooian of Western Victoria have recently been recovered from borings in the Dialooka area, but have not yet been studied.

ECONOMIC GEOLOGY

Building Stone

Apart from their importance as aquifers, some of the limestones of the Murray Basin make excellent building stones, particularly the Gambier Limestone which has been extensively worked for a number of years (Jack, 1923 pp. 41-44) and is now mostly sawn into ashlars by electrical means. It is comparable stratigraphically and physically with the Oamaru Stone of New Zealand.

The Morgan Limestone locally has properties comparable with those of the Gambier Limestone but thickness of overburden

and variability of texture limit its exploitation. It has been quarried and sawn on a small scale at Overland Corner.

Both the Mannum Formation and Norwest Bend Formation are capable of forming hard "freestone" which makes excellent but expensive building stone. Murray Bridge 'freestone' (Mannum Formation) was used for several public buildings in Adelaide (Jack 1923 p. 54), including the superstructure of St. Peter's Cathedral.

"Freestone" from the Waikerie District belonging to the Norwest Bend Formation (Ludbrook, 1959) has been quarried principally from 2 areas: at Blake's quarry (pl. 14 fig. 2) north of the River Murray on Section 36 Hundred of Markaranka and from a quarry at Ramco on Section 451 Hundred of Waikerie owned by Standard Quarries. The Waikerie Freestone from Blake's Quarry is pale cream and of fairly uniform fine texture while the Ramco stone is characteristically cross-bedded and irregularly colour-banded in yellow-buff-white.

Both Waikerie and Ramco stone have been used wholly or in part for buildings in Adelaide: Waikerie stone for the Savings Bank, the Commercial Banking Company of Sydney, and Bank of New South Wales in King William Street and Bagots on North Terrace; Ramco stone was used wholly for Steamship Building and the lower part of the Bank of New South Wales. Waikerie stone has also been utilised for sculptural purposes in the plinth of the King George V Statue, the figure and plinth of the Pioneer Women's War Memorial, the West Torrens War Memorial and the foundation stone of the Art Gallery, and two figures in Roseworthy College Chapel. Outside the city area, Waikerie stone was used for the coping stone of the Bank of Adelaide at both Edwardstown and Kilkenny and for the door surround in the Mairns Post Office.

Concrete aggregate

Both the Loxton Sands and the gritty sands at the top of the Knight Group are exploited for concrete aggregate. The Loxton District Council at present operates a quarry in the Loxton Sands about ½ mile north of Loxton where a 30-foot face

of cross bedded gritty sands is well exposed.

The Knight sands (Plate 1) are worked by the Engineering and Water Supply Department where they come within a few feet of the surface on the upthrow side of the Tartwaup Fault on Section 718, Hundred of Blanche 8 miles north west of Mount Gambier.

Road Metal

Limestones of the Basin are used for road screenings and quarries are operated in the Naracoorte Limestone at Naracoorte and in the Namum Formation at Murray Bridge for this purpose. Red and grey dolomite occurring in the Gambier Limestone are worked mainly for road metal and ballast. Plate 4 shows the present extent of quarrying at Up and Down Rocks figured by Jack 1923, p. 42.

Minor uses

The Gambier limestone is utilized for minor purposes such as fillings and pharmaceutical products.

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PLATE 15

Eocene foraminifera of the Buccleuch Group

1. *Pseudopolymorphina* sp. Buccleuch A Type Section, Hundred of Coneybeer, Section 56 307-312 feet — X 25
2. cf. *Bolivinella* sp. Hundred of Strawbridge, Section 10 128-138 feet — X 25
3. cf. Bolivinella sp. broken specimen, vertical section, internal view. Buccleuch A Type Section Hundred of Coneybeer Section 56 297-302 feet — X 25
4. *Maslinella chapmani* Glaessner and Wade, dorsal view. Hundred of Strawbridge Section 10 98-108 feet — X 25
5. *Halkyardia* sp. Hundred of Strawbridge Section 10 170-180 feet — X 25
6. *Asterigerina adelaidensis* (Howchin). Buccleuch A Type Section, Hundred of Coneybeer 56 365-370 feet Dorsal view — X 50
7. .... Ventral view — X 50
8. *Globigerina linaperta* Finlay. Type Section Hundred of Coneybeer Section 56, 327-330 feet — X75
9. *Globigerapsis index* (Finlay). Type Section, Hundred of Coneybeer Section 56 327-330 feet — X 75

PLATE 16

Oligocene foraminifera of the Ettrick Formation and Gambier Limestone

1.	Victoriella "plecte" (Chapman) = conoidea (Rutten). Canopus Bore, 500-510 feet	X 25
2.	Astrononion centroplax Carter. Millicent Hospital Bore 85-105 feet	X 50
3.	Massilina torquayensis (Chapman). Lamner No. 1 Bore Hundred of Ettrick Section 26 250-310 feet	X 25
4.	Notorotalia crassimura Carter. Type Section Lamner No. 2 Bore Hundred of Ettrick Section 26 280-283 feet, dorsal view	X 50
5.	Ventral view	X 50
6.	Eponides repandus (Fichtel & Moll) Millicent Hospital Bore 85-105 feet, dorsal view	X 25
7.	.... , ventral view	X 25
8.	Cibicides brevoralis Carter. Type Section Lamner No. 2 Hundred of Ettrick. Section 26 260-270 feet, "ventral view"	X 50
9.	.... "dorsal view"	X 50
10.	Gyroidina cf. zealandica Finlay. Type Section Lamner No. 2 Hundred of Ettrick Section 26. 200-210 feet dorsal view	X 50
11.	.... ventral view	X 50
12.	.... apertural view	X 50

PLATE 17

Lower Miocene foraminifera of the Mannum Formation

All from Type Section

1.	_Textularia vertebralis_ Cushman. F 273/53		X 25
2.	_Gaudryina_ (_Siphogaudryina_) _victoriana_ Cushman. F 276/53		X 25
3.	_Sherbornina cuneimarginata_ Wade. F 276/53	dorsal view	X 35
4.	....	ventral view	X 35
5.	_Rotalia_ cf. _calcar_ d'Orbigny	dorsal view	X 75
6.	....	ventral view	X 75
7.	_Crespinella_ sp. nov.	ventral view	X 35
8.	....	apertural view	X 35

PLATE 18

Lower Miocene foraminifera of the Morgan Limestone and Cadell Marl

1. Amphistegina lessonii d'Orbigny. F 157/52 X 20
2. Lenticulina howchini Chapman & Crespin. F 32/56 X 12.5
3. Cyclina howchini Chapman. F 88/56 X 25
4. Clavulinoides victoriensis Cushman. F 9/56 X 25
5. Austrotrillina howchini (Schlumberger). F 129/53 X 50
6. Calcarina verriculata (Howchin & Parr) F 112/53 ventral view X 25
7. ..... dorsal view X 25
8. Parallina spaticulatiformis Wade. F 9/56 X 25
9. Globigerinoides bisphaericus Todd. F 63/56 X 75
10. Globigerina [illegible] Cushman. Typebed of Gordon Section 377 Sheet 18 267-296 X 75
11. Globigerinoides trilobus immaturus Le Roy. F 13/56 Morgan Railway Section, 42 feet from base of section X 75

PLATE 19

Miocene foraminifera of the Pata Limestone

All from Standard Subsurface Section Hundred of Gordon Section 377

1. Cibicides victoriensis Chapman, Parr, and Collins. 150-165 feet "ventral view" X 25
2. .... "dorsal view" X 25
3. Operculina victoriensis Chapman and Parr, broad form. 150-165 feet X 10
4. Orbulina universa d'Orbigny. 165-182 feet X 75
5. Candorbulina universa Jedlitschka. 165-182 feet X 75
6. Porticulasphaera glomerosa glomerosa (Blow). 165-182 feet X 75
7. Porticulasphaera glomerosa curva (Blow) 165-182 feet X 75
8. Porticulasphaera transitoria (Blow) 165-182 feet X 75
9. Biorbulina bilobata (d'Orbigny) 165-182 feet X 75

PLATE 20

Foraminifera of the Bookpurnong Beds

Hundred of Gordon Section 377 78-105 feet

1. Sigmoilina [illegible] (Howchin & Parr) X 50
2. Siphogenerina [illegible] (Parr) X 50
3. Flintina intermedia (Howchin) spinose variety X 50
4. Elphidium pseudonodosum Cushman X 70

PLATE 21

Lower Miocene molluscs of the Cadell Marl Lens, Type Section, Natural size, Tate Collection Adelaide University unless otherwise stated.

1. Turritella (Maoricolpus) murrayana Tate. Holotype T1400-B
2. Triton radialis Tate. Holotype T 462D.
3. Murex basicinctus Tate. Holotype T 417A
4. Triton tortirostris Tate. Paratype T 510C.
5. Austrovoluta antiscalaris (McCoy) S.A. Mines Department Collection
6. Murex pachyatirus Tate. Holotype T410
7. Peristernia purpurdiana Tate. Holotype T 574B
8. Glycymeris subtrigonalis (Tate). Topotype
9. .... S.A. Mines Dept. Collection
10. Corbula ephamilla Tate. Paratype T335A
11. Corbula ephamilla Tate. Paratype T335B
12. Cucullaea corioensis McCoy
13. .... S.A. Mines Department Collection
14. Verticordia rhomboidea Tate Holotype T1082 X3
15. .... X3

PLATE 22

Eocene, Oligocene and Miocene echinoids and molluscs

Natural size, unless otherwise stated.

1,2. Anatalanthus longianus Gregory

F148/52. [illegible] Sherlock, Section 13 252-254 feet

Upper Eo[illegible]

[illegible] Limestone