SOUTH AUSTRALIA

Department of Mines

GEOLOGICAL SURVEY OF SOUTH AUSTRALIA

Bulletin No. 36

Stratigraphy of the Murray Basin in South Australia

By N. H. LUDBROOK, M.A., Ph.D., D.I.C., F.G.S.

Issued under the authority of
The Honourable Sir A. Lyell McEwin, K.B.E., M.L.C.
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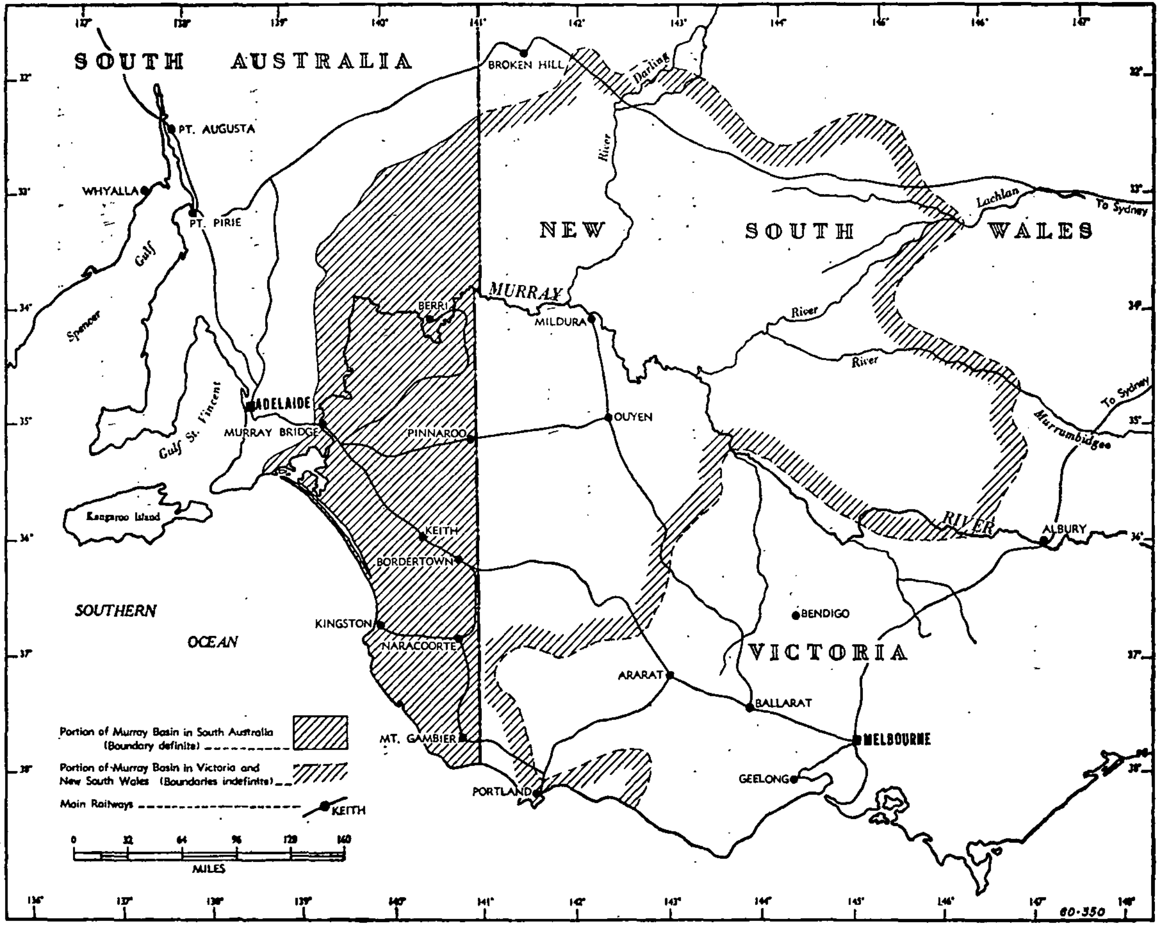

LOCALITY MAP

Showing the extent of the Murray Basin

Frontispiece]

LETTER OF TRANSMITTAL

Geological Survey Office, Department of Mines,
Adelaide, 5th August, 1960.

Sir,

I have the honour to present a report by Dr. N. H. Ludbrook (Palaeontologist) dealing with the stratigraphy of the Murray Basin Province of South Australia. The work leading up to this report has played a major part in the understanding of the sedimentary succession of this important basin-area of the State. The data contained herein are of technical value in the evaluation of the Basin as a source of groundwater, and it also provides an invaluable reference for oil exploration.

I have, etc.,
T. A. BARNES,
Government Geologist.

To the Hon. Sir A. Lyell McEwin, K.B.E., M.L.C., Minister of Mines.

Submitted for approval to print as a Bulletin of the Geological Survey of South Australia.

Approved,
A. LYELL McEWIN,
Minister of Mines.

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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 Sunklands.

Knowledge of the Mesozoic in the Murray Basin proper is limited to two bores in the Loxton area which entered siltstones and mudstones below 1,350ft. In the Gambier Sunklands 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 1,000ft. in thickness in the basin proper but at least 4,000ft. thick in the Gambier Sunklands. 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 River Murray 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 re-measured and sampled and the complexity of the stratigraphy developed from a preliminary study of the microfaunas of exposed sections and numerous water bores.

The locations of the type sections are shown on the maps of figs. 35 and 36.

Detailed faunal studies have still to be undertaken.

All type material with the exception of molluscan holotypes, is housed in the palaeontological collection in the South Australian Department of Mines museum.

ACKNOWLEDGEMENTS

The writer is indebted to her colleagues of the Geological Survey and the Boring Branch of the Department of Mines for assistance in the field and in the collection and logging of bore cuttings prior to their submission for palaeontological examination. The work would not have been possible without the full collaboration of Mr. E. P. D. O'Driscoll (Senior Geologist, Hydrology). Mr. A. James of Naracoorte and Mr. L. G. Carter of Mannum assisted in the collection of material. Standard Quarries Pty. Ltd. and Mr. W. H. Blake of Waikerie provided information on Waikerie building stones.

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 I. The areas over which the units have been noted are shown in figs. 35 and 36.

PROTEROZOIC AND PALAEOZOIC BEDROCK

In the Murray Basin proper no bore has so far gone deeper than 1,805ft. at which "Company" bore near Loxton bottomed in Lower Cretaceous sediments. In Australian Oil and Gas Company's Loxton bore Lower Cretaceous shales below 1,500ft. carried boulders of Kanmantoo greywacke. South of the River Murray most bores reaching bedrock have entered phyllitic slates, micaceous schist, greywacke or granitized 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. Farther north in the hundreds of Anna and Brownlow the Tertiary laps on to Adelaide System rocks in Levi 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 1,275 feet.

PERMIAN

Beyond records of boulder clays in bores between Lake Alexandrina, the Coorong and Coomandook, 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 Loxton area: below 1,596ft. in "Company" bore sunk in 1910 by the Engineer-in-Chief's Department for the Loxton Farming Company, 15 miles northeast of Loxton, on section 17, hundred of Gordon, and below 1,350ft. in Australian Oil & Gas Corporation's Loxton oil bore put down in 1956 on part section 6B, hundred of Bookpurnong.

Columnar sections of these two bores are shown in fig. 1.

Log of "Company" Bore—1910

Depth From ft.	To ft.	Description
Surface	1	Red-brown sandy surface soil.
1	2	Pinkish quartz sand (rounded grains) and kunkar.
2	7	Nodular kunkar.
7	12	Light-red loosely consolidated medium to coarse sand.
12	15	Reddish-brown sandy clay.
15	16	Grey and red mottled sandy clay.
16	19	Light-grey and red mottled clay.
19	39	Grey-buff clay.

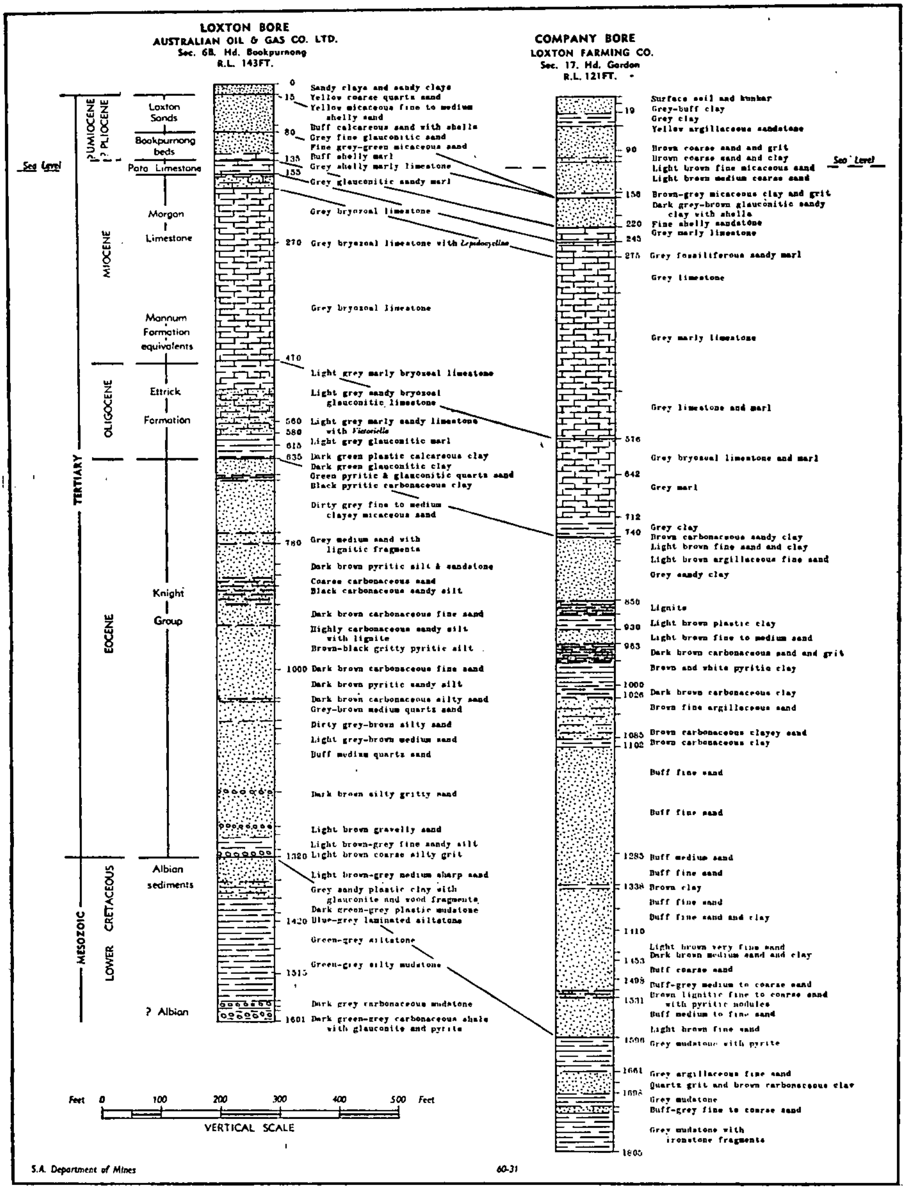

FIG. 1—LOXTON OIL BORES

Columnar sections

LOG OF "COMPANY" BORE—1910—*continued*

Depth From ft.	To ft.	Description
39	51	Grey plastic clay.
51	57	Yellow-grey argillaceous incoherent sandstone.
57	65	Yellow coarse argillaceous incoherent sandstone.
65	74	Loose yellowish coarse sand.
74	76	Light-brown coarse sand.
76	90	Dark-brown coarse sand and grit.
90	97	Brown coarse sand and grit.
97	105	Dark-brown coarse micaceous sand and clay.
105	128	Light-brown unsorted coarse to fine somewhat clayey micaceous sand.
128	134	Light-brown fine micaceous sand.
134	146	Light-brown fine micaceous sand, with some quartz grains, to grit size.
146	156	Light-brown even-grained medium coarse sand.
156	169	Dark grey-brown micaceous sandy plastic clay.
169	173	Brown-grey micaceous clay and grit.
173	176	Light grey-brown coarse sand.
176	199	Dark grey-brown fine highly glauconitic sandy clay with large shell fragments.
199	216	Dark-grey highly glauconitic clay.
216	220	Grey shelly marly fine sandstone.
220	245	Grey fossiliferous limestone.
245	273	Grey fossiliferous sandy marl with subrounded quartz grains.
273	280	Grey glauconitic marl and limestone.
280	330	Grey limestone.
330	364	Grey marly limestone.
364	497	Grey marly limestone.
497	576	Grey limestone and marl.
576	642	Grey bryozoal limestone and marl.
642	683	Grey marl.
683	712	Grey marl.
712	740	Grey clay.
740	747	Brown carbonaceous sandy clay.
747	752	Light-brown fine sand.
752	758	Brown medium clayey sand.
758	760	Dark-brown lignitic sandy clay.
760	786	Light grey-brown argillaceous fine sand.
786	789	Dark-brown carbonaceous clay.
789	802	Light-grey and buff mottled clay.
802	856	Grey sandy clay.
856	883	Lignite.
883	908	Light-brown plastic clay.
908	930	Light-brown fine to medium coarse sand.
930	938	Coarse quartz sand.
938	943	Dark-brown carbonaceous clay and grit.
943	950	Dark-brown carbonaceous sandy clay.
950	963	Dark-brown carbonaceous clay and grit.
963	1,000	Brown and white pyritic clay.
1,000	1,026	Dark-brown carbonaceous clay.
1,026	1,044	Brown fine carbonaceous clayey sand.
1,044	1,071	Brown carbonaceous clay.
1,071	1,085	Brown carbonaceous clayey sand.

LOG OF "COMPANY" BORE—1910—*continued*

Depth From ft.	To ft.	Description
1,085	1,102	Brown carbonaceous clay.
1,102	1,180	Buff fine sand.
1,180	1,285	Buff fine sand.
1,285	1,297	Buff medium sand.
1,297	1,322	Buff fine sand.
1,322	1,338	Buff fine sand—some coarse quartz grains.
1,338	1,340	Brown clay.
1,340	1,360	Buff fine sand.
1,360	1,372	Buff fine to coarse sand—angular to subangular grains.
1,372	1,397	Buff fine sandy clay, some mica.
1,397	1,410	Buff fine sand, some coarse, slightly argillaceous.
1,410	1,416	Brown carbonaceous sandy clay with some coarse quartz grains.
1,416	1,426	Brown medium-coarse carbonaceous sand.
1,426	1,453	Light-brown very fine sand.
1,453	1,462	Dark-brown medium carbonaceous and argillaceous sand.
1,462	1,498	Buff coarse sand—angular to subangular grains.
1,498	1,516	Buff-grey fine sand.
1,516	1,523	Buff-grey medium, some coarse, sand.
1,523	1,531	Brown lignitic fine to coarse sand with pyritic nodules.
1,531	1,554	Buff-grey medium coarse sand.
1,554	1,566	Buff-grey fine sand.
1,566	1,569	Light-brown fine sand.
1,569	1,579	Buff-grey fine sand.
1,579	1,596	Light-brown fine sand and carbonaceous clay.
1,596	1,660	Grey pyritic mudstone.
1,660	1,672	Brown-grey argillaceous fine sand.
1,672	1,679	Light-buff fine to coarse sand.
1,679	1,684	Grey quartz grit grading to gravel with milky quartz grains.
1,684	1,687	Buff fine sand.
1,687	1,689	Light-brown fine sand and clay.
1,689	1,698	Quartz grit and brown carbonaceous clay.
1,698	1,715	Grey mudstone.
1,715	1,722	Buff-grey fine to coarse sand.
1,722	1,726	Grey mudstone.
1,726	1,731	Buff-grey fine to coarse sand.
1,731	1,800	Grey mudstone with ironstone fragments.
1,805		Grey mudstone with ironstone fragments.

The succession of grey mudstone and fine sands below 1,596ft. in this bore are considered to be of Lower Cretaceous (Albian) age. They are equated with the interval between 1,350 and 1,587ft. in Australian Oil & Gas Corporation 1956 bore. In both bores the sediments carry megaspores of the water fern *Azolla* somewhat similar to those described as *Thomsonia* by Madler (1955) from the Wealden of Germany. These and other trilete spores in the two Loxton bores are almost always present in the Albian of the Great Artesian Basin. No foraminifera were recovered from the interval in either bore but a fish tooth was present with *Azolla* at 1,805ft. in "Company" bore.

Material from this part of the sequence was submitted to Dr. Cookson for confirmation and the results published by Cookson and Dettman (1958a p. 48).

Australian Oil & Gas Corporation Loxton bore entered at 1,315ft. below carbonaceous silty sands of the Knight Group, light-brown coarse angular silty grit passing into paralic sandy plastic clay, siltstone, and sandy mudstone at 1,350ft. The mudstones contain quartz, muscovite, biotite, chlorite, glauconite and carbonaceous matter. At 1,587ft. the boring entered greenish-grey carbonaceous shale rich in glauconite and carrying several species of arenaceous foraminifera including *Ammobaculoides romaensis* and *Trochammina minuta* in some abundance, with a few individuals identified with some uncertainty as species of *Gaudryina, Dorothia, Textularia, Haplophragmoides* and *Ammobaculoides.*

The fauna is impoverished and poorly preserved, and on somewhat negative evidence the age of the sediments was determined as Albian. (Ludbrook, unpublished report. Geol. Survey S. Aust. G. 593, Pal. Rep. 14/56.)

"Company" bore appears to have been abandoned above this level.

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 Merino Group is probably represented below 650 feet. Mesozoic sediments were apparently entered at 650ft., the uppermost of which were fine soft grey mudstones. Sedimentation is fairly uniform to the bottom of the bore at 1,122ft., a change occurring at about 700ft. where a corresponding peak occurs in the radiometric log. The upper mudstones have been correlated with the Runnymede Formation (Boutakoff and Sprigg, 1953, Ludbrook, 1958). No palynological study of the arkosic sandstones below 708ft. has been attempted; mudstone at 650ft. was determined as Jurassic (Cookson, 1953, p. 463) later as Cretaceous (Cookson, 1954) and Lower Cretaceous, possibly Albian (Cookson and Dettman 1958, p. 125).

A small collection of 11 labelled and several unlabelled specimens from South Australian Oil Wells No. 1 bore, section 714, hundred of Waterhouse ("Robe 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 ft.	Description
1,400	Grey mudstone.
1,630	Grey-green siltstone.
1,780	Greenish-grey micaceous siltstone.
2,325	Greenish-grey micaceous siltstone.
2,360	Greenish-grey laminated siltstone.
3,150	Darker greenish-grey carbonaceous siltstone.
3,200	Dark greenish-grey siltstone with carbonized plant fragments.
3,325	Greenish-grey somewhat sandy siltstone.
3,500	Greenish-grey laminated carbonaceous siltstone.
4,300	Coal.
4,490	Light greenish-grey arkosic sandstone.

The specimens from above 4,490ft., so far as could be determined from the small amount of material available, were tentatively suggested (Ludbrook, 1958) as corresponding to the 650-708ft. interval in Comaum bore and the arkosic

TABLE I

TERTIARY STRATIGRAPHIC UNITS OF THE MURRAY BASIN IN SOUTH AUSTRALIA

AGE	GROUP	FORMATION OR MEMBER	LITHOLOGY	DOMINANT MEGAFAUNA	DOMINANT MICROFAUNA
PLIOCENE		NORWEST BEND	Calcareous sandstones with thick oyster beds.	*Ostrea arenicola, O. sturtiana, Anodontia sphericula, Diastoma provisi*	*"Rotalia" beccarii*
		LOXTON SANDS	Yellow micaceous sands, grits and silty sands generally cross-bedded with shelly bands.	*Ostrea sturtiana, Tawera dictua, Donax (Plebidonax) depressa, Placamen subroborata.*	*Marginopora vertebralis, "Rotalia" beccarii, Flintina intermedia*
MIOCENE — MIDDLE ? UPPER		BOOKPURNONG BEDS	Green, grey and yellow micaceous glauconitic sands and marls with abundant mollusca.	*Serripecten yahliensis, Placamen subroborata. Tawera dictua, Leiopyrga quadricingulata.*	*Siphonaperta ammophila, Sigmoilopsis lapidigera, Flintina intermedia, Elphidium pseudonodosum.*
MIOCENE — MIDDLE ? UPPER	MURRAY	PATA LIMESTONE	Grey-white partially recrystallized bryozoal limestone.	*Species of Nuculana, Limopsis, Carditidae. Dentalium, Turritella in bores.*	*Operculina victoriensis, Cibicides victoriensis, Orbulina universa, Candorbulina universa, Globigerinoides bisphaerica*
MIOCENE	MURRAY	CADELL MARL LENS (MORGAN LIMESTONE)	Grey marl.	*Antigona dimorphophylla, Verticordia rhomboidea, Corbula ephamilla, Turritella murrayana. Austrotriton radialis, Austrotriton tortirostris. Murex basicinctus, Murex pachystirus.*	*Operculina victoriensis, Amphistegina lessonii, Gypsina howchini, Parellina craticulatiformis. Globigerinoides triloba, Globigerinoides bisphaerica, Marginopora vertebralis, Austrotrillina howchini.*
MIOCENE	MURRAY	MORGAN LIMESTONE	Fine-grained cream-yellow and grey bryozoal limestone grading to marly limestone.	*Chlamys murrayana, Turritella murrayana.*	*Operculina victoriensis, Amphistegina lessonii Gypsina howchini. Parellina craticulatiformis, Lepidocyclina howchini, Globigerinoides triloba, Globigerinoides bisphaerica, Austrotrillina howchini.*
MIOCENE — LOWER	MURRAY	FINNISS CLAY	Mottled light blue-grey green and brown clay with large gypsum nodules.		*Amphistegina lessonii, Cibicides pseudoungerianus, Operculina victoriensis, Quinqueloculina vulgaris.*
MIOCENE — LOWER	MURRAY	MANNUM FORMATION	Yellow limonitic calcareous sandstones and limestones with abundant Echinoids. Sandstone at base.	*"Lovenia forbesi". Monostychia australis. Eupatagus murrayanus, Chlamys sturtiana. Cypraea dorsata, Aturia. Eutrephoceras.*	*Operculina victoriensis, Crespinella sp. nov., Sherbornina cuneimarginata, Astrononion centroplax, Planorbulinella plana, Calcarina verriculata, Sherbornina atkinsoni,*
MIOCENE — LOWER	MURRAY	NARACOORTE LIMESTONE	Cream rubbly limestone.	*Chlamys gambierensis. Chlamys (Mesopeplum) incerta, Serripecten yahliensis, Cypraea dorsata. Alcithoe (Cottonia) heptagonalis, Aturia, Eutrephoceras.*	*Operculina victoriensis, Carpenteria rotaliformis, Globigerinoides triloba.*
OLIGOCENE	GLENELG	ETTRICK FORMATION / GAMBIER LIMESTONE	Grey-white glauconitic marls, sandy marls and grey limestone.		*Cassidulina subglobosa with Astrononion centroplax. Massilina torquayensis. Gyroidina novozelandica, Cibicides umbonifer. Cibicides brevoralis.*
OLIGOCENE	GLENELG	GAMBIER LIMESTONE	Cream-white fine-grained bryozoal limestone, glauconitic near base.	*Chlamys gambierensis. Chlamys (Mesopeplum) incerta, Scutellina patella. Echinolampas gambierensis.*	*Gaudryina (Pseudogaudryina) crespinae, Nodosaria soluta, Eponides repandus. Globigerina bulloides. Astrononion centroplax. Victoriella plecte..*
OLIGOCENE	GLENELG	COMPTON CONGLOMERATE	Brown limonite pebbles in recemented matrix		
EOCENE — UPPER	BUCCLEUCH	BEDS C	Black limonitic clay and grey-brown carbonaceous clay.		*Bulimina pupoides. with Globulina gibba. Spirillina sp. Stomatorbina concentrica, Cibicides pseudoconvexus. C. umbonifer. Sherbornina atkinsoni.*
EOCENE — UPPER	BUCCLEUCH	BEDS B	Dirty brown bryozoal clayey sand with much material derived from limestone of Buccleuch A. Black pyritic clay and mudstone.	*Turritella aldingae*	*Sherbornina atkinsoni, Bulimina pupoides. Spirillina sp., Gümbelina rugosa, Cibicides pseudoconvexus, C. umbonifer, Anomalina perthensis.*
EOCENE — MIDDLE TO UPPER	BUCCLEUCH	BEDS A	White bryozoal limestone grading downwards to greenish glauconitic marl.	*Australanthus longianus*	*Maslinella chapmani. Globigerina linaperta. Globigerapsis index. Hastigerina micra. Halkyardia sp., Linderina sp.. Crespinina kingscotensis. Pseudopolymorphina sp.. Asterigerina adelaidensis.*
EOCENE — MIDDLE TO UPPER	KNIGHT	MOORLANDS COAL MEASURES; UNDIFFERENTIATED	Quartz gravels and grits, carbonaceous clays and silts, medium carbonaceous sands.	*Turritella aldingae, Dentalium (Gadilina) tatei, fish teeth, corals..*	*Globigerapsis index. Cibicides umponifer, C. pseudoconvexus, species of Angulogerina Cassidulina.*

sandstone at 4,490ft. to those below 708ft. in Comaum. Cookson and 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 1,000ft. in thickness although in the Gambier Sunklands the Nelson bore proved them to be at least 4,000ft. thick. The oldest Tertiary strata belong to the Knight Group, of Eocene age.

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 limonitic grits with Paleocene 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 and 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 northwest 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.

Thickness ft.	in.	Lithology	Formation
2	0	Dark-brown surface soil	—
3	0	Weathered cream glauconitic bryozoal limestone	Gambier Limestone
1	6	Rubbly limestone—concealed	Gambier Limestone
8	0	Yellow-brown bryozoal limestone with large limonitic nodules and bands of secondary calcification	Gambier Limestone
1	6	Basal conglomerate with dark brown limonitic pebbles in recemented matrix; pebbles up to 2in. 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	Knight Group

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.

Moorlands Coal Measures

The Moorlands Coal Measures occur in this manner at depths of 60 to 100ft. 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 given 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 500ft. 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 Loxton and Pinnaroo oil bores and over 400ft. in Canopus No. 1 bore.

Sands with abundant *Turritella aldingae* 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 Buccleuch Group into which they pass conformably. In addition to *Turritella aldingae* they contain Upper Eocene foraminifera and the scaphopod *Dentalium* (*Gadilina*) *tatei* Sharp and Pilsbry, described from the Eocene of the Adelaide Plains and apparently restricted to that level.

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 Eucla Basin existed over a limited area in the southwest of the Murray Basin where in a small but probably moderately deep embayment (fig. 4) extending roughly from Milang to the Marmon Jabuk Range and down to Coonalpyn marine limestones and sands interbedded with carbonaceous clays were laid down.

These were named (Ludbrook, 1957, p. 179) the Buccleuch 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 180ft. and 206ft. 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 Buccleuch Group.

The beds are still insufficiently described and are 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 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 252ft. on section 13, hundred of Sherlock and 290ft. on section 31, hundred of Roby.

Standard Subsurface Section, Coonalpyn Township Bore—Section 56, Hundred of Coneybeer

Engineering and Water Supply Department bore No. 2, Coonalpyn water supply (Department of Mines bore serial No. 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.

FIG. 2—KNIGHT GROUP CLAY AND GRAVELS
Section 718, hundred of Blanche—View south

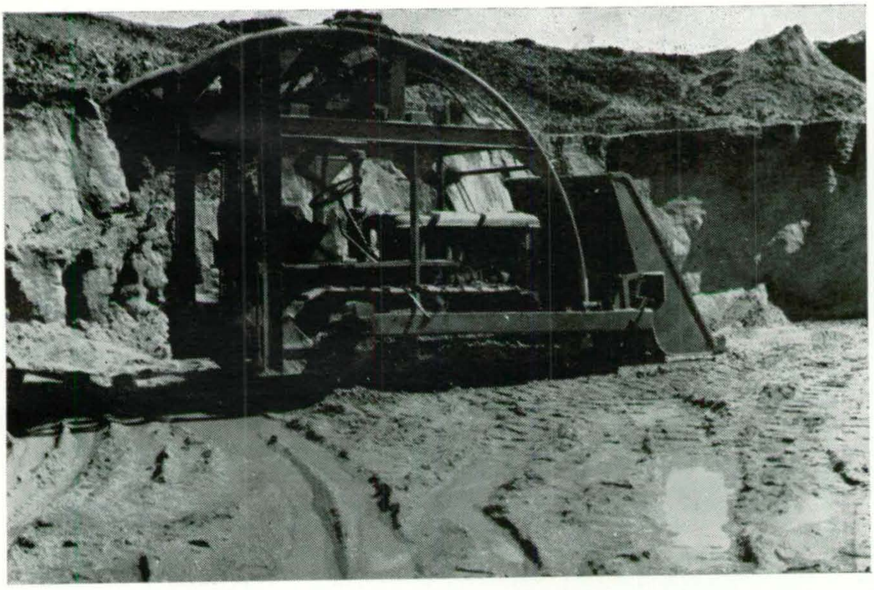

FIG. 3—VIEW OF QUARRY FACE AND MACHINERY
Section 718, hundred of Blanche—Close view

In upward succession, the sequence in Coonalpyn township bore consists of:

Knight Group sediments (Upper Eocene)

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

Buccleuch Group

The base of the marine beds forming the Buccleuch Group is at 382ft. Above this level a white bryozoal limestone 147ft. thick with a glauconitic lower member between 322 and 382ft. was penetrated. This limestone, at present unnamed and referred to as Buccleuch A is physically similar to the Gambier Limestone, but lower in the stratigraphic column (see table I). 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 13ft. black pyritic clay is succeeded by a brownish-grey bryozoal sand between 210ft. and 222ft. referred to as Buccleuch B. The fauna is partially derived from the underlying limestone but includes abundant *Sherbornina atkinsoni* and associated small foraminifera of the Upper Eocene. The uppermost bed of the group is a black limonitic clay between 208ft. and 210ft. with a characteristic microfauna dominated by *Bulimina pupoides*. The bed is at present known as Buccleuch C.

Glenelg Group

A stratigraphical break occurs at 208ft. in the bore and the base of the Glenelg Group is represented by the Compton Conglomerate between 195ft. and 208ft. 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 100ft. of Pleistocene-Recent foraminifera occurring with *Victoriella "plecte"* and other "Janjukian" species. Above 100ft. quartz grains are mixed with reworked limestone, but the exact boundary is obscured by possible contamination in percussion drilling.

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

PLEISTOCENE

Depth From ft.	To ft.	Description
Surface	5	Cream sandy limestone with secondary calcification (kunkar).
5	10	Cream sandy limestone and kunkar.
10	15	Cream calcareous sandstone with a few worn shallow-water faraminifera, species of *Cibicides* and *Elphidium*.
15	20	Cream calcareous sandstone with abundant foraminifera, mostly *Globigerina bulloides,* and one derived species of *Eponides*.
20	25	Similar to previous sample, with *Globigerina bulloides* dominant.
25	55	Cream-white sandy recrystallized and reworked bryozoal limestone with *Globigerina bulloides* and derived species.
55	75	Cream-white sandy reworked bryozoal limestone with *Elphidium rotatum, Rotalia beccarii, Notorotalia* sp. and derived small brachiopods.

Depth From ft.	To ft.	Description
75	80	Cream-white sandy reworked glauconitic limestone with *Victoriella "plecte"* and other species derived from underlying Gambier Limestone.
80	95	Similar to 75-80ft.
95	100	Similar to 75-80ft. with *Elphidium rotatum* and derived *Victoriella "plecte"*.
		GLENELG GROUP
		Gambier Limestone
100	115	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	Pink recrystallized limestone with the echinoids *Scutellina* and *Fibularia* and a poor microfauna.
145	150	Similar to 115-145ft. with shark's tooth.
150	155	Similar to 115-145ft. with *Scutellina,* small brachiopods and *Chlamys* sp.
155	195	Recrystallized limestone with small brachiopods and a poor microfauna consisting namely of species of *Cibicides, Gyroidina* and *Cassidulina.*
		Compton Conglomerate.
195	200	Crystalline limestone and ferruginous sandstone with fragments of brachiopod shells, bryozoa and a few foraminiferal species: *Cibicides* sp., *Globigerina* sp., *Cassidulina subglobosa.*
200	208	Ferruginized crystalline limestone with small brachiopods.
		BUCCLEUCH GROUP
		Buccleuch C
208	210	Black limonitic clay. Washings consist of abundant limonite, large subrounded smoky quartz grains and quartz grains with pitted surfaces. Few worn foraminifera.
		Buccleuch B
210	215	Dirty brown-grey bryozoal clayey sand with abundant pyrite aggregates, carbonaceous matter, and *Sherbornina atkinsoni.* The sand is richly foraminiferal with *Spirillina, Stomatorbina concentrica, Bulimina pupoides* and small species.
215	218	Dirty brown-grey clayey bryozoal sand with *Sherbornina atkinsoni* and the same, but less abundant microfauna as 210-215ft.
218	222	Dirty brown-grey bryozoal sand, typical of this formation, rich in worn fragments of bryozoa probably derived from the underlying limestone. Numerous *Sherbornina atkinsoni* are present.
222	227	Black pyritic clay with *Turritella "aldingae"* Tate, *Sherbornina atkinsoni, Bulimina pupoides.*
227	232	Black pyritic clay with *Sherbornina atkinsoni, Gümbelina rugosa, Bulimina pupoides,* and species of *Anomalina, Globigerina, Angulogerina* and *Cassidulina.*
232	235	Black pyritic mudstone with *Turritella,* sharks' teeth and a microfauna similar to that of 232-235ft.
		Buccleuch A
235	237	Dirty brown hard limestone partially recrystallized. Microfauna in the sample is that of the overlying clay.
237	242	White bryozoal limestone with numerous examples of a species of *Rotalia.*

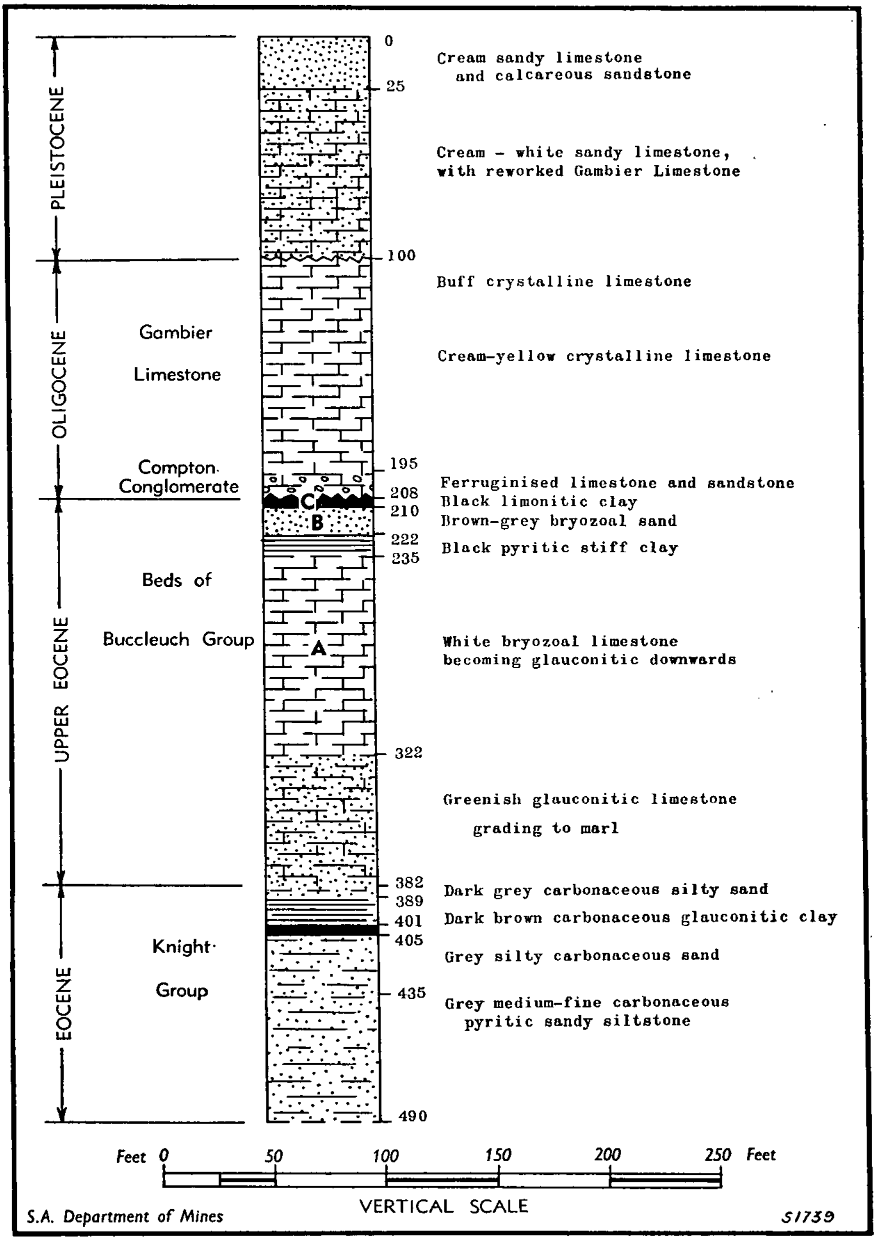

FIG. 4—COONALPYN TOWNSHIP BORE
(Section 56, hundred of Coneybeer)
Columnar section

Depth From ft.	To ft.	Description
242	262	White bryozoal limestone with *Ditrupa* and the foraminifera *Carpenteria rotaliformis* and *Cibicides pseudoconvexus.*
262	277	White bryozoal limestone with *Carpenteria rotaliformis, Maslinella chapmani* and an associated microfauna occurring in Eocene rocks in South Australia.
277	297	White bryozoal limestone with *Carpenteria rotaliformis, Maslinella chapmani,* a genus close to *Linderina* and an apparently undescribed genus related to *Bolivinella.*
297	307	White bryozoal limestone with *Halkyardia,* cf. *Linderina,* cf. *Bolivinella, Crespinina kingscotensis, Maslinella chapmani.*
307	312	White bryozoal limestone with *Halkyardia, Globigerina linaperta, Gümbelina rugosa, Lamarkina airensis,* and associated species of the Upper Eocene.
312	317	White bryozoal limestone with *Asterigerina adelaidensis, Catapsydrax* sp., *Globigerapsis index.*
317	322	White bryozoal limestone becoming glauconitic with *Globigerapsis index, Crespinina kingscotensis,* cf. *Linderina,* etc.
322	330	White glauconitic limestone with planktonic fauna including *Globigerapsis index. Asterigina adelaidensis* present.
330	360	Greenish glauconitic and pyritic marly limestone with *Gümbelina,* species of *Cerobertina, Lamarckina, Heronallenia,* a large *Lenticulina,* and cf. *Bolivinella.*
360	365	Glauconitic marly limestone with cf. *Linderina, Hastigerina micra, Lamarckina airensis, Asterigerina adelaidensis, Maslinella chapmani,* and cf. *Bolivinella.*
365	378	Glauconitic marl with bright green glauconite, pyrite and abundant sponge spicules and foraminifera including *Asterigerina adelaidensis.*
378	382	Glauconitic carbonaceous and pyritic marl with species of *Asterigerina, Gyroidina, Cibicides, Globigerinoides* and *Alabamina.*

KNIGHT GROUP

382	388	Dark-grey carbonaceous silty sand with *Halkyardia, Globigerina linaperta, Cibicides pseudoconvexus.*
388	391	Dark-brown pyritic carbonaceous and glauconitic clay with rounded quartz pebbles up to ½in. diameter. Fauna includes *Turritella,* the restricted scaphopod *Dentalium* (*Gadilina*) *tatei* Sharp and Pilsbry, fish teeth and a microfauna with *Halkyardia* and species of *Asterigerina, Cerobertina, Cibicides, Alabamina* continuing from the overlying formation.
391	401	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	Dark-brown pyritic lignitic clay with a microfauna similar to 391-401ft.
405	435	Grey medium-fine carbonaceous silty sand with *Angulogerina, Gyroidina, Cassidulina* and less abundant forms.
435	490	Grey carbonaceous pyritic sandy siltstone with *Bolivinopsis crespinae, Cassidulina, Angulogerina, Lagena, Cibicides.* Samples below 445ft. are contaminated with species from the overlying limestone.

TABLE II

MICROPALAEONTOLOGICAL LOG—COONALPYN TOWNSHIP BORE, SECTION 56, HUNDRED OF CONEYBEER

	Pleistocene			Gambier Limestone							Buccleuch Group																																					Knight Group							
											C	B			A																																									
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	277–282	282–287	287–292	292–297	297–302	302–307	307–213	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
Cibicides pseudoungerianus (Cushman)	v	—	—	f	f	v	—	—	—	f	—	—	r	—	—	—	—	—	—	—	—	c	r	v	r	f	f	r	c	f	c	r	r	v	f	r	v	f	r	c	v	f	—	f	v	v	r	v								
Cibicides refulgens Montfort	v																																																							
Elphidium sp.	v																																																							
Elphidium macellum (Fichtel and Moll)	v																																																							
Uvigerina sp.	—	v	v																																																					
Angulogerina sp.	—	v	v																																																					
Eponides repandus (Fichtel and Moll)	—	v	—	v	—	—	—	v	—	—	—	—	—	—	r	—																																								
Cibicides lobatulus Walker and Jacob	—	v	v	—	—		—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	f	f	v	v	—	—	—	v	r	—	v	v	—	—	v	—	—	—	—	—	—	v	—	r	—	r	—	v			
Globigerina bulloides d'Orbigny	—	a	a	—	—	a																																																		
Textularia sp.				v	v	—	—	—	—	—	—	v	—	—	—	r	v	v	—	r	v	r	v	—	v	v	c	c	r	f	r	r	—	r	r	—	—	v	—	r	f	v	—	r	—	r										
Gaudryina sp.				v	v	—	—	—	—	—	—	—	—	—	—	r	—	—	—	r	r	r	f	v	v	r	c	f	v	v	v	v	f	—	v	v	—	—	—	—	v	v														
Cassidulina subglobosa Brady				v	v	—	—	v	—	c	—	v	—	—	—	v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	r	r	—	—	f	—	f	—	r	v	v	—	—	v	—	r	v	f	r	v	v	—	r
"*Discorbis*" *boueanus* (d'Orbigny)				v	v	v	—	v	—	v																																														
Notorotalia cf. *howchini* (C. P. and C.)				r	r																																																			
Notorotalia sp. A				f	f	f	v	—	—	r																																														
Guttulina problema d'Orbigny						r	—	—	—	—	—	—	v	—	—	—	—	—	—	—	v	—	v	v	—	v	—	—	r	—	—	v	—	—	v	v	—	—	v	r	—	r	v	r	—	—	—	r	r	—	—	r				
Guttulina crassicostata Cushman and Ozawa						r																																																		
Sigmomorphina subregularis Howchin and Parr						r	—	—	—	—	—	—	—	—	—	v	—	f																																						
Sigmoidella elegantissima (Parker and Jones)						r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v													
Calcarina mackayi (Karrer)						v	—	v																																																
Elphidium rotatum Howchin and Parr							r																																																	
"*Rotalia*" *beccarii* (Linnè)							r																																																	
Victoriella plecte (Chapman)								v																																																
Lenticulina (*Robulus*) sp.										v	—	—	—	—	—	—	v	v	—	v	—	—	—	—	v	—	—	—	—	v	—	v	—	—	v	r	v	r	v	v	r	f	—	f	f	r	r	v	—	r	—	v				
Gyroidina sp. A										v	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	f	f	f	r	f	v	v	r	f	r	—	v	v	f	c	v	a	r	r	—	r	r	f	v	f	v	r	—	—	—	v
Anomalina glabrata Cushman										v																																													
Anomalinoides procolligera Carter										v	—	—	f																																											
Bulimina pupoides d'Orbigny													a	r	r	a	a	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	—	—	—	v	—	—	v									
Cassidulina sp. A													f	v	—	v	r	—	—	—	—	v	—	—	—	v	r	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	r
Guttulina irregularis d'Orbigny													v	—	v	v	v	v	—	r	—	—	v	v	r	v	v	—	r	r	—	f	f	r	r	f	v	r	f	v	f	v	v	v	r	f	v	v	—	r	—	v				
Globulina gibba d'Orbigny													v	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	r	v	v	v	—	—	—	—	—	—	v	v	v	—	v	—	—	—	—	v					
Spirillina sp. 1													v	v	v	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	v									
Stomatorbina concentrica (Parker and Jones)													f	v	f	—	—	—	—	v	—	—	v	v	—	—	v	r	—	r	r	r	r	r	f	r	v	—	v	—	v	r	v	—	v											
Lamarckina glencoensis Chapman and Crespin													v																																											
Notorotalia crassimura Carter													r	—	—	—	v	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v	—	—	—	—	—	—	—	—	v	—	—									
Cibicides pseudoconvexus Parr													v	—	f	—	—	r	—	c	c	c	c	c	f	c	a	c	c	c	c	r	a	f	c	f	f	v	r	r	f	v	v	r	v	r	v	v	r	—	v					
Sherbornina atkinsoni Chapman													a	r	c	r	v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	v																								
Anomalina perthensis Parr													f	f	r	c	a	r	—	—	—	—	v	—	—	—	v	r	—	v	—	v	—	v	—	—	—	—	r	—	—	—	—	r	v	r	v	—	—	v						
Dorothia sp.															r	—	—	—	—	r	—	—	—	—	v	v	—	v	—	v	—	—	v	r	v	v	v	—	—	v	v	—	v	v	—	—	—	v	v	v						
Quinqueloculina spp.															f	—	—	f	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	v										
Pyrgo sp.															v	v	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	v													
Sigmoilina victoriensis Cushman															f	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v	—	r	v													
Guttulina cf. *yamazukii* Cushman and Ozawa															v	—	—	v	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	v	—	v				
Guttulina jarvisi Cushman and Ozawa															v																																									
Pseudopolymorphina rutila var. *parri* C. and O.															v																																									
Sigmoidella sp.															v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v																
Glabratella sp. A															v	—	—	r	—	v	—	—	—	—	v	—	r	—	—	—	—	v	—	—	v	v	—	—	—	—	v															
Osangularia sp.															v	—	—	—	—	—	—	—	—	v	—	—	—	—	v	—	v	—	v	—	—	—	—	—	—	—	—	v	v	—	—	—	v									
Discorbis sp.															v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	v	v	—	—	f	v	f	—	r	—	v	v	—	v	—	—	r	v	v				
Carpenteria rotaliformis Chapman and Crespin															v	—	—	—	—	—	r	r	v	c	a	c	f	f	f	r	r	a	f	f	f	c	r	f	r	v	f	r	r	r	r	v	v									
Cibicides umbonifer Parr															v	v	—	v	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	v	r	—	—	v	—	—	—	v	—	—	r	—	r	c	—	c	v	v	—	v	—	v
Nonion sp.															v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v													
Angulogerina spp.																—	c	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	v	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	c	c	r	—	—	r
Buliminella sp.																v																																								
Sphaeroidina sp.																v	v																																							
Lagena hexagona Williamson																v	v	—	—	—	—	—	v	—	—	—	—	v	—	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	v			

TABLE II—*continued*

MICROPALAEONTOLOGICAL LOG—COONALPYN TOWNSHIP BORE, SECTION 56, HUNDRED OF CONEYBEER—*continued*

	Pleistocene			Gambier Limestone								Buccleuch Group																																				Knight Group							
												C	B			A																																								
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	277–282	282–287	287–292	292–297	297–302	302–307	307–213	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
Lagena striata d'Orbigny																v																																								
Cyclammina sp.																	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v														
Trifarina bradyi Cushman																	r	—	—	—	—	v	—	—	—	v	v	r	r	—	v	—	—	r	—	—	—	—	v	r	r	—	—	—	—	v	—	—	—	—	—	—	r			
Sigmoidella kagaensis Cushman and Ozawa																	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v															
Nodosaria spp.																	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	r	—	—	v	—	—	—	—	v	v	—	v	v	v	—	—	—	—	—	—	—	v
Eponides lornensis Finlay																	r	r	—	c	r	r	r	r	f	r	v	r	r	v	v	f	f	r	r	r	—	r	f	—	v	—	—	f	v	—	v								
Globigerina linaperta Finlay var.																	r																																							
Globigerina aff. *parvi* Bolli																	f																																							
Gumbelina rugosa Parr																	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	r	r	—	—	f	r	—	—	—	—	—	—	—	v				
Cornuspira sp.																		v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	r	v																	
Triloculina sp.																		v																																						
Marginulina sp.																		v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v				
"*Rotalia*" sp. A																				a	—	v																																		
Guttulina sp.																				v	—	—	—	—	—	—	—	—	—	r	r	—	r	—	—	—	—	—	—	—	—	—	v	r	r	v										
Cibicides vortex Dorreen																						f	—	r	—	—	v	a	—	f	—	—	r	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	r							
Globigerina linaperta Finlay																						v	—	—	—	v	v	—	—	—	—	—	r	r	c	f	f	c	r	f	r	v	—	—	v	—	r	—	f	—	—	r				
Maslinella chapmani G. and W.																									f	—	—	v	v	v	r	a	—	c	r	f	a	v	v	r	c	r	f	—	r	v	v									
Sigmomorphina sp.																									r	v	—	—	—	v	v	—	—	f	—	v	r	v	—	—	v	v	—	v	—	—	—	v								
Alabamina westraliensis Parr																											v	—	—	—	—	—	—	v	r	v	—	—	—	—	—	—	—	—	—	—	r	v	v	v	—	r	—	v		
Pullenia bulloides d'Orbigny																											v	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	v	v	—	—	—	—	v	—	—	v				
Gypsina globulus Reuss																											v	—	—	—	—	r																								
Guttulina sp.																											v	—	—	—	r	—	r	r	r	—	—	—	v	—	v	—	—	—	—	—	r	v	—	—	v					
Gen. aff. *Linderina*																												v	—	—	—	—	r	r	—	r	—	v	—	—	—	—	—	v												
Gen. aff. *Bolivinella*																												r	v	c	c	a	f	r	—	v	—	r	v	v	f	v	—	v	v	v	r									
Lagena sulcata, Walker and Jacob																												v	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	v		
Astrononion sp. A																													v	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	v	—	—	v	—	v	v			
Alabamina sp.																													v	—	—	v	v	—	—	—	—	—	—	v																
Reussella sp.																													v	—	—	—	—	—	—	—	—	—	—	—	—	v														
Glabratella crassa Dorreen																													v	—	—	—	—	v	—	—	—	—	—	—	—	—	v	—	v	—	—	—	—	—	—	v				
Sigmoidella sp.																													v	—	v	r	—	—	v	—	—	—	—	—	v	—	—	r												
Fissurina sp.																													v	—	—	—	—	—	—	—	—	v	—	—	v	v	—	v	—	v	—	—	—	—	v	—	v			
Gen ?																														v																										
Karreriella sp.																														v																										
Sherbornina crassata Wade																															v																									
Eponides cf. *dorsopustulatus* Dorreen																															f	f																								
Asterigerina sp. A																															v	—	—	v	v	—	—	—	—	—	v	v														
Asterigerina cf. *lornensis* Finlay																																r	—	—	—	v	—	—	v	v	—	—	v	v												
Crespinina kingscotensis Wade																																v	—	—	—	v	—	—	—	—	v															
Halkyardia sp.																																v	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v						
Planorbulina sp.																																v	r	—	v	v	—	v	—	—	—	—	—	—	v											
Patellina corrugata Williamson																																v																								
Pseudopolymorphina sp. nov.																																r	—	r	—	v	v	v	—	—	v															
Heronallenia pusilla Parr																																	v	—	—	v	v	v	v	v	r	—	—	—	r	r										
Gen. B																																	v	v	—	—	—	—	v	—	—	—	—	—	—	—	v									
Globigerinoides index Finlay																																	r	f	v	f	c	f	—	v	v	v	v	—	v	—	r	v	—	—	r					
Lamarckina airensis Carter																																		v	—	—	—	—	r	r	—	r	v	v	—	—	v									
Sigmoidella bortonica Finlay																																		f	—	r	—	—	v	—	v	v														
Asterigerina adelaidensis (Howchin)																																			r	—	—	r	—	—	—	—	—	v	r											
"*Catapsydrax*" sp.																																			v	v	r	v	v																
Frondicularia sp.																																			v																				
Elphidium sp.																																				v																			
Angulogerina subangularis Parr																																					v	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	v			
Spirillina decorata Brady																																					v	—	v	—	—	—	v													
Glabratella sp. B																																						v	v																	
Notorotalia sp. B																																						v	v	—	—	—	—	v	—	—	v									
Massilina sp.																																						v	v	v	v	v	r	r	—	r	v									

TABLE II—*continued*

MICROPALAEONTOLOGICAL LOG—COONALPYN TOWNSHIP BORE, SECTION 56, HUNDRED OF CONEYBEER—*continued*

	PLEISTOCENE			GAMBIER LIMESTONE								BUCCLEUCH GROUP																																					KNIGHT GROUP							
												C	B			A																																								
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	277–282	282–287	287–292	292–297	297–302	302–307	307–213	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
Cerobertina spp.																																							f	f	v	v	r	v	r	v	r	—	—	v	—	r				
Heronallenia lingulata Burrows and Holland																																							v	v																
Hoglundina elegans (d'Orbigny)																																							v	v	v	—	—	v	v											
Robulus gyroscalprum Stache																																							r	—	—	—	—	r												
Globulina sp.																																							r																	
Frondicularia sp.																																							v																	
Pyrulina cylindroides (Roemer)																																								v	—	—	—	—	v	v										
Vaginulina sp.																																								v																
Bolivinopsis crespinae Parr																																									v	—	—	—	—	—	—	—	—	—	v					
Pullenia quinqueloba (Reuss)																																									v	—	—	—	—	v	—	v	—	v	—	v	v			
Sherbornina sp.																																									v	—	—	—	—	—	—	—	—	—	—	—	v			
Tubulogenerina sp.																																									v															
Carpenteria sp.																																										r														
Plectofrondicularia sp.																																										v														
Globigerina sp.																																											v	v	—	f	—	—	—	—	v	r				
Hastigerina micra (Cole)																																											v	v	—	—	—	—	—	—	v	—	v			
Reussella finlayi Dorreen																																											v													
Guttulina cf. *lehneri* Cushman and Ozawa																																											v													
Biloculinella globula (Bornemann)																																											v	—	—	v										
Gyroidina sp. B																																											—	f	v	f	r	v	—	—	f					
Glabratella sp. B																																												v	—	—	—	—	—	—	—	—	v			
Spirillina unilatera Chapman																																												v												
cf. *Pseudoglandulina clarkei* Parr																																												v												
Globigerina cf. *linaperta* Finlay																																												v	v	v										
Asterigerina sp. B																																														v	v	v	—	v						
Globigerina cf. *ampliapertura* Bolli																																														v										
Lagena spp.																																																			v	—	—	—	—	v
Bolivina sp.																																																			v					
Lagena terrilli Parr																																																			v					
Siphotextularia sp.																																																				v				
cf. *Discorbis assulatus* Cushman																																																								v

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

Bore for C. O. Klitscher, Coonalpyn—Section 10, *Hundred of Strawbridge*

Bore No. 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 98ft. and 203ft. depth.

Before entering bedrock schist at 203ft., the boring passed through bryozoal limestone of uniform character throughout except for a change of colour from cream to pink-cream between 45ft. and 88ft. Faunal examination shows that at least two limestones are present, the limestone of Buccleuch A between 98ft. and 203ft. and the Gambier Limestone between 5ft. and 75ft. The 23-ft. interval between 75ft. and 98ft. 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 170ft., *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 5ft. and 75ft. is typical of the Gambier Limestone, with *Victoriella "plecte"* at 15-25ft. This is of "Janjukian" (Oligocene) age.

Sludge samples, taken every 5ft., were as follows:

Depth From ft.	To ft.	Description
Surface	2	Brown fine surface sand.
2	5	Light-brown calcareous sandstone with a few small species of foraminifera, probably representing a thin Pleistocene cover on Gambier Limestone.
5	15	Cream bryozoal limestone with an abundant "Janjukian" microfauna of the Gambier Limestone.
15	25	Cream bryozoal limestone with *Victoriella "plecte"* and associated Janjukian foraminiferal species.
25	38	Cream bryozoal limestone with abundant *Amphistegina lessonii.*
38	45	Cream hard bryozoal limestone.
45	55	Pink-cream bryozoal limestone with small foraminiferal species mainly *Rotaliidea.*
55	65	Pink-cream bryozoal limestone with small brachiopods, *Eponides* and *Notorotalia.*
65	75	Pink-cream bryozoal limestone with *Rotaliidea.* The boring is still in the Gambier Limestone at this level.
75	88	Pink-cream bryozoal limestone with *Sherbornina atkinsoni* and an associated microfauna mainly *Rotaliidea.*
88	98	Cream bryozoal limestone with *Sherbornina atkinsoni* and a microfauna with Eocene and Oligocene elements.
98	108	Cream bryozoal limestone (Buccleuch A) with *Crespinina kingscotensis, Linderina, Maslinella chapmani* and *Sherbornina atkinsoni.*

Depth From ft.	To ft.	Description
108	118	Cream bryozoal limestone with *Halkyadia, Crespinina kingscotensis, Linderina* and associated species occurring in the Upper Eocene in South Australia.
118	128	Cream bryozoal limestone with genus of *Bolivinella, Halkyardia, Linderina, Maslinella chapmani.*
128	138	Cream bryozoal limestone with abundant larger foraminifera dominated by *Linderina* and cf. *Planorbulina.*
138	158	Similar to 128-138ft.
158	170	Cream sandy bryozoal limestone with abundant larger foraminifera dominated by *Linderina,* cf. *Planorbulina* and cf. *Bolivinella.*
170	180	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	Cream sandy bryozoal limestone with *Halkyardia* and larger foraminifera as at 170-180ft.
203	252	At 203ft. the boring entered grey sericitic schist.

TABLE III

Micropalaeontological Log—Section 10, Hundred of Strawbridge

	Pleistocene		Gambier Limestone								Buccleuch A									
Depth (in feet)	0–2	2–5	5–15	15–25	25–35	45–55	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
Bolivina spp.	—	v	f	—	—	—	—	v												
Cibicides sp.	—	r	r	r	—	r	—	f	v	r	—	—	—	—	—	—	—	f	—	v
Globigerina sp.	—	f																		
Dorothia sp.			v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v
Lagena spp.			r																	
Lenticulina sp.			v																	
Guttulina irregularis d'Orbigny			v	—	—	—	—	v												
Guttulina cf. *jarvisi* Cushman and Bermudez			r																	
Sigmoidella elegantissima Parker and Jones			f																	
Sigmomorphina subregularis Howchin and Parr			v	f																
Cassidulina subglobosa Brady			a	—	v	—	—	c	r	—	—	—	v							
Sphaeroidina bulloides d'Orbigny			r	v																
Discorbis sp.			v																	
Stomatorbina concentrica (Parker and Jones)			v	—	—	f	v	v	—	—	—	—	r	v	a	—	—	v		
Gyroidina soldanii d'Orbigny			r	—	—	—	—	r												
Eponides repandus (Fichtel and Moll)			v	v	—	r	r	v	f											
Cibicides pseudoungerianus (Cushman)			a	v	—	c	—	v	r	—	—	v								
"*Discorbis*" *boueanus* (d'Orbigny)			f	v																
Cibicides umbonifer Parr			f	—	—	—	—	—	r											
Cibicides refulgens (Montfort)			v	—	—	c	—	c	a											
Anomalina glabrata Cushman			c	r	—	v	—	v												
Globigerina bulloides d'Orbigny			f	f																
Carpenteria sp.			v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—
Nonionella sp.			v																	
Astrononion australe Cushman and Edwards			r	r																
Elphidium howchini Cushman			r	—	—	r	—	v												
Amphistegina "*lessoni* d'Orbigny"			r	f	a	—	—	v												
Notorotalia howchini (C. P and C)			c	—	—	r														

TABLE III—*continued*

MICROPALAEONTOLOGICAL LOG—SECTION 10, HUNDRED OF STRAWBRIDGE—*continued*

	PLEISTOCENE		GAMBIER LIMESTONE							BUCCLEUCH A										
DEPTH (in feet)	0–2	2–5	5–15	15–25	25–35	45–55	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
Notorotalia crassimura Carter	—	—	f	—	—	r	v	r	r	f	—	—	—	—	—	—	—	—	—	—
Astrononion centroplax Carter	—	—	r	v	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—
Calcarina mackayi (Karrer)	—	—	f	r	f	v	—	—	v	—	—	—	—	—	—	—	—	—	—	—
Guttulina irregularis d'Orbigny	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—
Angulogerina sp.	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Trifarina bradyi Cushman	—	—	—	v	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Heronallenia parri Carter	—	—	—	v	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—
Victoriella plecte Chapman	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dorothia parri Cushman	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Osangularia sp.	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Reussella simplex Cushman	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Guttulina sp.	—	—	—	—	—	v	—	—	v	—	—	—	—	—	—	—	—	—	—	—
Cibicides perforatus (Karrer)	—	—	—	—	—	—	—	c	a	—	—	—	—	—	—	—	—	—	—	—
Sherbornina atkinsoni Chapman	—	—	—	—	—	—	—	—	r	c	r	—	r	—	—	—	v	f	r	v
Cibicides lobatulus Walker and Jacob	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—
Crespinella sp.	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—
Guttulina sp.	—	—	—	—	—	—	—	—	v	—	—	v	—	—	—	—	—	v	—	—
Reussella finlayi Dorreen	—	—	—	—	—	—	—	—	—	f	—	—	—	—	—	—	v	—	v	—
Eponides lornensis Finlay	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	v	v	v
Cibicides pseudoconvexus Parr	—	—	—	—	—	—	—	—	—	v	—	—	—	c	r	—	f	f	c	c
Cibicides vortex Dorreen	—	—	—	—	—	—	—	—	—	a	—	v	f	c	f	—	r	f	—	—
Anomalina perthensis Parr	—	—	—	—	—	—	—	—	—	f	—	—	v	—	—	—	—	f	v	v
Heronallenia pusilla Parr	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	v	v	—	v
Elphidium sp.	—	—	—	—	—	—	—	—	—	r	—	—	v	v	—	—	—	f	—	—
Valvulineria sp.	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—
Glabratella crassa Dorreen	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	v	—
Crespinina kingscotensis Wade	—	—	—	—	—	—	—	—	—	—	a	c	f	r	r	—	r	a	r	r
Linderina sp.	—	—	—	—	—	—	—	—	—	—	f	a	a	a	a	—	a	c	f	c

Maslinella chapmani Glaessner and Wade	——	——	——	——	——	——	——	——	——	——	a	c	c	v	r	—	f	c	f	r
Halkyardia sp.	——	——	——	——	——	——	——	——	——	——	——	r	v	—	—	—	—	v	c	f
Carpenteria rotaliformis Chapman and Crespin	——	——	——	——	——	——	——	——	——	——	——	v	—	—	—	—	cf	—	r	—
Rotorbinella sp.	——	——	——	——	——	——	——	——	——	——	——	——	r	v	—	—	v	v	r	—
Eponides dorsopustulatus Dorreen	——	——	——	——	——	——	——	——	——	——	——	——	v	—	—	—	v	—	—	—
Textularia sp.	——	——	——	——	——	——	——	——	——	——	——	——	v	—	—	—	—	—	v	—
Gaudryina sp.	——	——	——	——	——	——	——	——	——	——	——	——	r	—	r	—	—	—	—	v
Gen. aff. *Bolivinella*	——	——	——	——	——	——	——	——	——	——	——	——	v	c	f	—	f	f	c	f
Planorbulina johannae Carter	——	——	——	——	——	——	——	——	——	——	——	——	——	v	v	—	—	v	v	v
Amphistegina sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	a	a	—	r	—	—	v
Lagena hexagona Williamson	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	v	—
Asterigerina adelaidensis (Howchin)	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	f	r	—
Sigmomorphina sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	—	v
Cassidulina sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	c	r	—
Astrononion sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	—	v
Gyroidina sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	r	——	——
Elphidium sp. 1	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	——	——
Elphidium sp. 2	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	f	——	——
Gyroidina sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	r	——	——
Gypsina cf. *howchini* Chapman	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	r	—	v
Alabamina westraliensis Parr	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	v
Globigerina linaperta Finlay	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	—
Calcarina sp. ? nov.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	r	—
Elphidium parri Cushman	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	f	v
Elphidium chapmani Cushman	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	—
Asterigerina cf. *cyclops* Dorreen	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	—
Bolivina sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	—
Bulimina cf. *semicostata* Nuttall	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v	v
Glabratella sp.	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v
Gyroidina sp. B	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	——	v

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

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. 13).

Compton Conglomerate

The Glenelg Group is a normal marine sequence of limestones, marls and sandy marls. The base is marked by the Compton Conglomerate 1½ft. 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 *Gaudryina* (*Pseudogaudryina*), *Dorothia, Reussella, Cassidulina, Globigerina,* and *Cibicides.*

The formation and its equivalents have been recognized 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 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 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 megafossils (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 soluta, 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.*

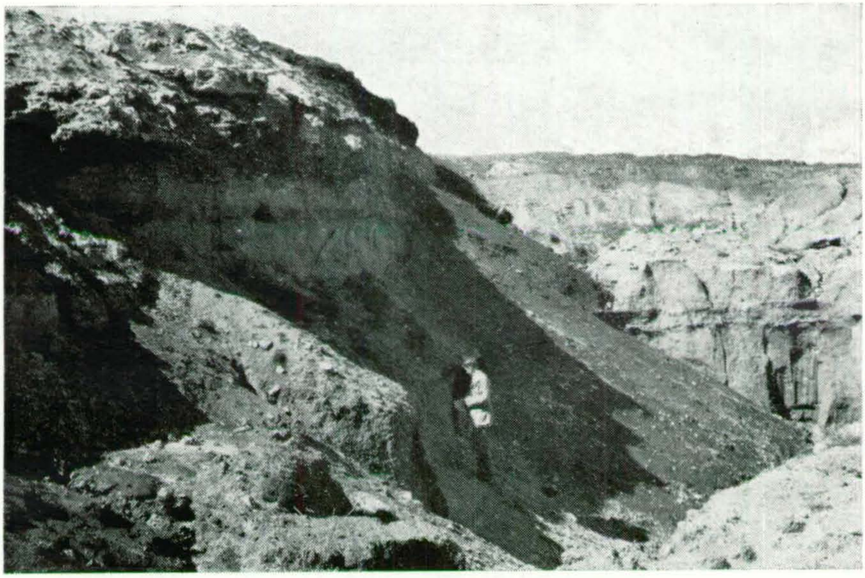

FIG. 5—GAMBIER LIMESTONE WITH COMPTON CONGLOMERATE AT BASE OVER KNIGHT GROUP

Section 718, hundred of Blanche

FIG. 6—GAMBIER LIMESTONE AND COMPTON CONGLOMERATE—CLOSE VIEW

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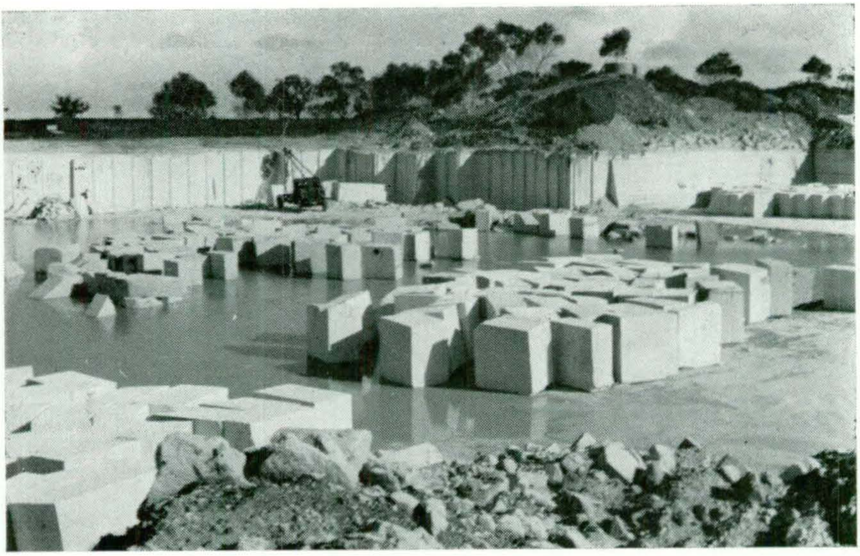

FIG. 7—GAMBIER LIMESTONE
Kain and Shelton Quarry (1956)

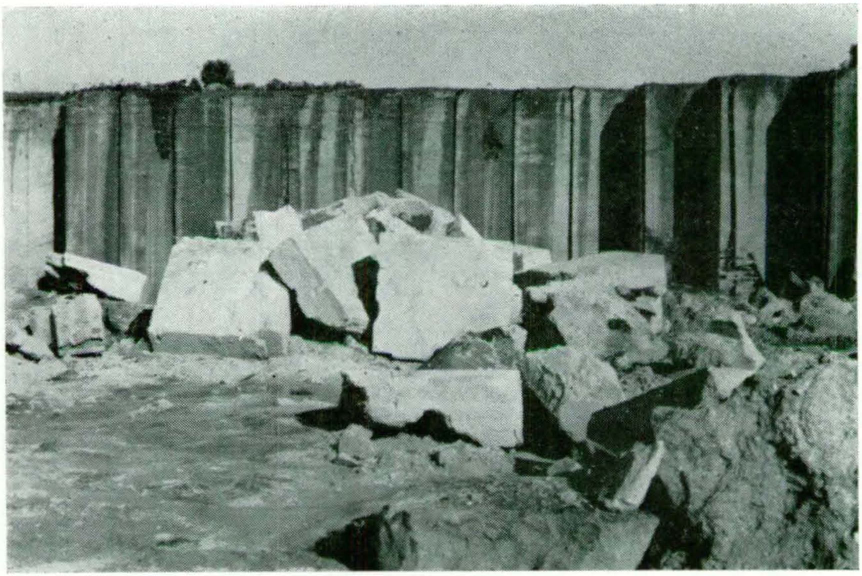

FIG. 8—SOLUTION CAVITIES IN GAMBIER LIMESTONE
Kain and Shelton Quarry

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 12ft. 6in. under the surface soil in the type section measured at the quarry on section 718, hundred of Blanche (see page 13).

The lowest 8ft. over the Compton Conglomerate consists of yellow-brown limonitic bryozoal limestone with occasional quartz grains up to 2 mm. to 5 mm. diameter with a poorly preserved fauna, mainly as casts and moulds of mollusca and small brachiopods. The uppermost 3ft. 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, brachiopoda, a large asteroid, *Chlamys gambierensis* and *Limatula jeffreysiana,* 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 533ft. 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. One 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, one 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.

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 20ft. of Naracoorte Limestone capped by 2ft. of aeolianite. The quarry face in Naracoorte Limestone is 40ft. 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 mollusca and echinoids. *Aturia* and *Eutrephoceras* are common.

The mollusca 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 corrugata, 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 burned 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 90ft. at Frances.

The Ettrick Formation

On the western margin of the Murray Basin underlying the yellow limestone of the Mannum 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 recognized.

The formation is named from A. R. Launer's No. 2 bore on section 21, hundred of Ettrick, 20 miles east-northeast of Murray Bridge where it is represented by 75ft. of glauconitic marl from 210-285 feet.

In upward succession the sequence in Launer's No. 2 bore is as follows.

Ettrick Formation—210-285 Feet

At the base of the formation from 270ft. to 285ft. 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 240ft. and 270ft. and by a grey-brown marl from 210-230 feet.

Mannum Formation—130-210 Feet

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

FIG. 9—DOLOMITE QUARRY—UP AND DOWN ROCKS, NEAR TANTANOOLA CAVE
Showing 80-ft. face of dolomite (October, 1958)

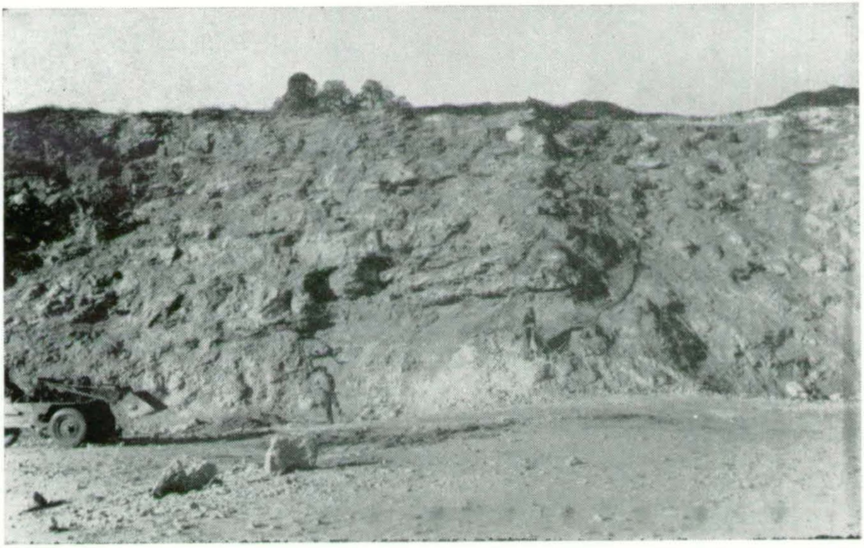

FIG. 10—NARACOORTE LIMESTONE
A. James & Sons quarry

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FIG. 11—NARACOORTE LIMESTONE OVERLYING GAMBIER LIMESTONE
North side of A. James & Sons quarry

? Loxton Sands—10-130 Feet

Between 10ft. and 130ft. 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 10ft. of kunkar, is logged as follows from samples taken every 10ft.:

Depth From ft.	To ft.	Sample No.	Description
Surface	10	F143/53	Kunkar.
			? LOXTON SANDS
10	20	F144/53	Yellow-brown sandy and gritty limestone with a few pauperate foraminifera.
20	30	No sample.	
30	50	F145/53 F146/53	Red-brown ferruginous and calcareous sandy clay.
50	60	F147/53	Red-brown sandy clay.
60	70	F148/53	Yellow calcareous sandstone, with "*Rotalia*" *beccarii*, *Crespinella umbonifera*, and small species.
70	80	F149/53	Yellow calcareous sandstone, with "*Rotalia*" *beccarii*, *Crespinella umbonifera*, and *Elphidium* spp.
80	90	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	F151/53	Yellow-brown calcareous gritty sandstones with abundant mica, coarse subrounded quartz grains, echinoid fragments, bryozoa and a small microfauna similar to that of the 70-80ft.
100	110	F152/53	Yellow fine micaceous sandy limestone with *Crespinella umbonifera*, "*Rotalia*" *beccarii tepida*, *Elphidium pseudonodosum*.
110	120	F153/53	Brown-yellow sandy recrystallized limestone with "*Rotalia*" *beccarii tepida*, *Elphidium crassatum*, *Valvulineria*, sp.
120	130	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	F155/53	Cream-yellow partially recrystallized limestone, with a few coarse, well-worn subrounded quartz grains, echinoid fragments, limonitic internal casts of foraminifera, bryozoa. *Amphistegina*, *Planorbulinella inaequilateralis* and *Crespinella* are present.

Depth From ft.	To ft.	Sample No.	Description
140	150	F156/53	Yellow, poorly fossiliferous recrystallized limestone with *Crespinella* sp. nov. and *Textularia vertebralis*.
150	160	F157/53	Cream-yellow sandy limestone with fine angular quartz grains, *Fibularia gregata* and abundant *Crespinella* and *Cibicides pseudoungerianus*.
160	170	F158/53	Similar to F157/53, with *Sherbornina atkinsoni*.
170	180	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	F160/53	Similar to F159/53 with *Fibularia gregata*.
190	200	F161/53	Cream sandy limestone with fine angular quartz grains and a rich microfauna similar to F159/53.
200	210	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*.

ETTRICK FORMATION

Depth From ft.	To ft.	Sample No.	Description
210	220	F163/53	Grey-green glauconitic marl, with bright-green fresh glauconite, abundant sponge spicules, *Massilina torquayensis* and a rich associated microfauna of numerous small species.
220	230	F164/53	Grey-green glauconitic marl, similar to previous sample, with abundant *Massilina torquayensis* and associated small Janjukian species.
230	240	No sample.	
240	250	F165/53	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	F166/53	Grey sticky calcareous carbonaceous clay with pale-green glauconite. Microfauna similar to previous sample.
260	270	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*.

Depth From ft.	To ft.	Sample No.	Description
270	280	F168/53	Grey sandy marl, with green ironstained clay, limonite grains, subangular fine to medium quartz grains, bryozoa, echinoid fragments; foraminifera fairly abundant.
280	285	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 iron-staining of clay. Microfaunal assemblage dominated by *Cibicides*.

TABLE IV

MICROPALAEONTOLOGICAL LOG—HUNDRED OF ETTRICK, SECTION 21, BORE 2

	Loxton Sands								Mannum Formation								Ettrick Formation						
Depth (in feet) and Sample No.	10–20 F144/53	60–70 F148/53	70–80 F149/53	80–90 F150/53	90–100 F151/53	100–110 F152/53	110–120 F153/53	120–130 F154/53	130–140 F155/53	140–150 F156/53	150–160 F157/53	160–170 F158/53	170–180 F159/53	180–190 F160/53	190–200 F161/53	200–210 F162/53	210–220 F163/53	220–230 F164/53	240–250 F165/53	250–260 F166/53	260–270 F167/53	270–280 F168/53	280–283 F169/53
Bolivina spp.	v	—	—	—	—	—	—	—	—	—	—	—	—	—	x	—	—	—	r	v			
Cassidulina sp.	v																						
Heronallenia parri Carter	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	r
"*Discorbis*" *boueanus* (d'Orbigny)	f																						
Trifarina bradyi Cushman	—	v	—	—	—	—	—	—	—	—	—	—	r	v	f	—	f	—	a	f	v	f	r
Cassidulina subglobosa Brady	—	v	—	—	—	—	—	—	—	—	—	c	a	a	a	a	r	—	r	v	f	v	v
Sphaeroidina bulloides (d'Orbigny)	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	c	r	—
Notorotalia howchini (C. P. and C.)	—	v	v	—	—	v	v	r	—	—	r	v	f	—	f	v	—	f					
Anomalina glabrata Cushman	—	v	—	—	—	—	—	v	f	—	—	—	—	f	c	f	v	—	f	r	r	r	r
Elphidium pseudonodosum Cushman	—	r	v	v	v																		
"*Rotalia*" *beccarii tepida* Cushman	—	c	f	f	r	v	c	c															
Crespinella umbonifera (Howchin and Parr)	—	c	f	v	v	f																	
Valvulineria sp.					r	—	r	v															
Nonion victoriense Cushman					v																		
Notorotalia sp.						v	—	v	v														
Elphidium pseudonodosum Cushman						v																	
Guttulina problema d'Orbigny							v	v	—	—	—	—	—	—	v	—	—	—	—	—	v	v	
Elphidium crassatum Cushman							r	c															
Elphidium advenum Cushman								v	—	—	—	—	—	—	r	r	v	—	—	—	f		
Guttulina irregularis d'Orbigny							f	c	v														
Elphidium macellum (Fichtel and Moll)								v															
Pullenia quinqueloba (Reuss)									v														
Cibicides refulgens Montfort									c	—	—	—	—	—	—	—	—	—	—	—	—	f	—
Planorbulinella inaequilateralis (H. A. and E.)									v														
Amphistegina "*lessonii* d'Orbigny"									r														
Astrononion australe Cushman and Edwards									f	—	—	—	—	v	—	—	—	—	v	—	—	—	v
Elphidium advenum var. *depressulum* Cushman									r														
Anomalina sp. A									v	f	a	r	f	v	v	r	r						

Textularia vertebralis Cushman										v	v												
Dorothia parri Cushman										v	—	—	—	—	—	—	r	f	—	—	—	r	v
Nodosaria sp.										r													
Stomatorbina concentrica (Parker and Jones)										v	—	—	—	—	—	—	v	—	—	—	v	—	v
Elphidium howchini Cushman										v													
Eponides repandus (F. and M.)											f	—	—	—	—	—	—	—	—	—	f	f	
Cibicides pseudoungerianus (Cushman)											a	r	c	c	f	c	c	v	f	—	r	f	c
Gyroidina sp. A.											v	—	—	—	v	—	—	—	v	—	v	v	v
Sherbornina atkinsoni Chapman												v	—	v	v	r	r	—	r	v	—		
Cibicides umbonifer Parr													c	r	r	f	c	f	v	f	f	v	c
Cibicides brevoralis Carter													v	r	f	c	r	v	r	—	a	v	f
Cibicides vortex Dorreen													r	f	f	v	c	f	—	—	—	—	v
Cibicides concentricus Cushman													v	—	—	r	r						
Baggina philippinensis (Cushman)													v	—	—	v	—	—	—	—	—	—	v
Eponides lornensis Finlay													v	—	v								
Elphidium crespinae Cushman													f	f	r	r	r						
Lagena hexagona Williamson														v	v	—	—	—	—	—	—	v	v
Marginulina sp.														v									
Anomalina sp. B															v								
Globigerinoides triloba (Reuss)														v	v								
Dorothia sp.															v	v	—	f	—	—	—	v	v
Globigerina bulloides d'Orbigny															r	—	r						
Liebusella rudis (Costa)																v							
Cornuspira sp.																v	—	v					
Robulus sp.																v	v	v	—	—	v		
Plectofrondicularia sp.																v							
Sigmomorphina sp.																v							
Sigmoidella elegantissima (Parker and Jones)																v							
Gyroidina sp. B.																r							
Heronallenia parri Carter																v	v	v	—	r			
Heronallenia lingulata (Burrows and Holland)																v	—	v	—	v	v		
Ammosphaeroidina sphaeroidiniformis (Brady)																	r						
Quinqueloculina lamarckiana d'Orbigny																	f	r	—	—	f		
Quinqueloculina spp.																	r	v					
Sigmoilopsis sp. 1																	f	r	—	v	r	v	
Massilina torquayensis (Chapman)																	v	c	v	v	c		
Massilina sp. 1																	f	r	v	v	f	—	f
Sigmoilina victoriensis Cushman																	r	r	—	—	v	—	v
Triloculina sp.																	v						
Pyrgo spp.																	v	r	—	—	v	—	v
Guttulina (*Sigmoidina*) *silvestrii* C and O																	v	v	v	—	r	—	—

TABLE IV—*continued*

MICROPALAEONTOLOGICAL LOG—HUNDRED OF ETTRICK, SECTION 21, BORE 2—*continued*

	Loxton Sands								Mannum Formation								Ettrick Formation						
Depth (in feet) and Sample No.	10–20 F144/53	60–70 F148/53	70–80 F149/53	80–90 F150/53	90–100 F151/53	100–110 F152/53	110–120 F153/53	120–130 F154/53	130–140 F155/53	140–150 F156/53	150–160 F157/53	160–170 F158/53	170–180 F159/53	180–190 F160/53	190–200 F161/53	200–210 F162/53	210–220 F163/53	220–230 F164/53	240–250 F165/53	250–260 F166/53	260–270 F167/53	270–280 F168/53	280–283 F169/53
Pullenia bulloides (d'Orbigny)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Spirillina decorata Brady	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	v	—	—	—
Rotorbinella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Spirillina tuberosa Carter	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Quinqueloculina vulgaris d'Orbigny	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	—	r	—	—
Quinqueloculina cuvieriana d'Orbigny	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v	—	—	—	—
Triloculina trigonula (Lamarck)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Pyrulina fusiformis (Roemer)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Sigmomorphina subregularis H and P.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Reussella finlayi Dorreen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Genus B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	r	—	—	v	v
Cibicides lobatulus (W and J)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	v	—	f	r
Bolivinopsis crespinae Parr	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	v	r	—
Uvigerina sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Reussella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Angulogerina subangularis Parr	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	f	v	—	—	—
Patellina corrugata Williamson	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Discorbis cf. *finlayi* Dorreen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Glabratella crassa Dorreen	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Glabratella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Lamarckina glencoensis Chapman and Crespin	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v	v	—	r
Gavelinopsis sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Genus A..................................	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	r	—	—
Dyocibicides biserialis Cushman and Valentine	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—
Siphotextularia sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Cornuspira involvens Reuss	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Plectofrondicularia sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Gavelinopsis sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Conorbella patelliformis Brady	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—

B

Globigerina ampliapertura Bolli	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—	v	—
Globigerina linaperta Finlay	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Spirillina unilatera Chapman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Notorotalia crassimura Carter	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Gaudryina (*Pseudogaudryina*) *crespinae* Cushman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Vulvulina sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Planispirina sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Articulina cf. *byramensis* Cush.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Biloculinella globula (Bornemann)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Valvulineria sp. B.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Sigmomorphina chapmani (H. A. and E.)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Textularia sagittula Defrance	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v
Lagena sulcata W and J	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v
Bolivinella folia (P and J)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v
Frondicularia lorifera Chapman	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v
Spiroloculina sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v

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

The same sequence was intersected in Launer'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 142ft. deeper than bore No. 2 and entered below 325ft. 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*; *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 recognized 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 8 miles west of Coonalpyn cream bryozoal limestone entered at shallow depth on sections 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 6ft. 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 280-285ft. 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).

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.

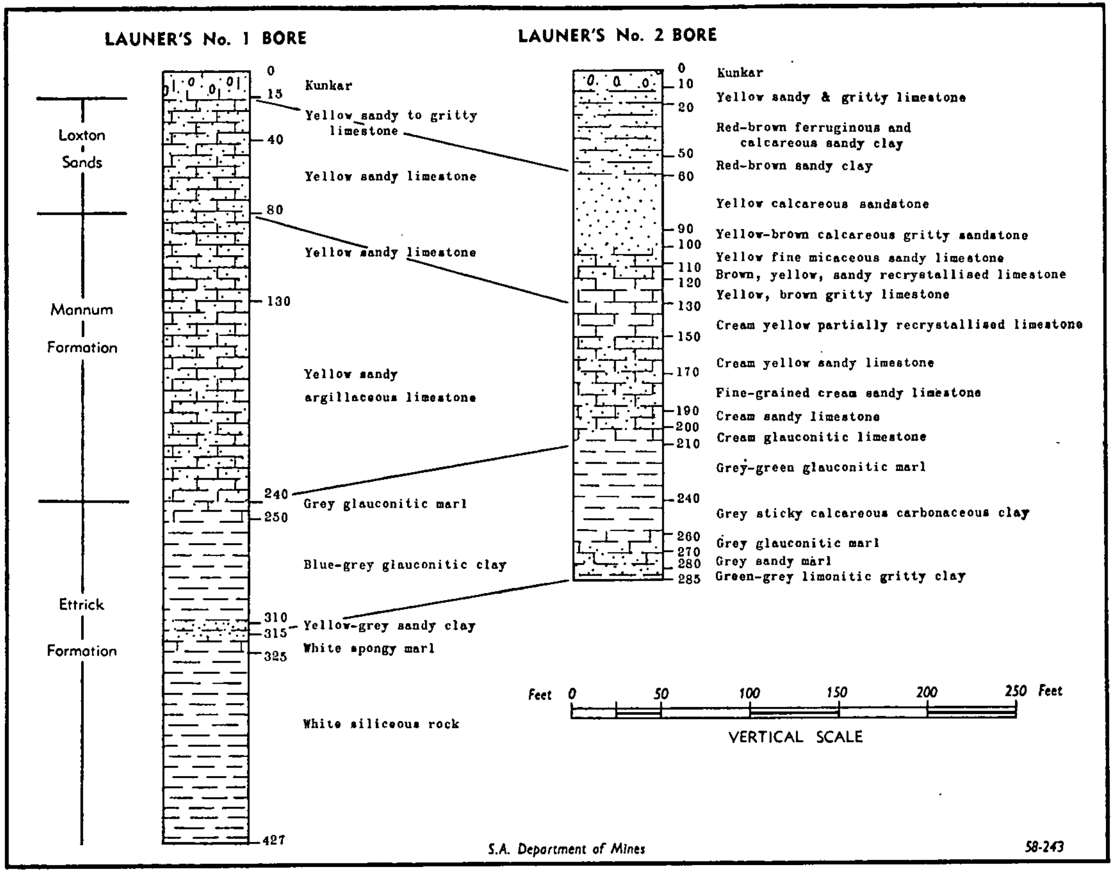

FIG. 12—LAUNER'S NO. 1 BORE AND LAUNER'S NO. 2 BORE
(Section 21, hundred of Ettrick)
Columnar sections

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 resampled 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 on to 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 Mannum, South Australia

In 1953, the Tertiary section was clearly exposed at Mannum 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. 130ft. (datum level—Port Adelaide L.W.O.S.T. = 100ft.) 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 5ft. 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 in figs. 17 and 18.

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

Stratigraphic Units

The general succession in the Mannum area is divided into four stratigraphical units, measured at the type section at the pumping station.

Formation (in downward sequence)	Thickness (ft.)
Loxton Sands	16
Morgan Limestone	8½
Finniss Clay	6
Mannum Formation	62+
	92½

FIG. 13—MANNUM FORMATION AS EXPOSED BEFORE LEVELLING
Mannum pumping station

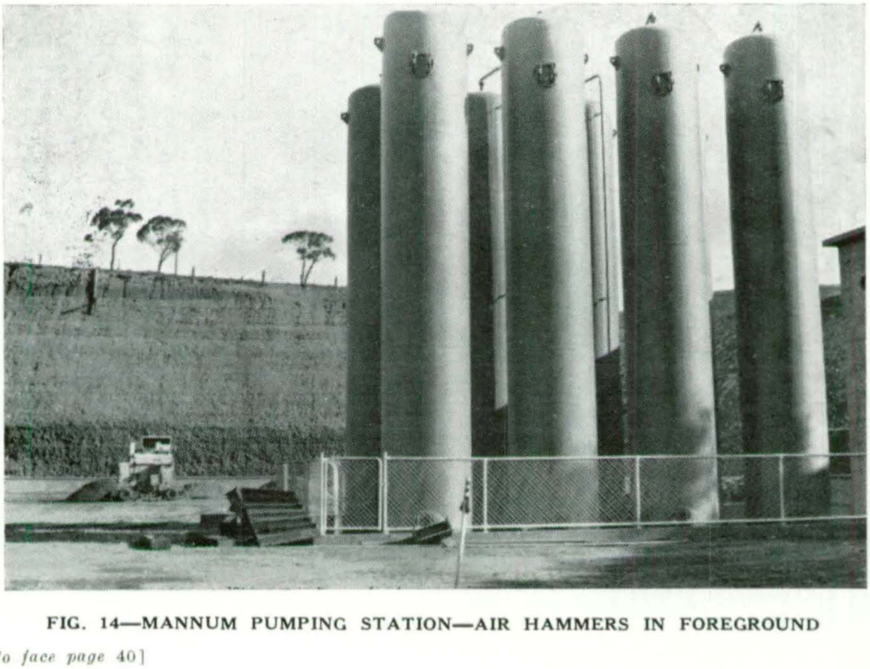

FIG. 14—MANNUM PUMPING STATION—AIR HAMMERS IN FOREGROUND

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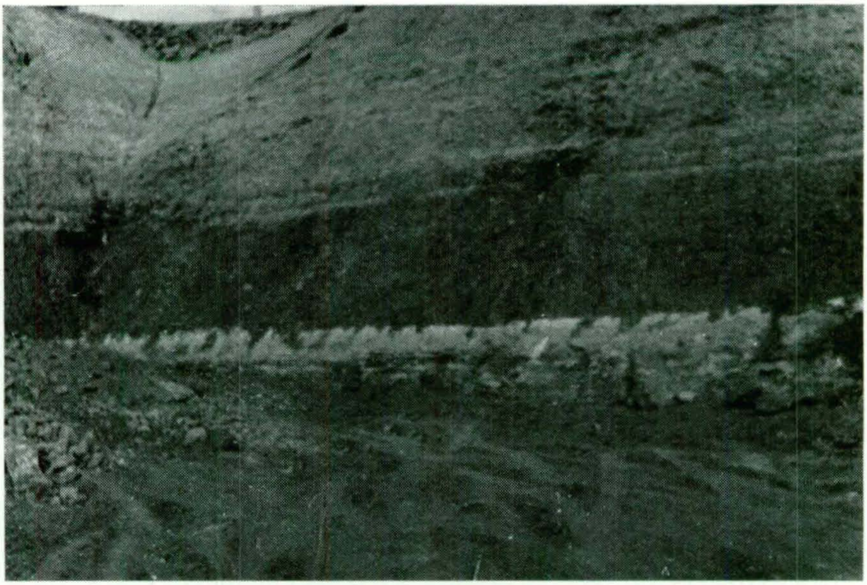

FIG. 15—UPPER SURFACE OF MANNUM FORMATION, SUCCEEDED BY FINNISS CLAY, MORGAN LIMESTONE, AND LOXTON SANDS
Top of cut behind tanks—Mannum pumping station

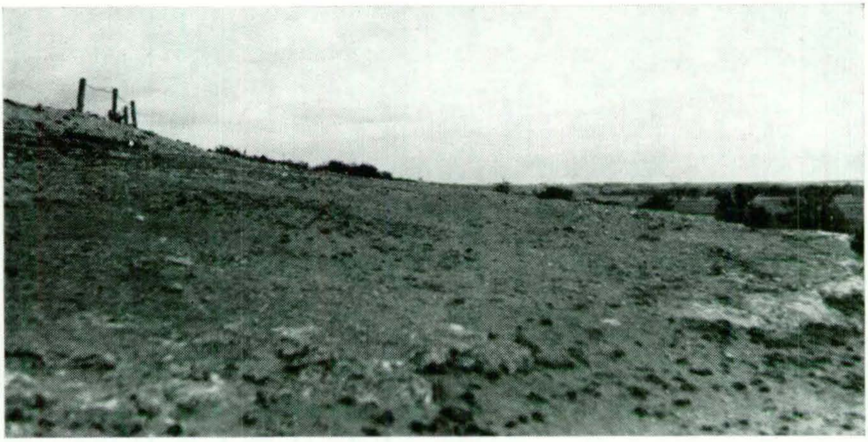

FIG. 16—UPPER SURFACE OF MANNUM FORMATION (FOREGROUND); SLOPE OF FINNISS CLAY; MORGAN LIMESTONE (UPPER LEFT AT FENCE)
Section 19, hundred of Younghusband

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 100ft. 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 a 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 Loxton 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 but conspicuous break in sedimentation above the Mannum Formation. At R.L. 174ft. 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 southeastern side of the river where it forms a conspicuous physiographical feature. About 200yds. beyond the Ponde 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 recognized 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.

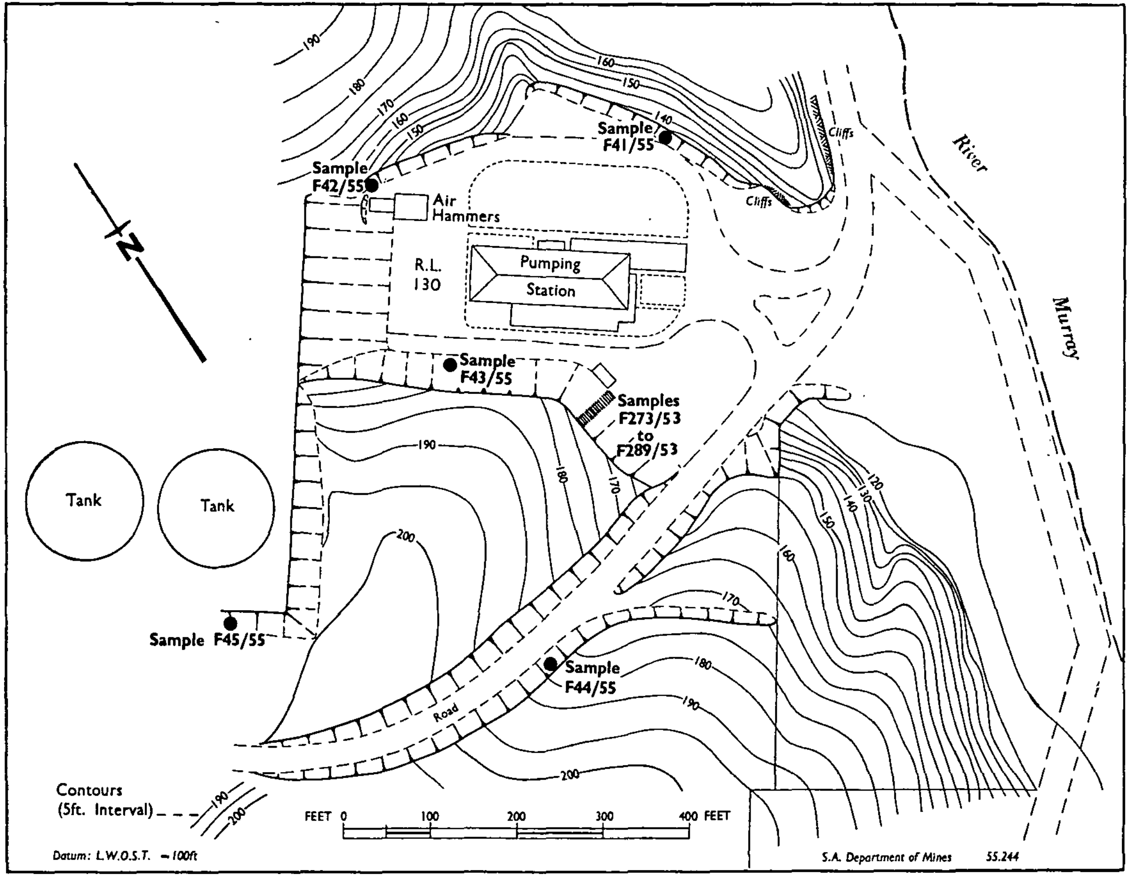

FIG. 17—CONTOUR AND SAMPLING PLAN
Mannum pumping station area

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. 112.4ft. upwards the member consists of 15ft. 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 10ft. of irregularly banded hard medium coarse-grained light yellow-brown calcareous

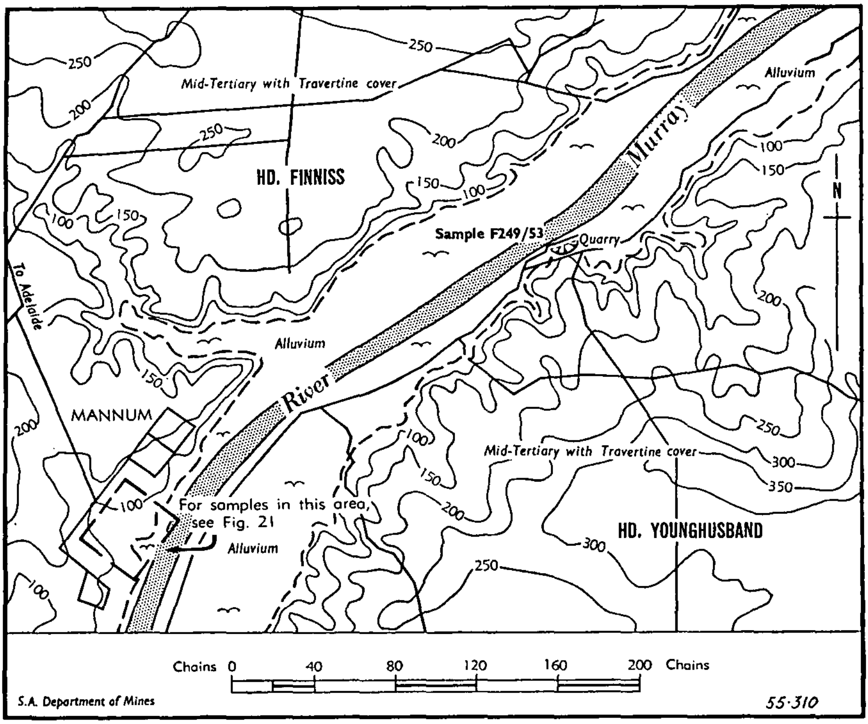

FIG. 18—PLAN SHOWING CONTOURS AND SAMPLE LOCATIONS
Mannum district

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 bryozoa 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 25ft., 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. 85.5ft., the underside of the floor for "A" suction sump, the same formation persisted.

Megafauna.—(Samples Nos. 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 *Caberea.*

Brachiopoda

Magadina compta (Sowerby).
Magadina lunata (Tate).
Murravia catinuliformis (Tate).

Echinoidea

Psammechinus woodsi (*Laube*).
Fibularia gregata Tate.
Lovenia "*forbesi* T. Woods".
Scutellina patella Tate.
Monostychia australis (*Laube*).
cf. *Echinolampas posterocrassus* Gregory.
Pygorhynchus vassali Wright.
Meoma 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 dorsata Tate.

Microfauna.—(Samples Nos. F273/53 to F278/53). The microfauna is characterized 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 lorifera, Gaudryina* (*Siphogaudryina*) *victoriana, Heronallenia lingulata, Planorbulinella inaequilateralis, Sigmoidella elegantissima. Textularia vertebralis* occurs in abundance in the lowest sample and *Operculina victoriensis* comes in some 6ft. from the top of the member. Other species less commonly appearing are listed in table II.

Upper Member

Lithology.—At R.L. 137ft. 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.

FIG. 19—THICK EXPOSURES OF MANNUM FORMATION
Marne River valley—View northeast

FIG. 20—MANNUM FORMATION TRANSGRESSIVE ON STEEPLY DIPPING KANMANTOO ROCKS
Marne River valley—Section 345, hundred of Ridley

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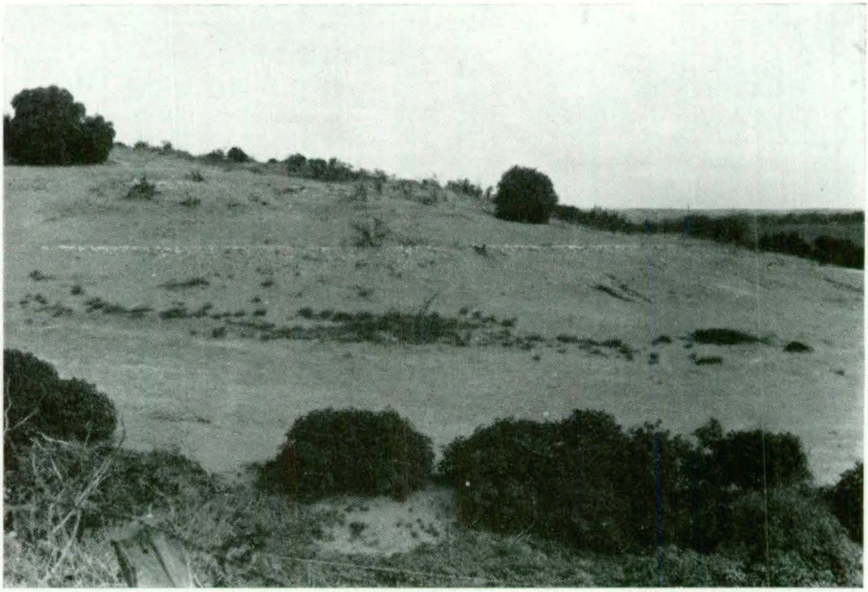

FIG. 21—LINE OF KUNKAR MARKING TOP OF MANNUM FORMATION
Section 19, hundred of Younghusband

FIG. 22—THIN TERTIARY COVER ON GRANITE
Section 156, hundred of Younghusband

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

Thickness.—The thickness of the member is 37 feet.

Megafauna.—Samples Nos. 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).
Eupatagus murrayanus Laube.
cf. *Echinobrissus vincentinus* Tate.

CEPHALOPODA

Aturia australis McCoy.
Eutrephoceras altifrons (Chapman).
Eutrephoceras geelongensis (Foord).

PELECYPODA

Nuculana woodsi (Tate).
Glycymeris sp. indet.
Chlamys sturtianus (Tate).
Serripecten yahliensis (T. Woods).
Spondylus pseudoradula McCoy.
Ostrea sp.

GASTROPODA

Cassis cf. *textilis* Tate.

Microfauna.—Samples Nos. 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. 1, *Dorothia parri, Elphidium crassatum, Elphidium crespinae, Guttulina irregularis, Notorotalia howchinii, Planorbulinella inaequilateralis, Rotalia* cf. *calcar, Sigmoidella elegantissima.* Species spasmodically occurring are listed in the palaeontological log, table XI.

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, hundred of 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.

FORAMINIFERA (SAMPLE No. F249/53).

Textularia vertebralis Cushman.
Textularia sagittula Defrance.
Textularia pseudogramen Chapman and Parr.
Frondicularia lorifera Chapman.
Sigmomorphina subregularis Howchin and Parr.
Sigmoidella elegantissima (Parker and Jones).
Elphidium crespinae Cushman.
Notorotalia howchini (Chapman, Parr and Collins).
Operculina victoriensis (Chapman and Parr).
Stomatorbina concentrica (Parker and Jones).
Eponides sp. indet.
Crespinella sp. nov.
Amphistegina sp. indet.
Globigerina sp.
Sherbornina cuneimarginata Wade (common).
Astrononion centroplax Carter.
Cibicides pseudoungerianus Cushman (abundant).
Cibicides refulgens Montfort.
Planorbulina mediterranensis d'Orbigny.
Planorbulinella plana (Heron-Allen and Earland).

The Mannum Formation is well developed in the southwest 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 Marne 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 1ft. thick and sandstone unconformably overlie steeply dipping rocks of the Kanmantoo Group. Maximum thickness of the sandstone is 25ft. It contains *Sherbornina atkinsoni*. Above the sandstone 5ft. to 10ft. 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. 174ft. at the type section at the pumping station are 15ft. of mottled light blue-grey, green and brown marine clays with large nodules of radiating gypsum about 6in. in diameter in a band about 2ft. 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. 176ft., 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 Nos. 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, Sigmoilopsis* 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 18in. 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 8ft. 6in. above the uppermost clay band in the Mannum section.

Fauna.—(Samples Nos. F288/53, 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 foulcheri (T. Woods).
Chlamys murrayana (Tate).

FORAMINIFERA

Textularia porrecta, Dorothia cf. *hayi, Dorothia karreri, Sigmoidella kagaensis, Parellina craticulatiformis, Elphidium macellum* var. *limbatum* and *Crespinella umbonifera* enter and the assemblage is dominated by *Operculina victoriensis, Amphistegina lessonii, 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 these 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 V. *Aturia australis* enters at the base of the upper member of the Mannum Formation and the two nautiloids occur in this member. *Chlamys murrayanus* 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 V

VERTICAL RANGE OF MEGAFOSSILS—MANNUM PUMPING STATION

	Mannum Formation		Finniss Clay	Morgan Limestone
	Lower	Upper		
Brachiopoda—				
Magadina compta (Sowerby)	———	———		
Magadina lunata (Tate)	———	———	- - - -	———
Magellania garibaldiana (Davidson)				———
Murravia catinuliformis (Tate)	———	———	- - - -	———
Echinoidea—				
cf. *Psammechinus* sp.	———			
Psammechinus woodsi (Laube)	———			
Fibularia gregata Tate	———	———	- - - -	———
Lovenia "forbesi T. Woods"	———	———		
Monostychia australis (Laube)	———	———		
cf. *Echinolampas posterocrassus* Gregory	———			
Eupatagus rotundus Duncan	———			
Eupatagus murrayensis Laube	———	———		
Meoma sp.	———			
cf. *Echinobrissus vincentinus* Tate		———		
Pygorhynchus vassali Wright	———			
Scutellina patella Tate	———	———		
Cephalopoda—				
Aturia australis McCoy		———		
Eutrephoceras altifrons (Chapman)		———		
Eutrephoceras geelongensis (Foord)		———		
Pelecypoda—				
Nuculana woodsi (Tate)		———		
Glycymeris sp. indet		———		
Lentipecten sp.	———			
Serripecten yahliensis (T. Woods)	———	———		
Chlamys foulcheri (T. Woods)	———	- - - - -	- - - -	———
Chlamys murrayana (Tate)		———		———
Chamys sturtiana (Tate)		———		
Spondylus pseudoradula McCoy		———		
Ostrea sp.	———	———		
Scaphopoda—				
Dentalium aratum Tate	———			
Gastropoda—				
Cypraea dorsata Tate	———			
Cassis cf. *textilis* Tate		———		

TABLE VI

Distribution Table—Foraminifera

Measured Section, Mannum Pumping Station, in Upward Sequence

	Mannum Formation												Finniss Clay			Morgan Limestone	Loxton Sands
	Lower Member						Upper Member										
Sample Number	273/53	274/53	275/53	276/53	277/53	278/53	279/53	280/53	281/53	282/53	283/53	284/53	285/53	286/53	287/53	288/53	289/53
R.L.	ft. in. 112 4 to 117 4	ft. in. 117 4 to 122 4	ft. in. 122 4 to 127 4	ft. in. 127 4 to 132 0	ft. in. 132 0 to 135 0	ft. in. 136 0 to 138 0	ft. in. 139 0 to 143 0	ft. in. 144 0 to 145 6	ft. in. 146 0 to 149 6	ft. in. 150 0 to 155 6	ft. in. 155 9 to 163 6	ft. in. 163 6 to 174 0	ft. in. 174 0 to 176 0	ft. in. 176 0 to 180 0	ft. in. 176 0 to 180 0	ft. in. 180 0 to 188 6	ft. in. 190 0
Textularia australis Parr	v	—	—	—	—	—	—	—	—	—	f	r					
Textularia pseudogramen Ch. and Parr	f	v	v	f	r	—	v	v	f	—	—	f					
Textularia vertebralis Cushman	a																
Gaudryina (Pseudogaudryina) crespinae C.	v	v	—	v	r	—	—	—	v	—	v	—	—	v			
Dorothia parri Cushman	r	—	v	f	v	—	—	—	c	v	r	f	—	v	v	f	—
Nodosaria spp.	v																
Lagena spp.	v	—	—	r	—	—	—	—	—	—	—	v					
Frondicularia lorifera Chapman	f	r	r	r	v	—	v	—	—	—	v						
Guttulina irregularis d'Orbigny	r	—	v	r	—	—	—	v	r	r	r	f					
Sigmomorphina subregularis H. and P.	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—
Reussella simplex Cushman	v	v	—	v	r	r	r	v	r	—	v						
Angulogerina australis (H. A. and E.)	r																
Trifarina bradyi Cushman	v																
Loxostomum sp.	v	—	v	—	—	v	—	v	—	—	—	f					
Cassidulina subglobosa Brady	f	r	—	v	v	—	—	r	r	v	r	r					
Pullenia quinqueloba (Reuss)	v	v	—	v													
Spirillina sp.	v	v	—	—	—	—	—	—	v	v	—	v					
"*Discorbis*" *boueanus* (d'Orbigny)	f	f	—	c	—	v	—	—	v								
Valvulineria sp.	f	r	—	v	v	—	—	—	—	—	—	—	—	v			
Eponides lornensis Finlay	r	v	—	v	r	—	—	—	—	—	v	v					
Baggina philippinensis (Cushman)	f	v	r	r													
Siphonina australis Cushman	c	v	r	f	r	—	r	—	r	r	v	r					
Cibicides lobatulus W. and J.	f	r	v	v	v	—	v	v	r	—	—	r	—	—	—	v	—
Cibicides pseudoungerianus Cushman	a	a	c	a	c	c	c	f	a	a	c	c	c	f	r	f	—
Cibicides refulgens Montfort	c	f	c	f	r	—	r	f	f	f	—	c					
Cibicides brevoralis Carter	r	—	v														
Planulina spp.	f	v	—	v	—	—	—	—	—	v							
Anomalina sp. 1	f	f	—	—	—	—	—	v									
Globigerina bulloides d'Orbigny	v	v	—	—	—	—	—	—	—	—	—	c	—				
Planorbulina mediterranensis d'Orbigny	r	—	v	f													
Planorbulinella inaequilateralis (H. A. and E.)	r	v	—	—	v	v	v	r	v	v	—	v					
Astrononion centroplax Carter	f	f	r	f	v	r	f	—	v	c	—	v					
Astrononion australe Cushman and Edwards	r																
Elphidium sp.	v	—	—	—	—	—	—	—	v	—	—	c					
Sherbornina cuneimarginata Wade	r	r	r	c	v	—	v	—	r								
Notorotalia howchini (C. P. and C.)	a	f	r	c	c	r	r	f	r	—	a						
Notorotalia crassimura Carter	v	r	r	r	r	v	—	—	r								
Heronallenia lingulata (Burrows and Holland)	r																
Heronallenia parri Carter	r	—	—	—	—	—	—	—	—	—	—	v					
Ceratobulimina dehiscens H. A. and E.	v	v															
Rotalia cf. *calcar* d'Orbigny	v	—	v	c	—	—	v	r	a	—	—	v					
Calcarina mackayi (Karrer)	r	v	f	r	f	c	a										
"*Crespinella*" sp. nov.	f	r	r	c	c	r	f	—	v	c	c	—	—	—	—	r	—
Gaudryina (Siphogaudryina) victoriana C.	—	r	r	c	f	v	v	v									
Bolivinella folia (P. and J.)	—	v	—	—	—	—	—	—	v								
Guttulina lactea (W. and J.)	—	v	v	f	—	—	—	v	—	—	v						
Guttulina regina B. P. and J.	—	v	—	v													
Cibicidella variabilis d'Orbigny	—	v	v	r													
Nonion victoriensis Cushman	—	v	—	—	—	—	—	—	—	—	v	v					
Elphidium crassatum Cushman	—	v	r	f	r	r	—	v	r	—	v						
Rotalia beccarii (Linne)	—	v	—	v	—	—	—	—	c								
Stomatorbina concentrica (Parker and Jones)			v	v	v	v	v	—	—	—	—	—	—	v			
Conorbella patelliformis (Brady)			v	f	r	v	v	—	r	r	—	r					

TABLE VI—*continued*

DISTRIBUTION TABLE—FORAMINIFERA—*continued*

Measured Section, Mannum Pumping Station, in Upward Sequence—continued

	MANNUM FORMATION												FINNISS CLAY			MORGAN LIME-STONE	LOXTON SANDS
	LOWER MEMBER						UPPER MEMBER										
Sample Number ..	273/53	274/53	275/53	276/53	277/53	278/53	279/53	280/53	281/53	282/53	283/53	284/53	285/53	286/53	287/53	288/53	289/53
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
R.L.	112 4 to 117 4	117 4 to 122 4	122 4 to 127 4	127 4 to 132 0	132 0 to 135 0	136 0 to 138 0	139 0 to 143 0	144 0 to 145 6	146 0 to 149 6	150 0 to 155 6	155 9 to 163 6	163 6 to 174 0	174 0 to 176 0	176 0 to 180 0	176 0 to 180 0	180 0 to 188 6	190 0
Glabratella cruciformis (Howchin)			v	f													
Planulinoides biconcavus (Jones and Parker) ..			v	v	—	—	—	—	v	—	—	—	—	—	—	v	—
Valvulineria cf. *porifera* (Parr)			v														
Spirillina unilatera Chapman			r	—	—	—	—	—	v	v	—	v					
Globigerina sp.			v	r	—	—	—	f	v	v							
Elphidium crespinae Cushman			f	r	—	—	—	r	r	r	c	f					
Elphidium parri Cushman			r	—	r	—	v	v	—	—	—	r					
Nodosaria vertebralis Batsch				v	—	—	—	—	—	—	v	v					
Palmula sp.				v													
Sigmoidella kagaensis C. and O.				v	v	—	—	—	—	—	r						
Reussella spinulosa (Reuss)				f	v	v	—	f	a								
Angulogerina spp.				r	—	—	—	—	—	—	—	r					
Buliminella madagascariensis var. *spicata* Cushman				v	—	v	—	—	—	—	—	v					
Bolivina crespinae Cushman				v													
Bolivina hebes var. *victoriensis* Cushman				v													
Bolivinella cf. *australis* Cushman				v	—	—	—	—	v	—	—	v					
Bolivinella folia var. *ornata* Cushman				v													
Discorbis floridana Cushman				v	—	—	—	v	—	—	—	r					
Calcarina verriculata (Howchin and Parr).....				r	—	r	r	f	f	—	—	r	v	v	—	c	—
Carpenteria rotaliformis Chapman and Crespin				v													
Textularia cf. *sagittula* Defrance					v	—	—	v	—	—	—	f	—	—	—	r	—
Quinqueloculina spp.						v	—	v	r	—	—	—	v	v			
Pyrgo sp.					v	—	—	—	—	—	v						
Sigmoilina sp.					v	—	v	—	—	—	—	—	v				
Buliminella elegantissima d'Orbigny					v												
Bolivina victoriana Cushman					v	—	—	v	—	—	v	v					
Rotorbinella cycloclypeus (Howchin and Parr)..					r	v	v	—	c	v	v						
Cibicides concentricus Cushman.............					v	—	—	v	v	—	—	f					
Cibicides floridanus Cushman					f												
Operculina victoriensis Chapman and Parr					r	f	f	a	a	a	a	c	r	c	a	a	
Bolivina dilatata Reuss						v	—	—	—	—	—	r					
Annulopatellina annularis (P. and J.)						v											
Discorbis mira Cushman						v	—	v									
Globigerina trilocularis d'Orbigny						r	—	—	—	r	v						
Quinqueloculina seminulum (Linnè)							v	—	—	r	v	r					
Triloculina trigonula Lamarck							v	—	—	—	—	—	v	v			
Austrotrillina howchini (Schlumberger)							r	v	r	f	a	—	—	v			
Planorbulinella plana (Heron-Allen and Earland)							r	f									
Marginopora vertebralis Blainville								v									
Guttulina problema d'Orbigny								v	—	—	v	v					
Bolivina cf. *robusta* Brady.................								v	—	—	—	v					
Bolivina scalprata var. *retiformis* (Cushman) ..								v									
Eponides spp..............................								v									
Parvicarinina altocamerata (Heron-Allen and Earland)								v	—	—	—	v					
Cancris ovatus Cushman and Todd								v									
Dyocibicides biserialis C. and W.								f									
Acervulina inhaerens Schultze								r									
Triloculina tricarinata d'Orbigny									v								
Pyrgo sarsi (Schlumberger)									v								
Biloculinella globula (Bornemann)									v								
Globigerina sp.									v	v							

TABLE VI—*continued*

DISTRIBUTION TABLE—FORAMINIFERA—*continued*

Measured Section, Mannum Pumping Station, in Upward Sequence—continued

	Mannum Formation												Finniss Clay			Morgan Limestone	Loxton Sands
	Lower Member						Upper Member										
Sample Number ..	273/53	274/53	275/53	276/53	277/53	278/53	279/53	280/53	281/53	282/53	283/53	284/53	285/53	286/53	287/53	288/53	289/53
R.L.	ft. in. 112 4 to 117 4	ft. in. 117 4 to 122 4	ft. in. 122 4 to 127 4	ft. in. 127 4 to 132 0	ft. in. 132 0 to 135 0	ft. in. 136 0 to 138 0	ft. in. 139 0 to 143 0	ft. in. 144 0 to 145 6	ft. in. 146 0 to 149 6	ft. in. 150 0 to 155 6	ft. in. 155 9 to 163 6	ft. in. 163 6 to 174 0	ft. in. 174 0 to 176 0	ft. in. 176 0 to 180 0	ft. in. 176 0 to 180 0	ft. in. 180 0 to 188 6	ft. in. 190 0 to
Elphidium chapmani Cushman									r	r	c	—	v	v			
Quinqueloculina vulgaris d'Orbigny										r	r	—	—	—	f		
Textularia corrugata (Heron-Allen and Earland)											r						
Pyrulina fusiformis Roemer											v						
Gypsina howchini Chapman................											v	—	—	—	v	v	
Lagena acuticostata Reuss												v					
Lagenonodosaria scalaris (Batsch)												v					
Nodosaria comata (Batsch)												v					
Bolivina tortuosa Brady												v					
Globigerina angustiumbilicata Bolli												v					
Cancris intermedius C. and T.												f					
Cibicides subhaidingerii Parr													v	—	—	v	
Amphistegina lessoni d'Orbigny													v	v	a	a	
Clavinulinoides sp.														v			
Sigmoilopsis cf. *chapmani* (Cushman)														v			
Parellina craticulatiformis Wade............																f	
Crespinella umbonifera Howchin and Parr																v	

v = very rare (1–2)
r = rare (3–5)
f = frequent
c = common (11–25)
a = abundant (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 River Murray 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 sequence 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 gambierensis*	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 5ft. 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 No.	Description
3	F93/56	Hard limestone with *Panopea.*
	F92/56	Top of limestone.
4	F91/56	Bottom of 10ft. limestone bed.
5	F90/56	Clayey sand with *Cellepora*—north side of gully.
	F89/56	South side of gully.
6	F88/56	Top of marl lens.
	F87/56	15ft. from bottom of marl lens.
	F86/56	10ft. from bottom of marl lens.
7	3in. shell sand	Not observed.

Tate's Bed	Sample No.	Description
8	F85/56	5ft. from bottom of marl lens.
9	F84/56	Hard band at top of lower member.
	F83/56	Third marly band.
	F82/56	Third *Cellepora* band.
	F81/56	Second marly band.
	F80/56	Second *Cellepora* band.
	F79/56	First marly band.
	F78/56	First *Cellepora* band.
	F77/56	10ft. above river level.
	F76/56	5ft. above river level.
	Base of section.	

Morgan Limestone

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

The lower member, 45ft. thick (Tate's bed 9), is a fairly uniform soft bryozoal limestone, cavernous near the river and becoming banded in the upper 30ft. The hard bands each about 5ft. thick consist of masses of *Cellepora* 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, Gypsina howchini, Parellina craticulatiformis, Globigerinoides bisphaerica* 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 300ft., with a maximum thickness of 22ft. (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 morundiana, Leda obolella, Leda woodsii, Cucullaea corioensis, Dimya dissimilis, Myadora tenuilirata, Carditella polita, Lucina fabuloides, Antigona dimorphophylla, Verticordia rhomboidea, Zenatiopsis angustata, Capistrocardia fragilis, Solecurtus ellipticus, Corbula ephamilla.

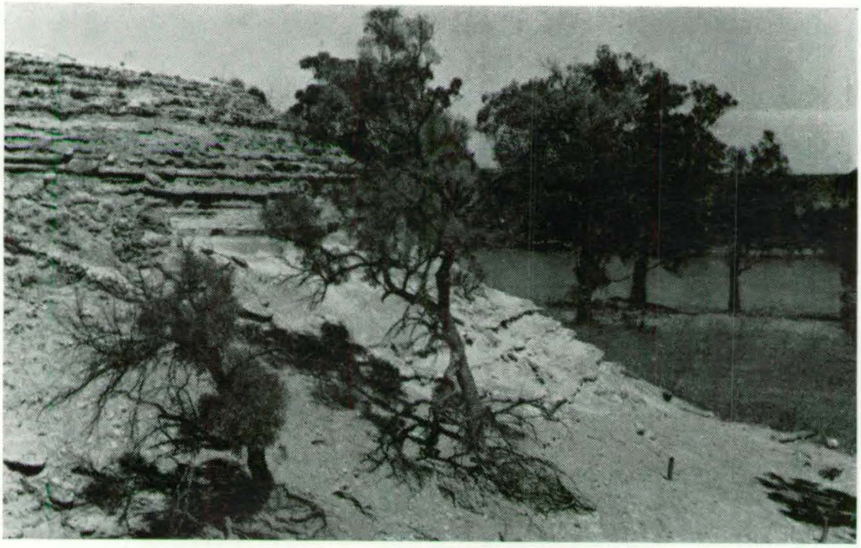

FIG. 23—MORGAN LIMESTONE AND CADELL MARL LENS—TYPE SECTION
Section G. hundred of Cadell

FIG. 24—MORGAN LIMESTONE
Morgan railway station yard

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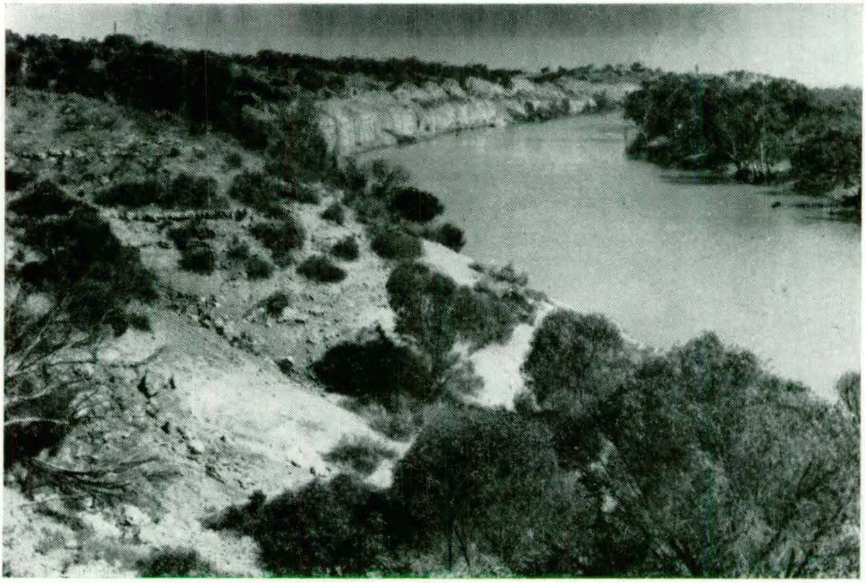

FIG. 25—RIVER MURRAY—IN MORGAN LIMESTONE
East of Waikerie

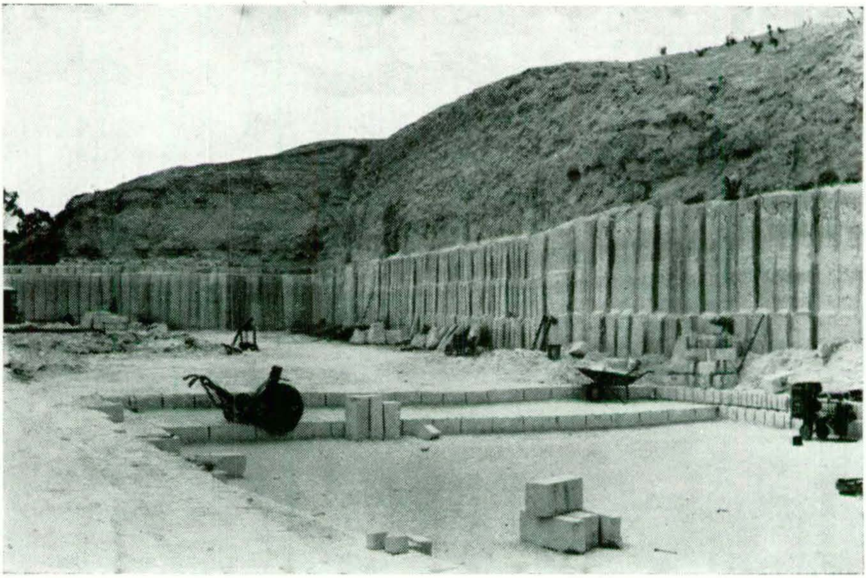

FIG. 26—QUARRY IN MORGAN LIMESTONE
Overland Corner

Scaphopoda

Dentalium aratum, Entalis subfissura.

Gastropoda

Turritella murrayana, Turritella acricula, Triton radialis, Triton tortirostris, Murex basicinctus, Murex pachystirus, Trophon mangelioides, Nassa tatei, Fasciolaria exilis, Fasciolaria decipiens, Fusus dictyotis, Fusus simulans, Fusus styliformis, Fusus spiniferus, Peristernia murrayana, Peristernia morundiana.

TABLE VII

Distribution of Foraminifera

Morgan Type Section in Upward Sequence

	Morgan Limestone Lower Member						Cadell Marl Lens				Morgan Limestone Upper Member			
Sample No.	F76/56	F77/56	F58/56	F79/56	F81/56	F83/56	F85/56	F86/56	F87/56	F88/56	F89/56	F91/56	F92/56	F93/56
Textularia pseudogramen C and P	r	—	—	—	—	v	—	r	v	—	—	—	—	v
Textularia corrugata H. A. and E.	r	r	—	v	—	—	—	—	—	—	—	—	—	—
Textularia spp.	r	—	—	—	r	f	v	—	v	—	v	—	—	—
Dorothia parri Cushman	r	c	—	r	r	f	r	—	—	—	—	—	—	v
Dorothia spp.	v	—	—	—	—	—	—	f	c	c	c	—	v	—
Clavulinoides victoriensis Cushman	r	r	—	—	c	c	a	—	—	—	—	—	—	—
Sigmoilina sp.	v	—	—	—	—	—	—	—	—	—	—	—	—	—
Lagenonodosaria scalaris (Batsch)	r	—	—	v	—	—	r	—	—	—	—	v	—	—
Tubulogenerina mooraboolensis (H. A. and E.)	r	—	—	v	—	—	—	—	—	—	—	—	—	—
Uvigerina spp.	v	—	—	—	—	—	—	—	—	—	f	a	c	—
Ehrenbergina sp.	v	—	—	—	f	—	—	—	—	—	—	—	—	—
Cibicides subhaidingerii Parr	r	—	—	—	r	f	—	v	—	f	—	—	—	—
Cancris ovatus Cushman & Todd	v	—	—	—	—	—	v	—	—	—	—	v	—	—
Cibicides lobatulus (Walker and Jacob)	f	—	—	—	—	v	v	—	—	—	—	—	—	—
Cibicides pseudoungerianus (Cushman)	v	—	v	c	a	v	f	v	—	—	c	f	f	f
Globigerina sp.	v	—	—	—	—	—	—	—	—	—	—	—	—	—
Globigerinoides bisphaerica Todd	v	—	—	v	v	r	—	r	—	—	—	f	—	—
Planorbulinella plana (H. A. and E.)	v	—	—	—	—	—	—	—	—	—	—	—	—	—
Gypsina globulus (Reuss)	v	f	—	—	v	f	r	—	—	—	—	—	—	—
Gypsina howchini Chapman	f	c	—	v	v	f	f	c	r	v	—	—	v	—
Nonion victoriense Cushman	v	—	—	—	—	—	—	v	—	—	f	c	v	—
Parellina craticulatiformis Wade	c	c	—	—	—	—	f	—	—	—	—	—	—	—
Amphistegina lessonii d'Orbigny	f	f	—	—	—	—	v	—	—	—	—	—	—	—
Operculina victoriensis Chapman & Parr	f	f	v	—	v	f	f	v	—	—	v	—	—	—
Gaudryina (Pseudogaudryina) crespinae Cushman	—	v	—	—	—	—	—	—	—	—	—	—	—	—
Globulina gibba d'Orbigny	—	v	—	—	—	—	—	—	—	—	—	—	—	—

Carpenteria proteiformis Goës	—	v	—	—	—	c								
Quinqueloculina vulgaris d'Orbigny			v	—	c	f	a	a	a	r				
Sigmoilopsis cf. *flintii* (Cushman)			v	—	c									
Austrotrillina howchini (Schlumberger)			v											
Cibicides subhaidingerii Parr			v	—	—	—	—	—	v	—	cf			
Siphonina australis Cushman			v	v	r	r	v	v	v	—	v	—	f	v
Anomalinoides procolligera Carter			v	—	—	v								
Anomalina sp.			v	v										
Uvigerina cf. *tenuistriata* Reuss				v										
Bolivina spp.				r	—	—	r	—	—	—	r	r		
Sphaeroidina bulloides d'Orbigny				v	c	—	—	v	v	—	—	f		
Reussella decorata H. A. and E.				v										
Cibicides refulgens Montfort				f	v	—	—	—	—	—	—	v	r	v
Glabratella globigeriniformis (H. A. and E.)				v										
Eponides repandus (F. and M.)				v										
Globigerinoides triloba (Reuss)				r	v	r	v	r	v	—	—	f		
Globigerina bulloides d'Orbigny				v	v	r	—	—	—	—	—	—	v	—
Elphidium howchini Cushman				f	—	—	—	—	—	—	—	—	—	v
Elphidium parri Cushman				v	—	—	—	—	—	—	—	—	v	—
Ammosphaeroidina sphaeroidiniformis (Brady)					r	f	v	v						
Gaudryina sp. cf. *collinsi* Cushman					r	f								
Triloculina trigonula (Lamarck)					v	r	r	r	r	v	v			
Quinqueloculina cuvieriana d'Orbigny					c	—	c	v						
Pyrgo sarsi (Schlumberger)					c									
Cornuspira involvens Reuss					r	v	—	—	v					
Cornuspira tasmanica Parr					r	—	v	v	v					
Pyrulina cylindroides (Roemer)					v	—	—	v						
Sigmoidella kagaensis Cush. and Ozawa					v									
Cassidulina spp.					v	—	—	—	—	—	r			
Reussella spinulosa (Reuss)					f	—	r	—	—	—	f	v	r	—
Pullenia quinqueloba (Reuss)					v									
Cibicides concentricus (Cushman)					v	—	—	—	—	—	c	r	r	—
Cibicidella variabilis (d'Orbigny)					v									
Liebusella rudis (Costa)						r								
Schenckiella howchini (Cushman)						v								
Pyrgo sp.						v	—	v	v	v				
Sigmoilina sp.						x	v	—	f					
Quinqueloculina sp.						x	v	v						
Articulina victoriana Cushman						x	v	v						
Triloculina tricarinata d'Orbigny						x	—	v						
Cornuspira sp.						x	r							

TABLE VII—*continued*

DISTRIBUTION OF FORAMINIFERA—*continued*

Morgan Type Section in Upward Sequence—continued

	Morgan Limestone Lower Member						Cadell Marl Lens				Morgan Limestone Upper Member			
Sample No.	F76/56	F77/56	F58/56	F79/56	F81/56	F83/56	F85/56	F86/56	F87/56	F88/56	F89/56	F91/56	F92/56	F93/56
Cornuspiroides expansus (Chapman)						x	—	—	r					
Dyocibicides biserialis Cushman and Valentine						x	r							
Textularia cf. *sagittula* Defrance							v							
Siphotextularia sp.							v							
Quinqueloculina polygona d'Orbigny							r							
Quinqueloculina berthelotiana d'Orbigny							r							
Spiroculina sp.							f							
Biloculinella globula (Bornemann)							f							
Miliolinella circularis (Bornemann)							v							
Dentalina sp.							v	—	v					
Fissurina spp.							r							
Parafissurina sp.							v							
Sigmomorphina subregularis Howchin and Parr							v							
Bolivina sublobata Cushman							r	v	—	—	r	—	c	—
Planorbulina sp.							v							
Elphidium chapmani Cushman							v							
Martinotiella bradyana Cushman								v	r					
Triloculina sp.								v						
Massilina cf. *australis* Cushman								f						
Spiroloculina antillarum d'Orbigny								v	r					
Massilina sp.								v	v					
Nodobaculariella sp.								v	v					
Marginopora vertebralis Blainville								v	v	—	—	—	—	v
Plectofrondicularia sp.								r						
Guttulina problema d'Orbigny								v						
Ramulina globulifera Brady								v						

Cancris intermedius Cushman and Todd	—	—	—	—	—	—	—	r	r	—	r	r	v	—
Calcarina verriculata (Howchin and Parr)	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Guttulina regina (B. P. and J.)	—	—	—	—	—	—	—	—	v	—	r	—	—	—
Virgulina sp.	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Astrononion australe Cushman & Edwards	—	—	—	—	—	—	—	—	r	—	—	—	v	—
Globigerinoides rubra (d'Orbigny)	—	—	—	—	—	—	—	—	v	—	—	—	—	—
Textularia vertebralis Cushman	—	—	—	—	—	—	—	—	—	r	—	—	—	—
Anomalina glabrata Cushman	—	—	—	—	—	—	—	—	—	—	r	v	r	—
Elphidium advenum Cushman	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Pullenia bulloides d'Orbigny	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Cassidulina subglobosa Brady	—	—	—	—	—	—	—	—	—	—	r	r	r	f
Pyrulina fusiformis (Roemer)	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Marginulina sp.	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Lagena spp.	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Trifarina bradyi Cushman	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Guttulina irregularis (d'Orbigny)	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Discorbis cf. *floridana* Cushman	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Globigerinoides transitoria Blow	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Gavelinopsis sp.	—	—	—	—	—	—	—	—	—	—	—	—	v	—

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

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 54ft. 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 Brownlow—Truro Military Sheet

Remnants of transgressive mid-Tertiary limestones occur at 413ft. 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 Creek, section 229E, hundred of Anna, and on section 26, hundred of Brownlow.

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 Creek, 1½ miles north-northwest of Stonefield, 13ft. 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 Precambrian 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, 5½ miles northerly from Stonefield on section 26, hundred of Brownlow, 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

Half a mile to the north of Levi 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 15ft. from the base, a pelecypod band with *Ostrea, Chlamys murrayana* (Tate) and *Antigona* (*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:

Sample No. F105/55—From south side of ridge about 100yds. 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. *Psammachinus* sp.
Serripecten yahliensis (T. Woods).

Sample No. F106/55—Southern end of ridge about 15ft. from base. Rubbly *Turritella* limestone, with the following:

BRYOZOA

Cellepora gambierensis T. Woods.

PELECYPODA

Cucullaea corioensis McCoy.

Glycymeris subtrigonalis (Tate).

Eotrigonia semiundulata (McCoy).

Spondylus pseudoradula McCoy.

Serripecten yahliensis (McCoy).

Myadora sp.

Modiolus sp.

Pleuromeris (?) *delicatula* (Tate).

Antigona (*Proxichione*) indet. but probably *dimorphophylla* (Tate).

Venerid indet.

Tellina sp. indet. cf. *albinelloides* Tate.

GASTROPODA

Turritella sp.

Sample No. F107/55—Sandy limestone at top of section.

FORAMINIFERA

Quinqueloculina vulgaris d'Orbigny.

Quinqueloculina sp.

Triloculina sp.

Sigmomorphina flintii (Cushman).

Sigmoidella elegantissima (Parker and Jones).

Nonion victoriense Cushman.

Cibicides pseudoungerianus (Cushman).

Calcarina verriculata (Howchin and Parr).

Notorotalia howchini (Chapman, Parr and Collins).

ECHINOIDEA

Monostychia australis (Laube).

BRACHIOPODA

Magellania divaricata (Tate).

PELECYPODA

Serripecten yahliensis (T. Woods).

GASTROPODA

Turritella sp.

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

	Sample No.	Lithology	Thickness ft.	in.
Top	F113/55	Calcareous sandstone	1	6
	F112/55	Yellow ferruginous limestone with abundant *Turritella*	2	0
	F111/55	Sandy limestone	1	0
	F110/55	Yellow ferruginous limestone with *Turritella*	2	0
	F109/55	Yellow rubbly calcareous sandstone with echinoids ..	4	0
Base	F108/55	Limestone with abundant large pelecypods, *Ostrea, Chlamys, Spondylus*	3	0
			13	6

Sample No. F108/55—Pelecypod bed, base of section, 3ft. 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.

Sample No. F109/55—Yellow rubbly calcareous sandstone 4ft. thick with echinoids.

BRYOZOA

Cellepora sp.

ECHINOIDEA

Lovenia "forbesi T. Woods".
Monostychia australis (Laube).
Eupatagus murrayensis Laube.
Psammechinus woodsi Laube.

PELECYPODA

Chlamys cf. *sturtiana* (Tate).

Sample No. F110/55—Yellow ferruginous limestone—*Turritella* band—2ft. thick.

PELECYPODA

Glycymeris sp.
Antigona (*Proxichione*) *dimorphophylla* (Tate).

GASTROPODA

Turritella sp.
Turritella murrayana Tate.

Sample No. F111/55—Sandy band 1ft. thick.

FORAMINIFERA

Quinqueloculina vulgaris d'Orbigny.
Dorothia parri Cushman.
***Elphidium* sp.**
- ***Operculina victoriensis* Chapman and Parr.**
Cibicides cf. *refulgens* Montfort.
Cibicides pseudoungerianus (Cushman).
Notorotalia howchini (Chapman, Parr and Collins).
Calcarina verriculata (Howchin and Parr).

BRYOZOA

Cellepora sp.
Others, not determined.

ECHINOIDEA

Psammechinus woodsi Laube.

PELECYPODA

Chlamys sp.

GASTROPODA

Turritella murrayana Tate.

Chlamys murrayana (Tate).
Turritella murrayana Tate.

Sample No. F112/55—Yellow limestone with *Turritella*—2ft. thick.

Sample No. F113/55—Calcareous sandstone 18in. 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.

Sample No. F264/53—

FORAMINIFERA

Quinqueloculina cf. *linneana* d'Orbigny.
Q. vulgaris d'Orbigny.
Q. lamarckiana d'Orbigny.
Triloculina trigonula Lamarck.
Sigmoilopsis cf. *flintii* (Cushman).
Siphonaperta 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 crespinae Cushman.
Elphidium parri Cushman.
Cibicides pseudoungerianus (Cushman).
Amphistegina lessoni d'Orbigny.
Calcarina verriculata (Howchin and Parr).
Notorotalia howchini (Chapman, Parr and Collins).

PELECYPODA

Ostrea sp.
Pinna sp.
venerid indet.

GASTROPODA

Turritella murrayana Tate.
Turritella sp.
Cypraea 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, hundred of Pyap, 2½ miles downstream from Loxton, first described by Howchin (1929, p. 168, pl. 7, fig. 1), measured and sampled by J. Spence of Frome-Broken Hill Co. Pty. Ltd. in 1957 as follows:

THICKNESS		LITHOLOGY	Formation
ft.	in.		
17	0	Kunkar and reddish aeolian sand	—
35	0	False-bedded coarse sand and gravel with fine sand...	Loxton Sands
47	0	Unconsolidated, yellow, micaceous fine-grained sand a few pelecypods in the lowest 1 ft.	Loxton Sands
1	9	Buff fine calcareous sandstone with *Cellepora*	Bookpurnong Beds
10	0	Yellow-brown ochreous incoherent shell bed with glauconite	Bookpurnong Beds

The bed continues below the River Murray.

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

The uppermost 1ft. 9in. contains, in addition to *Cellepora, Hinnites corioensis, Serripecten yahliensis, Corbula ephamilla* and *Turritella* (s.1). 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 rugosa, Discorbis dimidiatus, Discorbis globularis, Baggina philippinensis, Cancris intermedius, Cibicides pseudoungerianus, Elphidium macellum, Operculina victoriensis.*

The 10ft. shell bed is marly and glauconitic, rich in foraminifera, mostly miliolidae, and chalky fragile pelecypods. The foraminiferal assemblage contains *Textularia corrugata, Gaudryina* cf. *collinsi, Dorothia minima, Siphonaperta* spp., *Siphonaperta ammophila, Sigmoilopsis lapidigera, Cornuspiroides expansus, 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* (*Scaeoleda*) *woodsi, Nuculana* (*Scaeoleda*) *verconis, Ledella praelonga, Ledella* sp., *Poroleda* sp., *Cucullaea corioensis, Limopsis* cf. *morningtonensis, Hinnites corioensis, Serripecten yahliensis, Propeamussium atkinsoni, Crenella* sp., *Anomia sella, Myadora* cf. *corrugata, Cuspidaria subrostrata, Eucrassatella kingicoloides, Cuna polita, Cyclocardia* (*Scalaricardita*) *subcompacta, Pleuromeris pecten, Pleuromeris subpecten, Nemocardium* (*Pratulum*) sp., *Antigona dimorphophylla, Tawera dictua, Gari hamiltonensis, Gari aequalis, Panopaea* 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. D. O'Driscoll and the writer on 6th August, 1958. River level was then about 2ft. above normal.

THICKNESS	LITHOLOGY	FORMATION
ft. 10–15	Yellow, micaceous sands	Loxton Sands
11	Green-grey and yellow sandy marl	Bookpurnong Beds
3	Yellow glauconitic marl	Bookpurnong Beds

The lowest 3ft. contain abundant *Marginopora vertebralis, Operculina victoriensis* and *Ditrupa.*

Standard Subsurface Section—Drainage Shaft No. 18, Loxton

The drainage bore sunk to a depth of 295ft. from the bottom of the Engineering and Water Supply Department shaft No. 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 12ft. of the Bookpurnong Beds are exposed 2½ 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—

Morgan Limestone (*Lower Miocene*)

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

Between 182ft. and 196ft. 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.

Pata Limestone

The Pata Limestone occurs between 126ft. and 182ft. It is lithologically similar to the Morgan Limestone, and is typically a pale-grey partially recrystallized

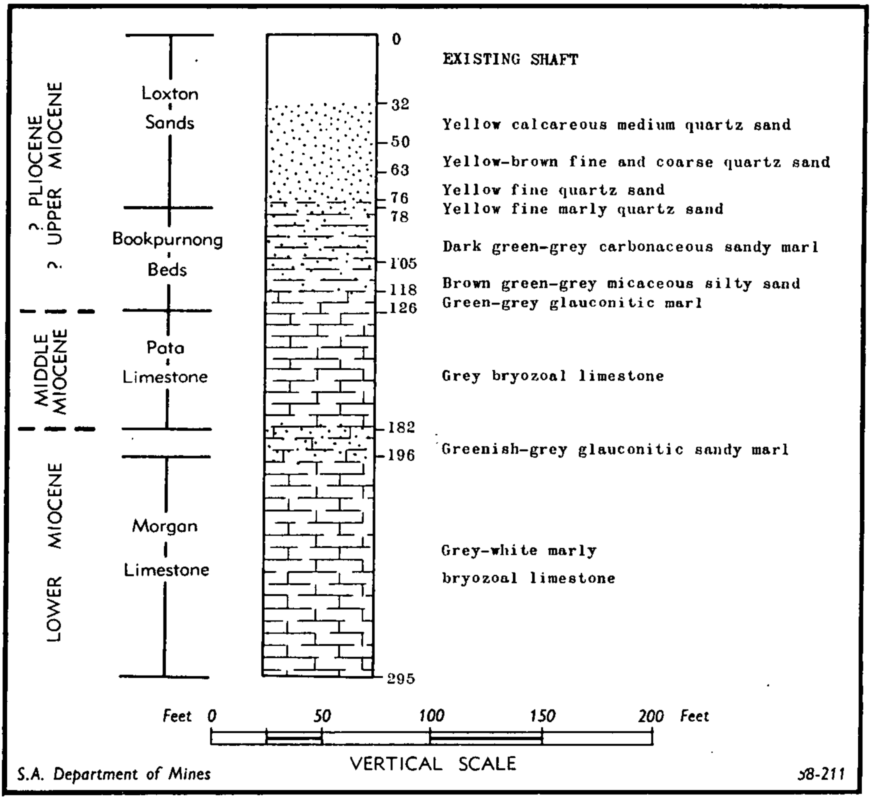

FIG. 27—DRAINAGE SHAFT NO. 18, LOXTON—SECTION 377, HUNDRED OF GORDON

Standard subsurface section

bryozoal limestone, marly in parts and with hard bands with abundant *Ditrupa*. The megafauna has not been described but includes species of *Turritella, Dentalium, Nuculana, Limopsis* and *Carditidae.*

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

FIG. 28—LOXTON SANDS—TYPE SECTION
Loxton pumping station

FIG. 29—LOXTON SANDS
Loxton District Council Quarry

FIG. 30—GREAT PYAP BEND, RIVER MURRAY—SECTION 11, HUNDRED OF PYAP
Loxton Sands in foreground; type section of Bookpurnong Beds (below, out of sight)

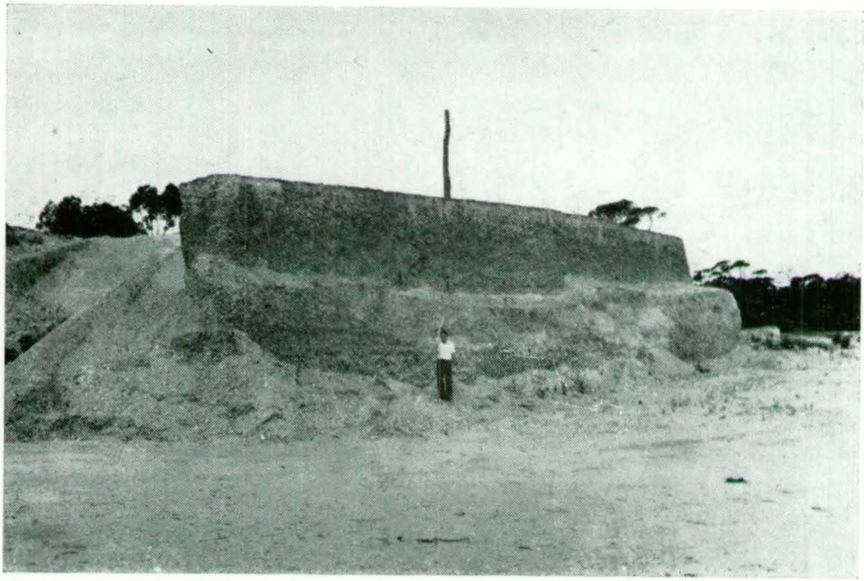

FIG. 31—QUARRY IN THICK OYSTER BED—MARNE RIVER VALLEY
Section 63, hundred of Ridley

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 mollusca including *Leiopyrga 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 315-325ft. in Mallee bore No. 9.

Loxton Sands

Above 78ft. 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. Descriptions of the sludges is as follows:

LOXTON SANDS

Depth From ft.	To ft.	Description
32	50	Yellow calcareous medium sand with subangular to subrounded quartz grains, fairly well polished, muscovite, shell fragments and a few poorly preserved foraminifera.
50	63	Yellow-brown calcareous fine and coarse quartz sand with subrounded polished quartz grains, muscovite, *Balanus* sp., and a few small foraminifera.
63	76	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	Yellow fine micaceous marly sand with fine angular quartz grains, abundant small muscovite flakes, ostracodes mollusca including *Syrnola (Evelynella) adelaidensis*, ostracodes and foraminifera with *Flintina intermedia, Elphidium advenum, E. pseudonodosum* and *E. macellum*.

BOOKPURNONG BEDS

78	105	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. Mollusca include *Leiopyrga quadricingulata, Placamen subroborata, Tawera dictua*. *Balanus* is also present.

Depth From ft.	To ft.	Description
105	118	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 mollusca are present with numerous small foraminifera dominated by *Bolivina* spp. and lagenids.
118	126	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. Mollusca include *Nuculana* sp. nov., *Turritella* sp., and *Dentalium* (*Laevidentalium*) sp.

PATA LIMESTONE

Depth From ft.	To ft.	Description
126	150	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	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. Mollusca (*Nuculana* and *Carditidae*) and crustacea are present.
165	182	Pale-grey marly bryozoal limestone with some glauconite. The microfauna is characterized by numerous *Operculina victoriensis* and *Cibicides victoriensis* with planktonic forms including *Orbulina universa, Orbulina suturalis, Globigerinoides bisphaerica, G. triloba* and species of the *Porticulasphaera glomerosa* series. The megafauna contains species of *Turritella, Dentalium, Nuculana, Limopsis* and *Carditidae.*

TRANSITIONAL BED

Depth From ft.	To ft.	Description
182	196	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 *Siphonaperta ammophila*. It appears to be transitional between that of the Morgan Limestone and that of the Pata Limestone.

FIG. 32—RAMCO STONE
Moulds of *Anodontia sphericula* on bedding plane

FIG. 33—WAIKERIE FREESTONE
Blake's quarry, northwest of Waikerie, hundred of Markaranka

To face page 68]

MORGAN LIMESTONE

Depth From ft.	To ft.	Description
196	202	Grey-white marly and partially recrystallized bryozoal limestone with *Operculina victoriensis, Amphistegina lessonii* and *Parellina craticulatiformis,* the latter restricted to the formation. Echinoids are also present.
202	209	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	Light-grey marly bryozoal limestone, with abundant bryozoa. Microfauna similar to that of 202-209ft.
245	267	Light-grey marly bryozoal limestone with *Lepidocyclina howchini* associated with *Operculina victoriensis Amphistegina lessonii, Parellina craticulatiformis, Globigerinoides bisphaerica.*
267	295	Light-grey marly bryozoal limestone, with a similar microfauna including numerous small species.

TABLE VIII

MICROPALAEONTOLOGICAL LOG—SECTION 377, HUNDRED OF GORDON—DRAINAGE BORE, SHAFT 18

	LOXTON SANDS				BOOKPURNONG BEDS			PATA LIMESTONE			MORGAN LIMESTONE					
Depth (feet)	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
Fissurina sp.	v	—	v	v												
Cassidulina sp.	v															
Elphidium sp.	v	v														
Reussella sp.	—	v	—	—	—	—	r									
Bolivina spp.	—	v	v	—	—	v	r	—	v	—	—	—	—	v	—	v
Cibicides pseudoungerianus (Cushman)	—	v	—	—	—	—	c	v	v	r	c	v	f	r	—	c
Lagena spp.			v	v	v	—	f									
Guttulina irregularis (d'Orbigny)			v	—	v	—	—	—	—	—	—	—	v	—	—	v
Guttulina problema d'Orbigny			v	—	v	r	r	—	—	v	v	—	v	v	—	v
Angulogerina sp.			v													
Patellina cf. *inconspicua* (Brady)			v													
Elphidium pseudonodosum Cushman			v	r	a	r	v									
Elphidium macellum (Fichtel & Moll)			v	v	r	r	c	—	v							
Elphidium sp.			r	f	f	r	—	v	—	—	v					
Notorotalia sp.			v	v	r	v	v									
Quinqueloculina vulgaris d'Orbigny				v	f	r	c	c	r	f	f	—	r			
Quinqueloculina spp.				v	c	c	v	—	v	v	r					
Flintina intermedia (Howchin)				r	c	v	—	—	v							
Lagena striata (d'Orbigny)				v												
Lagena sulcata Walker & Jacob				c	v											
Guttulina lactea (Walker & Jacob)				v	v											
Pseudopolymorphina sp.				v	—	—	—	—	—	—	—	—	v			
Elphidium advenum Cushman				f	r	r	v									
Astrononion sp.				v	—	v	r									
Triloculina trigonula (Lamarck)					r	—	v	—	—	v	—	r				
Triloculina sp.					v	—	v									
Flintina triquetra (Brady)					r											
Siphonaperta adelaidensis (Howchin & Parr)					r	—	—	v								

Sigmoilopsis lapidigera (Howchin & Parr)					f											
Pyrgo spp.					v	—	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	v	r	—	r	f	v	f	r
Guttulina yamazakii Cushman & Ozawa						v										
Guttulina cf. *austriaca* d'Orbigny						v										
Glandulina laevigata d'Orbigny						v										
Sigmoidella kagaensis Cushman & Ozawa						v	—	v	—	—	—	—	v	v		
Sigmomorphina semitecta (Reuss)						v										
Bolivina rugosa Parr						f	—	—	—	f						
Valvulineria sp.						r	f	—	—	—	—	—	—	—	—	v
Cancris intermedius Cushman & Todd						v	v	—	—	—	—	—	—	—	—	v
Nonion victoriense Cushman						r	c	—	v	—	r					
Nonion sp.						v										
Dorothia parri Cushman							r	v	—	f	v	—	—	—	v	—
Siphotextularia sp.							v									
Siphonaperta ammophila (Parr)							v	—	—	r	c	—	v	—	v	—
Sigmoilina sp.							v	v	v							
Marginopora vertebralis Blainville							v	c	r	v						
Plectofrondicularia australis (Heron-Allen & Earland)							v									
Uvigerina schwageri Brady							v	v	v							
Uvigerina subperegrina Cushman & Kleinpell							v									
Trifarina bradyi Cushman							v	—	—	—	—	—	—	v		
Loxostomum sp.							r									
Cibicides sp.							r									
Anomalina glabrata Cushman							v	—	v	v	—	v	—	—	—	f
Discorbis sp.							v									
Baggina philippinensis (Cushman)							v									
Elphidium parri Cushman							v	v	v	—	r	—	v			
Elphidium crassatum Cushman							v	v								
Notorotalia howchini (Chapman, Parr & Collins)							r	v	—	v	v	—	—	—	—	a
Rotalia sp.							v									
Operculina "*victoriensis*" Chapman & Parr							f	c	r	c	r	f	f	r	r	f
Textularia spp.							v	v	v	—	v	f	r			
Dorothia sp.								v	v	v	r	v	v			

TABLE VIII—*continued*

MICROPALAEONTOLOGICAL LOG—SECTION 377, HUNDRED OF GORDON—DRAINAGE BORE, SHAFT 18—*continued*

	Loxton Sands				Bookpurnong Beds			Pata Limestone			Morgan Limestone					
Depth (feet)	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
Articulina sp.	—	—	—	—	—	—	—	v	v	v	—	—	—	—	—	—
Massilina sp.	—	—	—	—	—	—	—	v	v	v	—	—	—	—	—	—
Cornuspira involvens Reuss	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—
Cornuspira tasmanica Parr	—	—	—	—	—	—	—	v	v	v	v	—	—	—	—	—
Cornuspira sp.	—	—	—	—	—	—	—	v	v	f	r	—	—	—	—	—
Sphaeroidina sp.	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—
Cibicides victoriensis Chapman, Parr & Collins	—	—	—	—	—	—	—	c	a	a	—	—	—	—	—	—
Sigmoidella cf. *elegantissima* (Parker & Jones)	—	—	—	—	—	—	—	—	cf	v	r	v	f	r	v	—
Sphaeroidina bulloides d'Orbigny	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—	f
Globigerina bulloides d'Orbigny...........	—	—	—	—	—	—	—	—	v	v	v	—	—	—	—	—
Siphonina australis Cushman	—	—	—	—	—	—	—	—	v	v	—	—	—	—	—	r
Textularia cf. *sagittula* Defrance	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Gaudryina (*Pseudogaudryina*) sp.	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—	r
Liebusella rudis (Costa)	—	—	—	—	—	—	—	—	—	f	—	—	v	—	—	—
Schenckiella howchini (Cushman)	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—	—
Sigmoilopsis asperula (Karrer)	—	—	—	—	—	—	—	—	—	f	r	—	—	—	—	—
Sigmoilopsis chapmani (Cushman)	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Sigmoilina victoriensis Cushman	—	—	—	—	—	—	—	—	—	v	v	v	—	—	—	—
Cornuspiroides expansus (Chapman)	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Lenticulina sp.	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Uvigerina spp.	—	—	—	—	—	—	—	—	—	v	—	v	—	—	—	r
Cibicides sp.	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Dyocibicides sp.	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Cancris sp.	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	—
Anomalinoides procolligera Carter..........	—	—	—	—	—	—	—	—	—	v	v	r	v	—	—	—
Globigerina apertura Cushman.............	—	—	—	—	—	—	—	—	—	v	r	—	—	—	f	f
Globigerina ciperoensis angustiumbilicata Bolli	—	—	—	—	—	—	—	—	—	r	—	—	—	—	—	—

Globigerina trilocularis d'Orbigny										v	—	—	—	v		
Globigerinoides bisphaerica Todd										r	c	—	r	f	f	—
Globigerinoides triloba immatura Le Roy										v						
Globigerinoides transitoria Blow										v	—	—	—	v	v	—
Biorbulina bilobata (d'Orbigny)										v						
Orbulina universa d'Orbigny										r						
Candorbulina universa Jedlitschka										r						
Porticulasphaera glomerosa glomerosa (Blow)										f						
Porticulasphaera glomerosa curva (Blow)										f	v					
Hastigerina murrayi Thompson										v						
Globoquadrina dehiscens (C. P. & C.)										v	—	—	v			
Elphidium howchini Cushman (?)										r	v	—	v	v	v	v
Quinqueloculina lamarckiana d'Orbigny											r	—	v			
Triloculina tricarinata d'Orbigny											v					
Sphaeroidina bulloides d'Orbigny											v	—	v			
Cibicides refulgens Montfort											v	—	v	v		
Cibicides subhaidingerii Parr											v	—	f	f	v	r
Astrononion australe Cushman & Edwards											v	—	—	—	—	a
Carpenteria rotaliformis Chapman & Crespin											v	—	—	—	—	r
Sigmomorphina subregularis Howchin & Parr												v	v	v	—	v
Chrysalidinella costata (H. A. & E.)												v	—	r		
Cassidulina subglobosa Brady												r	v	—	—	f
Ehrenbergina sp.												f	f	c	—	f
Cibicides lobatulus (Walker & Jacob)												v	r	—	—	v
Stomatorbina concentrica (Parker & Jones)												v	v	v	—	—
Parellina craticulatiformis Wade												v	f	c	f	v
Ceratobulimina (*Ceratocancris*) australis C. & H.												v				
Cerobertina sp.												v				
Amphistegina lessonii d'Orbigny												r	f	c	f	f
Textularia corrugata H. A. & E.													f	—	v	v
Textularia pseudogramen Chapman & Parr													r	cf	—	r
Gaudryina (*Pseudogaudryina*) *crespinae* Cushman													f			
Clavulinoides victoriensis Cushman													v			
Biloculinella globula Bornemann													v			
Nodosaria soluta Reuss													v			
Dentalina sp.													v			
Robulus spp.													v			
Marginulina spp.													v			
Sigmomorphina chapmani (H. A. & E.)													v			

TABLE VIII—*continued*

MICROPALAEONTOLOGICAL LOG—SECTION 377, HUNDRED OF GORDON—DRAINAGE BORE, SHAFT 18—*continued*

	Loxton Sands				Bookpurnong Beds			Pata Limestone			Morgan Limestone					
Depth (feet)	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
Guttulina (Sigmoidina) silvestrii C. & O. ...	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Guttulina (Sigmoidina) pacifica C. & O......	—	—	—	—	—	—	—	—	—	—	—	—	r	v	—	—
Globulina gibba d'Orbigny	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Reussella simplex Cushman	—	—	—	—	—	—	—	—	—	—	—	—	v	v	—	—
Reussella decorata H. A. & E.	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	r
Cassidulina laevigata d'Orbigny	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	r
Eponides repandus (Fichtel & Moll)	—	—	—	—	—	—	—	—	—	—	—	—	v	r	r	r
Planorbulinella plana (H. A. & E.)	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—
Gypsina globulus Reuss	—	—	—	—	—	—	—	—	—	—	—	—	v	v	r	r
Carpenteria proteiformis Goës	—	—	—	—	—	—	—	—	—	—	—	—	r	—	—	—
Conorbella patelliformis (Brady)	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	v
Crespinella sp.	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Reussella ensiformis Chapman	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Reussella spinulosa (Reuss)	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Tubulogenerina mooraboolensis Cushman ...	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Glabratella "cruciformis" (H. A. & E.)	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—
Lepidocyclina howchini Chapman & Crespin.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r	—
Globigerina cf. *venezuelana* Hedberg........	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r
Loxostomum limbatum (Brady)	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	r

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

CORRELATION OF OTHER DRAINAGE BORES IN THE HUNDRED OF GORDON

	SECTION 489	SECTION 537	SECTION 496
	Depth From To ft. ft.	Depth From To ft. ft.	Depth From To ft. ft.
Existing shaft	Surface—30	Surface—35	Surface—24
Loxton Sands	30—76	35—71	24—54
Bookpurnong Beds	76—105	71—72½	54—112
Pata Limestone			112—167
Transitional bed			167—180
Morgan Limestone			180—200

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 50ft. thick, consisting of a shell bed 5ft. thick at the base above water-level (R.L. of river 142ft., normal pool level 139ft.) overlain by about 45ft. of cross-bedded gritty sands. The fauna of the shell bed contains water-worn and comminuted shells of *Nuculana* sp., *Glycymeris cainozoica, Pleuromeris pecten, Tawera dictua, Donax* (*Plebidonax*) *depressa, Cantharidus* (*Phasianotrochus*) sp., and *Calyptraea corrugata.* The microfauna is poor, with *Quinqueloculina, Notorotalia,* and *Elphidium chapmani.*

The Loxton District Council operates a quarry on section 32, hundred of Gordon, in which 30ft. of Loxton Sands are quarried for concrete aggregate.

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. Molluscan species include *Glycymeris cainozoica, Glycymeris convexa, Cucullaea* sp., *Ostrea sturtiana, Neotrigonia* sp., *Miltha hora, Cytherea murrayana, Tawera dictua, Placamen subroborata* 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 silty 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 ¼ mile downstream where they were dredged in 1958 for building sand.

In borings in the northeast 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 characterized principally by thick oyster beds discordantly 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 28ft. of sandy limestone with *Ostrea sturtiana, Glycymeris convexa, Neotrigonia howitti* and *Donax* (*Plebidonax*) *depressa* rest on 42ft. 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 northwest side of Ramco, "Ramco stone" was quarried before the 1939-1945 war. This is lithologically similar to Waikerie freestone 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 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 River Murray, 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.

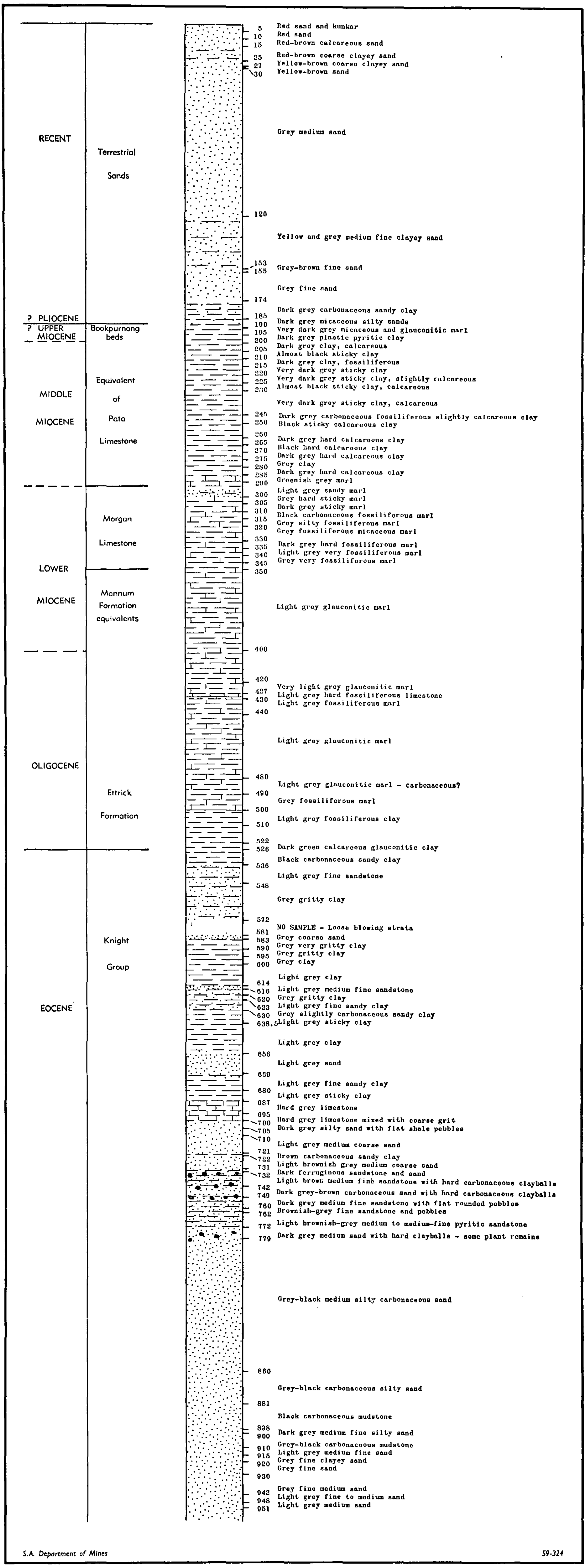

FIG. 34—CANOPUS NO. 1 BORE
Columnar section

Stratigraphical and Faunal Sequence—Canopus Bore No. 1

Canopus Bore No. 1 was drilled for water in 1952-53 by the South Australian Department of Mines for Canopus Pastoral Company on Pastoral Lease No. 1664, 45 miles north of the River Murray and adjacent to the New South Wales border.

Rather poor 860-grain sheep water was struck at 572ft., 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 910ft. and 951ft. This was tested at 600 gallons per hour.

Stratigraphical Sequence

The boring first passed through 174ft. of Recent and Pleistocene terrestrial sands and dark-grey sandy clay which may be of Pliocene age. Between 185ft. and 536ft. the mid-Tertiary sequence of Bookpurnong Beds downwards to equivalents of the Ettrick marls was intersected. At 536ft. the boring entered sands and carbonaceous clays of the Knight Group in which the boring ceased at 951 feet.

Pleistocene to Recent terrestrial sands—0-174 Feet

This formation consists of an upper 5ft. of red ferruginous sandy surface soil and subsoil with nodular kunkar; then, in downward sequence, 20ft. of red calcareous clayey quartz sand, less ironstained when washed than the surface sands, and 149ft. 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.

? Pliocene carbonaceous sandy clay—174-185 Feet

? Pliocene carbonaceous sandy clay occurs between 174ft. and 185ft.

Bookpurnong Beds—185-195 Feet

The Loxton Sands are missing in the bore which at 185ft. entered 10ft. of dark-grey micaceous silty sands with pyrite and glauconite representing the Bookpurnong Beds. Mollusca 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.

Black clay equivalent of Pata Limestone—195-285 Feet

The boring passed into black very plastic pyritic clay at 195ft. 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 mollusca, corals, ostracodes and bryozoa. *Cibicides victoriensis* occurs between 205ft. and 235ft. 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* (*Maoricolpus*) *murrayana, Turritella* (*Colpospira*) *tristira, Turritella* sp., *Cerithiopsis* sp., *Syrnola* sp., *Hinia* (*Reticunassa*) *tatei.*

Morgan Limestone equivalent—285-350 Feet

At 285ft. the black plastic clay is replaced by a greenish-grey calcareous sandy highly fossiliferous marl, with a clay intercalation between 300ft. and 335ft. There is a fairly conspicuous faunal change and the microfauna contains *Tubulogenerina mooraboolensis, Globigerinoides triloba, Gypsina howchini, Carpenteria proteiformis, Amphistegina lessonii,* and *Operculina 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*, *Obtortio* sp., *Turritella* (*Gazameda*) *acricula*, *Turritella* (*Colpospira*) *conspicabilis*, *T.* (*C.*) *tristira*, *Cerithiella trigemmata*, *Cirsotrema* (*Dannevigena*) sp., *Cirsotrema* (*Propescala*) *pachypleura*, *Personella gemmulata*, *Hexaplex* (*Murexsul*) *trochospira*, *Hinia* (*Reticunassa*) *tatei*, *Marginella* (*Eratoidea*) *wentworthi*, *Guraleus* sp.

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

Equivalents of Mannum Formation—350-500 Feet

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

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 "plecte"* occurs between 500ft. and 510ft. The foraminiferal assemblage contains also *Massilina torquayensis* together with *Clavulinoides victoriensis*, *Dorothia parri*, *Gaudryina* (*Siphogaudryina*) *victoriana*.

? Equivalents of Compton Conglomerate—522-536 Feet

At 522ft. 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. *Cibicides umbonifer* is the dominant foraminifer. This bed appears to be synchronous with the Compton Conglomerate.

Knight Group—536-951 Feet

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

TABLE IX

Canopus No. 1 Bore—Micropalaeontological Log

Equivalents of	Bookpurnong Beds	Pata Limestone									Morgan Limestone							Mannum								—	Gambier					—	Ettrick		Compton			
Depth (feet)	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	410–420	420–427	427–430	430–440	440–450	450–460	460–470	470–478	478–480	480–490	490–500	500–510	510–520	520–522	522–526	526–536
Quinqueloculina vulgaris d'Orbigny	v	f	r	r	r	r	v	v	v	—	a	f	r	—	r	c	v	r	v	r	f	v	v	f	r	r	f	f	f	r	r	f	v	v	c	f	r	r	v
Ammosphaeroidina sphaeroidiniformis	v	—	r	v	v	f	f	f	c	r	c	r	v	—	v	f	f	v	v	v	—	r	—	v	r														
Sigmoilopsis chapmani	v	c	f	r	r	f	f	v	v	v	a	f	v	v	r	f	r	f	v	f	r	r	v	v	r	v	r	v	v										
Sigmoilopsis sp. 1	v	—	—	—	—	r	—	—	—	—	—	—	—	—	—	—	—	r	—	v																			
Nodosaria saluta	v	v	—	v	—	—	—	—	—	—	v	—	—	—	—	—	v	—	v	—	—	v	—	—	—	—	v	v	v	v	—	—	v	r	—	r	v		
Lagenonodosaria hispida	v	—	v																																				
Lagenonodosaria 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	v	v	r	r	r	—	—	v	—	f	v	c	r	r		
Guttulina problema	f	—	v	—	—	v	—	—	—	—	v	—	—	—	—	—	v	—	—	v	v	—	—	—	v	—	v												
Sigmoidella elegantissima	f	—	v	—	—	v	—	—	—	—	v	v	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	v	v							
Reussella spinulosa	v	r	v	—	—	—	—	—	—	—	c	f	—	—	—	f	f	v	r	c	v	f	—	r	r	—	v	r	v										
Bolivina dilatata	r	v	—	—	—	—	—	—	—	—	r	—	—	—	—	v	r	—	v	v	r	—	—	—	—	—	—	v	—	—	—	—	—	v					
Bolivina plicatella	r	v																																					
Bolivina sublobata	f	c	v	v	—	—	—	—	—	—	r	—	—	—	—	v																							
Bolivina subreticulata	r	v	—	—	—	—	—	—	—	—	r	—	—	—	—	v	r	—	—	f	v	—	—	v	—	—	v	v											
Loxostomum sp.	v	v	—	v	—	—	v	—	v	r	a	—	—	—	—	v	r	v	v	v	v	v	—	—	—	—	—	—	—	—	v								
Pullenia quinqueloba	v	v	v	v	—	—	—	—	v	—	—	—	—	—	—	—	—	v	v	r	—	v	v	—	—	v	v	v	r	v	—	r	v	f	v	r	v	v	
Spaeroidina bulloides	v	r	v	—	f	v	a	a	c	a	r	a	f	v	f	v	—	v	—	v	—	v	v	—	—	v	v	v	v	f	—	—	r	f	r	a	f	v	v
Discorbis mira	v																																						
Siphonina australis	r	f	v	r	f	r	c	f	f	c	c	f	r	r	f	c	r	v	v	f	r	v	v	r	r	c	r	r	r	r	v	c	f	f	v	f	r	v	—
Cibicides boueanus	r	v	—	—	v	—	—	—	—	v	r	v	—	v	r	c	v	r	f	c	f	r	r	v	v	f	f	c	f	f	f	r	r	—	c	v	v	v	v
Cibicides lobatulus	r	r	r	v	v	—	v	r	v	—	c	f	f	v	—	v	v	v	v	v	—	r	—	—	—	—	—	v	—	—	—	—	—	v					
Cibicides pseudoungerianus	a	a	a	a	a	a	a	a	c	a	a	a	a	f	a	a	a	f	—	a	a	a	c	f	a	a	a	c	a	a	c	f	f	a	c	a	c	c	c
Anomalina glabrata	a	f	f	v	f	f	f	f	c	r	c	c	v	f	f	f	f	v	v	c	r	f	v	r	r	v	r	r	r	r	—	f	f	f	—	f	r	r	—
Hoglundina elegans	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v										
Rotalia beccarii	c																																						
Rotalia cf. *hamiltonensis*	v																																						
Textularia pseudogramen	—	v	r	v	v	v	r	—	v	v	c	a	—	—	v	c	f	v	v	r	—	r	r	v	—	r	v	r	r	v	r	v	—	—	r				
Quinqueloculina lamarckiana	—	r	v	—	f	r	v	r	v	r	c	r	v	—	r	f	v	—	v	r	v	v	v	r	r	r	r	r	r	v	v	—	—	—	r	r	v	r	v
Quinqueloculina seminulum	—	v	r	—	—	v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v								
Sigmoilopsis sp. 2	—	r	r	v	f	v	r	r	v	—	f	r	—	v	v	r	—	—	v	r	v	v	v	v	—	—	v	v	—	—	—	—	—	v	v	v	—		
Biloculinella globula	—	f	v	—	—	v	—	—	—	—	f	v	—	—	r	f	—	v	v	v	v	v	v	v	—	—	v	—	—	—	—	v	v	—	v	—	—	v	—
Uvigerina sp.	—	f	v	—	v	v	c	f	f	f	—	—	—	—	—	—	r	—	—	—	—	—	—	v	—	—	v												
Cassidulina laevigata	—	v	v	v	—	—	—	—	—	—	v	r	—	—	—	v	r																						
Discorbis tuberculata australiensis	—	v	—	—	v	v	—	—	—	—	v	—	—	—	—	v	v	—	v	v	r																		
Cancris ovatus	—	r	—	—	v	v	—	v	—	—	—	v	—	—	—	—	—	—	—	—	—	v																	
Cancris intermedius	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	r	—	v	—	—	—	v																	
Elphidium advenum	—	r	—	v	v	—	—	—	—	—	v	v																											
Gaudryina (Pseudogaudryina) crespinae	—	—	v	—	—	—	—	—	—	—	c	v	—	—	—	f	f	v	v	—	—	—	v	r	v	—	r	v	v	v	r	v	v	v	r	v	v		
Dorothia parri	—	—	r	—	v	v	v	—	—	—	f	r	v	v	v	c	r	v	—	v	—	v	v	r	v	f	r	v	r	v	v	v	v	r	r	—	—	r	r
Sigmoilina victoriensis	—	—	v	—	r	v	v	—	r	—	v	f	v	v	v	r	r	v	—	r	v	v	—	v	v	r	v	—	v	—	—	v	—	—	v	—	—	—	—
Triloculina trigonula	—	—	v	v	v	v	—	—	—	r	f	v	—	—	—	f	r	v	v	v	—	—	v	v	v	—	f	v	v	v	v	—	—	v	f	v	v	v	—
Guttulina regina			r	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	v												
Discorbis dimidiatus			f	v																																			
Cibicides victoriensis			v	—	v																																		
Elphidium chapmani			v	—	—	v																																	
Notorotalia howchini			r	v	—	—	v	—	—	—	c	f	v	—	v	f	r	c	c	c	c	f	f	a	c	a	a	c	c	f	f	r	f	f	c	a	r	c	c
Cornuspira involvens				v	v	v	v	v	v	r	r	v	v	v	v	v	—	—	v	—	—	—	v	—	v	v	—	v	—	v	v	v	v	—	v				
Marginopora vertebralis				v	—	—	—	—	—	—	v	v																											
Triloculina sp.				v	—	v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	v	—	v			
Guttulina irregularis			v	—	—	—	—	—	—	—	v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	v											
Cassidulina subglobosa			v	v	r	r	r	c	r	f	r	f	c	—	v	v	r	f	f	f	v	v																	
Ehrenbergina sp.			—	v	v	—	—	—	—	—	c	r	—	—	—	—	—	v	v	r	—	v	—	v	—	—	v												
Anomalina procolligera				v	—	—	v	—	—	—	f	v	—	—	v	c	f	v	—	v	v	v	f	—	r	f	r	f	f	f	r	r	f	c	—	a	f	f	—
Calcarina verriculata				v	—	—	—	—	—	—	—	—	—	v	—	v	v	v																					
Quinqueloculina longirostris				—	v	—	—	v	—	—	f	r	r	—	f	f	r	v	v	r	r	r	v	v	r	r	r	v											

TABLE IX—*continued*

CANOPUS NO. 1 BORE—MICROPALAEONTOLOGICAL LOG

Equivalents of	Bookpurnong Beds	Pata Limestone									Morgan Limestone							Mannum								—			Gambier			—		Ettrick			Compton		
Depth (feet)	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	410–420	420–427	427–430	430–440	440–450	450–460	460–470	470–478	478–480	480–490	490–500	500–510	510–520	520–522	522–526	526–536
Cornuspiroides expansus					v	v	v	—	r	v	r	v	v	—	v	v	—	v	—	—	—	v	—	—	v														
Cibicides refulgens					v	—	—	—	—	—	r	—	—	—	—	—	c																						
Triloculina tricarinata					v	v	v	v	—	r	v	—	—	—	—	v	—	v																					
Sigmoilopsis asperula						v	v	—	—	—	f	r	—	—	—	v	v	—	—	—	—	v	—	v	v	v	—	v											
Sigmoilina cf. *edwardsi*						r	r	r	r	r	f	v	v	v	v	v	f	—	v	r	r	—	v	r	—	—	—	—	—	v									
Glandulina laevigata						v	v	r	v	v	—	—	v	—	v	v	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	v	v	f	v				
Discopulvinulina collinsi						v	—	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	v											
Nonion sp.						v																																	
Pyrulina cylindroides							v	v	—	r	—	—	v																										
Pyrgo bulloides							v	v	v	v	v	g	v	v	—	r	r	—	v	—	r	v	v																
Bolivina victoriana							—	v	—	—	f	r	—	—	—	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	v		
Ceratobulimina hauerii australis								r	f	r	v	v	r	r																									
Nodosaria vertebralis									v	—	f	v	—	—	—	—	—	—	—	—	v	—	—	v	—	v	—	—	v	—	—	—	—	v	r				
Textularia corrugata											v	—	—	—	—	r	f																						
Textularia porrecta											v	v																											
Vulvulina pectinata											v	—	—	—	—	v	—	—	—	—	—	—	v	—	—	—	—	—	—	—	—	—	—	v	v				
Clavulinoides victoriensis											c	f	—	—	—	v	v	—	v	—	—	—	v	v	v	f	r	r	—	—	—	—	—	v	c	v			
Liebusella rudis											v	—	—	—	—	—	—	—	v	—	v	—	r	v	v	v	v	v	v	—	—	v							
Cornuspira tasmanica											v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v											
Quinqueloculina polygona											r	—	—	—	—	v	v	—	—	v																			
Quinqueloculina undosa											c	r	—	—	—	f	r	—	—	—	—	v	—	—	—	v	—	r	—	—	—	v							
Sigmoilopsis tenuis											f	v	—	v	—	v	—	f	v	v	v	v	—	v	—	—	v	v	—	v	r	v	—	v	v	v			—
Articulina crespinae											c	v	—	—	v	v																							
Articulina victoriana											v	v																											
Sigmoidella kagaensis											v	v	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	v							
Buliminella madagascariensis var. *spicata*											f	—	—	—	—	r	r	—	—	r	v	—	—	v	—	—	v	v											
Buliminella elegantissima											v																												
Uvigerina flintii											f	—	—	—	—	v																							
Uvigerina proboscidea											f	v	v	—	—	r	—	f	f	c	f	c	v	v	r	—	f	v	v	—	—	v							
Trifarina bradyi											r	v	—	—	—	—	v	v	—	v	r	v	—	v	—	—	—	—	—	v	v	f	v	r	f	v	v	f	v
Tubulogenerina mooraboolensis											v	—	—	—	—	—	v																						
Pullenia bulloides											v	—	—	—	—	—	—	—	—	r	r	v	—	v	r	—	v	v	—	—	v	—	—	—	v	—	v	v	—
Eponides lornensis											v	v	—	—	—	—	—	—	—	—	—	—	v	—	v	r	v	v	r	v	—	—	v	v	r	v	v		
Cibicides concentricus											f	—	v	—	—	v	—	f	r	c	c	f	r	v	r	r	r	v	v	r	v	a	c	v	r	c	c		
Discorbis spp.											r																												
Globigerinoides triloba											v	—	—	—	v	c	r	f	—	v	v	r																	
Globigerina bulloides											f	—	—	—	—	r	v	—	v	c	—	r	v	—	—	—	r	v	—	—	—	—	—	v	—	—	—	v	—
Globigerina angustiumbilicata											v																												
Gypsina howchini											v	—	—	—	—	v	v																						
Carpenteria proteiformis											v																												
Elphidium crespinae											c	r																											
Amphistegina lessonii											c	v	—	—	v																								
Operculina victoriensis											f	r	—	—	—	—	—	—	v	v	—	—	—	—	v	—	—	v											
Karrierella cf. *colligera*												v	—	—	—	—	v																						
Bolivina hebes vgr. *victoriensis*												v	—	—	—	—	—	—	—	—	—	—	v	—	—	—	—	—	v	—	—	—	—	—	—	v	—	v	—
Globigerinoides bisphaerica															v	f	v																						
Robulus clericii																v	v	—	—	v	—	—	—	—	—	r	r	v	v	v	—	v	r	—	r	f			
Gaudryina collinsi																v																							
Calcarina mackayi																a	c	—	—	—	—	—	v	v	—	—	f	v	—	—	—	v	—	v					
Bolivina marginata																r	f																						
Bolivina advena																r	v	—	—	v	v	—	—	—	—	—	—	v											
Angulogerina australis																		v	v	f	r	r	r	v	r	—	v	v	v	—	v	r	—	—	—	—	—	v	—
Bolivina vadescens																			v	v																			
Elongobula sp.																		v	r	—	v	v	—	—	v														
Lamarckina glencoensis																		v																					
Miliolinella oblonga																			v	—	—	—	—	—	—	—	—	—	f	—	—	—	—	v					

TABLE IX—*continued*

CANOPUS NO. 1 BORE—MICROPALAEONTOLOGICAL LOG—*continued*

Equivalents of	Bookpurnong Beds	Pata Limestone									Morgan Limestone										Mannum				—			Gambier		—		Ettrick		Compton		
Depth (feet)	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	410–420	420–427	427–430	430–440	440–450	450–460	460–470	470–478	478–480	480–490	490–500	500–510	510–520	520–522	522–526	526–536
Spiroloculina canaliculata																			v	r	r	v	r	v	—	v	v	f	f	v	v	r							
Reophax scorpiurus																				v	v																		
Heronallenia parri																				v	—	—	v																
Gyroidina soldanii																							v	—	—	—	—	—	v	v	v	—	—	v					
Valvulineria paucilocula																									v	—	—	—	—	—	—	v	v						
Astrononion centroplax																										v	—	v											
Bolivina anastomosa																												v	v	—	v	v	—	r					
Gypsina globula																															v								
Karreriella advena																																	r	r	—	—	—	v	—
Globigerina ciperoensis ciperoensis																																		c					
Notorotalia crassimura																																		v	c	—	—	v	—
Gaudryina (Siphogaudryina) victoriana																																			f				
Massilina torquayensis																																			f				
Globulina gibba																																			f				
Bulimina pupoides																																			v				
Bolivina scalprata var. *retiformis*																																			v				
Bolivina cf. cookei																																			v	v	v		
Sphaeroidina austriaca																																			v	f	v		
Stomatorbina concentrica																																			f				
Victoriella plecte																																			c				
Karreriella cf. *advena*																																						v	
Quinqueloculina cf. *vicksburgensis*																																						v	v
Guttulina (Sigmoidina) pacifica																																						v	
Angulogerina sp.																																						v	—
Angulogerina sp.																																						v	—
Bolivina cf. *anastomosa*																																						v	—
Cibicides umbonifer																																						a	c
Robulus sp.																																							v

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

DISTRIBUTION OF TERTIARY FORMATIONS

The series of 8 maps presented in figs. 35 and 36 illustrates 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 (fig. 35) shows the limited area over which Eocene marine limestones and oryozoal sands of the Buccleuch Group have been recognized. 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 (fig. 35) shows the wide distribution of Oligocene limestones, marls and sandy marls of the Gambier Limestone and Ettrick Formation. 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 (fig. 35) pinpoints bores in which the Miocene Naracoorte Limestone and Mannum Formation occur, and shows the southwestern margin of the basin where the Mannum 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 Naracoorte Limestone is probably contemporaneous, at least in part, with the Mannum 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. (See figs. 35 and 36.)

Map 7 (fig. 36) 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 (fig. 36).

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 Hills (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 micaceous. 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 *Operculina* and echinoid fragments.

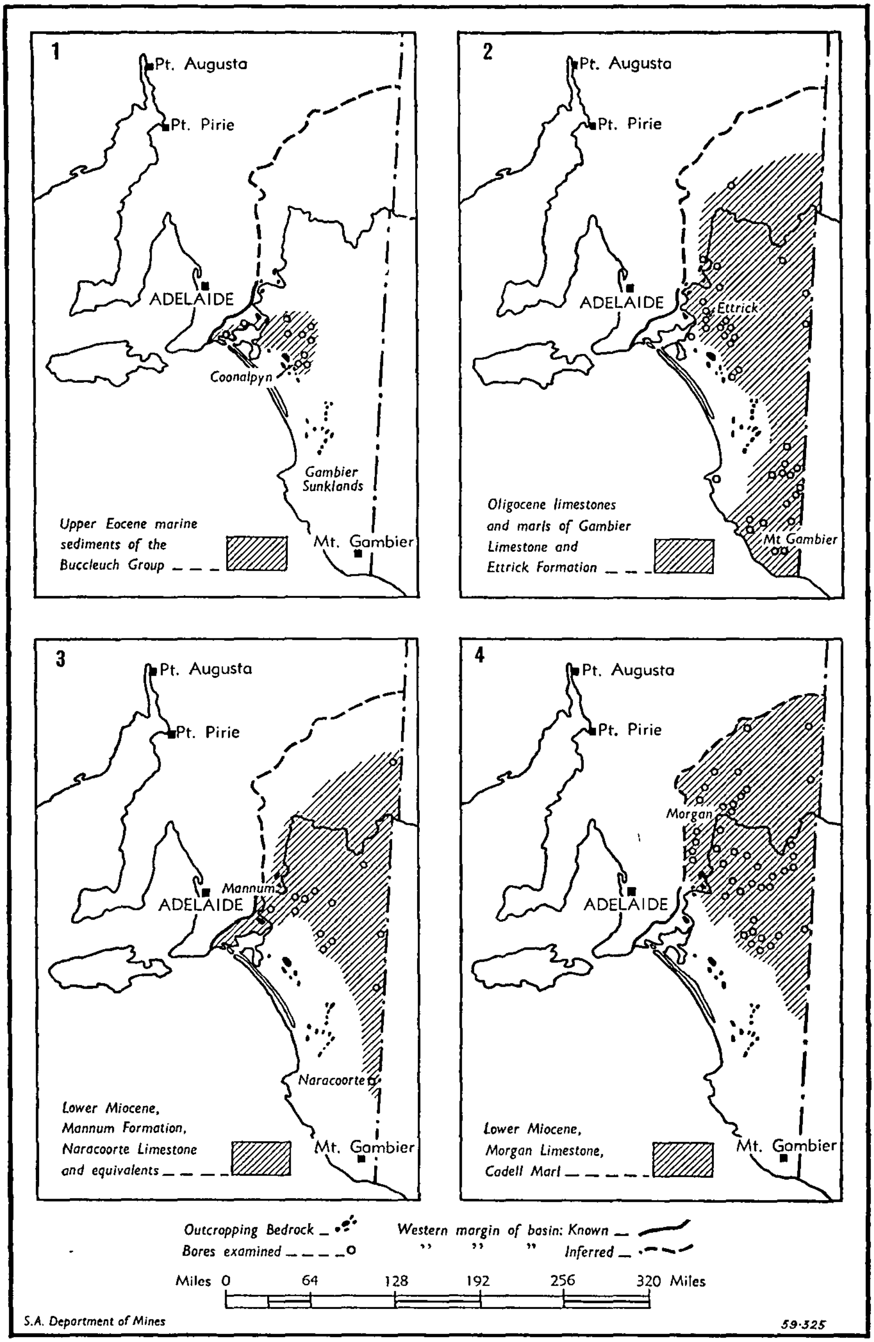

FIG. 35—DISTRIBUTION OF TERTIARY FORMATIONS IN THE SOUTH AUSTRALIAN PORTION OF THE MURRAY BASIN

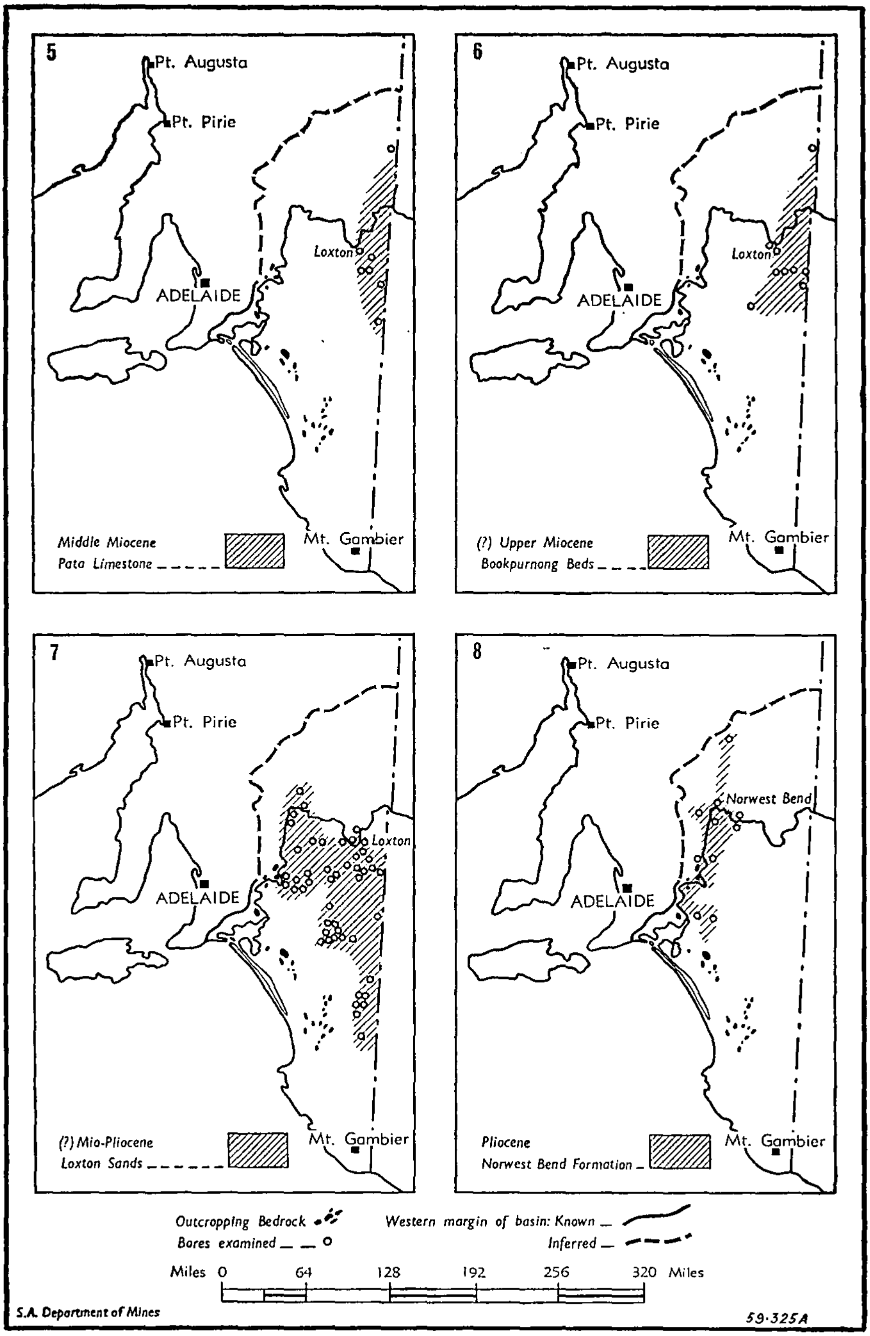

FIG. 36—DISTRIBUTION OF TERTIARY FORMATIONS IN THE SOUTH AUSTRALIAN PORTION OF THE MURRAY BASIN

The estuary in which the Norwest Bend Formation was deposited may have post-dated faulting along the eastern margin of the Mount Lofty Range 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 aeolianites. 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 XI 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 mexicana* 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 X. *Sherbornina atkinsoni* has a much more extensive range in South Australia than that stated by Wade and Carter (1957). 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 II but the species is doubtfully separable from *S. atkinsoni.*

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

The Upper Eocene Buccleuch Group may be correlated with the Browns 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.

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 the 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. the 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 triloba triloba—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 the lower part of the Pata Limestone.

TABLE X

Ranges of Benthonic Foraminifera of Biostratigraphic Significance

AGE	EOCENE				OLIGOCENE						MIOCENE				UPPER MIOCENE ? L. PLIOCENE		PLIOCENE
Murray Basin Proper	Knight Group	Buccleuch Group A	Buccleuch Group B	Buccleuch Group C	Ettrick Formation			Mannum Formation			Finniss Clay	Morgan Limestone	Cadell Marl	Pata Limestone	Bookpurnong Beds	Loxton Sands	Norwest Bend Formation
Gambier Sunklands	Knight Group	? Missing			Gambier Limestone: Glauconitic member	Gambier Limestone: Compton Conglomerate			Naracoorte Limestone			NOT RECOGNIZED					
Alabamina westraliensis	—	—															
Amphistegina "lessonii"								—	- - -	—	—	—	—				
Anomalina perthensis	—	—	—	—													
Asterigerina adelaidensis		—															
Asterigerina cf. *lornensis*		—															
Astrononion centroplax					—	—	—	—	—	—							
Austrotrillina howchini										—	—	—	—	—			
cf. *Bolivinella* sp.		—															
Bolivinopsis crespinae	—	—	—	- - -	—												
Calcarina mackayi						—	—	- - -	—								
Calcarina verriculata										—	- - -	—	—				
Carpenteria proteiformis												—	—				
Cibicides brevoralis								—									
Cibicides pseudoconvexus	—	—	—	—	—												
Cibicides subhaidingerii											—	—	—				
Cibicides umbonifer		—	- - -	- - -	—	—	—	—	—								
Cibicides victoriensis														—			
Crespinella umbonifera												—	- - -	—	- - -	—	
Crespinella sp. nov. A									—	—							
Crespinina kingscotensis		—	—														
Elphidium advenum															—		
Elphidium crassatum									—	—							
Elphidium pseudonodosum															—	—	
Flintina intermedia															—	—	
Gypsina howchini										—	—	—	—				
Halkyardia sp.	—	—															
Lamarckina airensis		—															
Lamarckina glencoensis				—	—	—											
Lepidocyclina howchini												—					
Linderina sp.		—															
Marginopora vertebralis													—	—	—	- - -	—
Maslinella chapmani		—															
Massilina torquayensis					—	—	—										
Notorotalia crassimura		—	—	- - -	—	—	—	—	- - -								
Notorotalia howchini								—	—	—	- - -	—	- - -	—	— - - -	—	
Operculina victoriensis								—	—	—	- - -	—	—	—	—		
Parellina craticulatiformis												—					
Planorbulina johannae		—															
Planorbulinella inaequilateralis									—	—							
Planorbulinella plana										—	- - -	—					
Rotalia cf. *calcar*									—	—							
Sherbornina atkinsoni		—	—	—	- - -	—	—	—	—								
Sherbornina crassata		—															
Sherbornina cuneimarginata									—	—							
Sigmoilopsis lapidigera															—		
Spirillina tuberosa						—											
Victoriella "plecte"						—	—										

TABLE XI

Ranges of Planktonic Foraminifera of Biostratigraphic Significance

AGE	EOCENE				OLIGOCENE						MIOCENE				UPPER MIOCENE ? L. PLIOCENE		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	Norwest Bend Formation
Gambier Sunklands	Knight Group	? Missing			Gambier Limestone: Glauconitic member	Gambier Limestone: Compton Conglomerate			Naracoorte Limestone				NOT RECOGNIZED				
Biorbulina bilobata														—			
Candorbulina universa														—			
Catapsydrax sp.		—															
Globigerapsis index		—															
Globigerina cf. *ampliapertura*		—															
Globigerina angustiumbilicata										—	- - -	—	- - -	—			
Globigerina apertura													—	—			
Globigerina bulloides							—	- - -	—	—	- - -	—	- - -	—			
Globigerina ciperoensis									—								
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							—					—	- - -	- - —			
Gümbelina rugosa		—	- - -	. . . .	—												
Hastigerina micra		—															
Hastigerina murrayi														—			
Orbulina universa														—			
Porticulasphaera glomerosa glomerosa														—			
Porticulasphaera glomerosa curva													—	—			

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 Tocuyo 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 sedimentation. 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 reviewed if faunal 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 southeast 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 Willalooka 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 mechanical 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 two areas: at Blake's quarry (fig. 33) north of the River Murray on section J6, 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 utilized 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, 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 Nairne 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 30ft. face of cross-bedded gritty sands is well exposed.

The Knight sands (fig. 2) 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 northwest 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 Mannum Formation at Murray Bridge for this purpose. Red and grey dolomite occurring in the Gambier Limestone is worked mainly for road metal and ballast. Fig. 9 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.

HYDROLOGY

The hydrology of the Murray Basin is the subject of a separate Bulletin by E. P. D. O'Driscoll. (See *Bulletin* 35 of the Geological Survey of South Australia, 1960.)

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EXPLANATION OF PLATES

PLATE I

EOCENE FORAMINIFERA OF THE BUCCLEUCH GROUP

Fig. 1.—*Pseudopolymorphina* sp. Buccleuch A type section; section 56, hundred of Coneybeer; 307-312ft.; x 25.

Fig. 2.—cf. *Bolivinella* sp. Section 10, hundred of Strawbridge; 128-138ft.; x 25.

Fig. 3.—cf. *Bolivinella* sp., broken specimen, vertical section, internal view. Buccleuch A type section; section 56, hundred of Coneybeer; 297-302ft.; x 25.

Fig. 4.—*Maslinella chapmani* Glaessner and Wade, dorsal view. Section 10, hundred of Strawbridge; 98-108ft.; x 25.

Fig. 5.—*Halkyardia* sp. Section 10, hundred of Strawbridge; 170-180ft.; x 25.

Fig. 6.—*Asterigerina adelaidensis* (Howchin). Buccleuch A type section; section 56, hundred of Coneybeer; 365-370ft.; dorsal view; x 50.

Fig. 7.—*Asterigerina adelaidensis* (Howchin). Buccleuch A type section; section 56, hundred of Coneybeer; 365-370ft.; ventral view; x 50.

Fig. 8.—*Globigerina linaperta* Finlay. Type section; section 56, hundred of Coneybeer; 327-330ft.; x 75.

Fig. 9.—*Globigerapsis index* (Finlay). Type section; section 56, hundred of Coneybeer; 327-330ft.; x 75.

PLATE II

OLIGOCENE FORAMINIFERA OF THE ETTRICK FORMATION AND GAMBIER LIMESTONE

Fig. 1.—*Victoriella "plecte"* (Chapman) = *conoidea* (Rutten). Canopus bore; 500-510ft.; x 25.

Fig. 2.—*Astrononion centroplax* Carter. Millicent Hospital bore; 85-105ft.; x 50.

Fig. 3.—*Massilina torquayensis* (Chapman). Launer's No. 1 bore, section 26, hundred of Ettrick; 250-310ft.; x 25.

Fig. 4.—*Notorotalia crassimura* Carter. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 280-283ft.; dorsal view; x 50.

Fig. 5.—*Notorotalia crassimura* Carter. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 280-283ft.; ventral view; x 50.

Fig. 6.—*Eponides repandus* (Fichtel and Moll). Millicent Hospital bore; 85-105ft.; dorsal view; x 25.

Fig. 7.—*Eponides repandus* (Fichtel and Moll). Millicent Hospital bore; 85-105ft.; ventral view; x 25.

Fig. 8.—*Cibicides brevoralis* Carter. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 260-270ft.; ventral view; x 50.

Fig. 9.—*Cibicdes brevoralis* Carter. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 260-270ft.; dorsal view; x 50.

Fig. 10.—*Gyroidina* cf. *novozelandica* Finlay. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 200-210ft.; dorsal view; x 50.

Fig. 11.—*Gyroidina* cf. *novozelandica* Finlay. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 200-210ft.; ventral view; x 50.

Fig. 12.—*Gyroidina* cf. *novozelandica* Finlay. Type section, Launer's No. 2 bore, section 26, hundred of Ettrick; 200-210ft.; apertural view; x 50.

PLATE III

LOWER MIOCENE FORAMINIFERA OF THE MANNUM FORMATION

All from Type Section

Fig. 1.—*Textularia vertebralis* Cushman. F273/53; x 25.

Fig. 2.—*Gaudryina* (*Siphogaudryina*) *victoriana* Cushman. F276/53; x 25.

Fig. 3.—*Sherbornina cuneimarginata* Wade. F276/53; dorsal view; x 35.

Fig. 4.—*Sherbornina cuneimarginata* Wade. F276/53; ventral view; x 35.

Fig. 5.—*Rotalia* cf. *calcar* d'Orbigny. Dorsal view; x 75.

Fig. 6.—*Rotalia* cf. *calcar* d'Orbigny. Ventral view; x 75.

Fig. 7.—*Crespinella* sp. nov. Ventral view; x 35.

Fig. 8.—*Crespinella* sp. nov. Apertural view; x 35.

Fig. 9.—*Crespinella* sp. nov. Dorsal view; x 35.

PLATE IV

Lower Miocene Foraminifera of the Morgan Limestone and Cadell Marl

Fig. 1.—*Amphistegina lessonii* d'Orbigny. F157/52; x 20.
Fig. 2.—*Lepidocyclina howchini* Chapman and Crespin. F32/56; x 12.5.
Fig. 3.—*Gypsina howchini* Chapman. F80/56; x 25.
Fig. 4.—*Clavulinoides victoriensis* Cushman. F9/56; x 25.
Fig. 5.—*Austrotrillina howchini* (Schlumberger). F129/53; x 50.
Fig. 6.—*Calcarina verriculata* (Howchin and Parr). F112/53; ventral view; x 25.
Fig. 7.—*Calcarina verriculata* (Howchin and Parr). F112/53; dorsal view; x 25.
Fig. 8.—*Parellina craticulatiformis* Wade. F9/56; x 25.
Fig. 9.—*Globigerinoides bisphaerica* Todd. F83/56; x 75.
Fig. 10.—*Globigerina apertura* Cushman. Section 377, hundred of Gordon, shaft 18; 267-296ft.; x 75.
Fig. 11.—*Globigerinoides triloba immatura* LeRoy. F13/56; Morgan railway station; 42ft. from base of section; x 75.

PLATE V

Miocene Foraminifera of the Pata Limestone

All from Standard Subsurface Section on Section 377, hundred of Gordon

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

PLATE VI

Upper Miocene or Lower Pliocene Foraminifera of the Bookpurnong Beds

Section 377, hundred of Gordon (78-105ft.)

Fig. 1.—*Sigmoilopsis lapidigera* (Howchin and Parr); x 50.
Fig. 2.—*Siphonaperta ammophila* (Parr); x 50.
Fig. 3.—*Flintina intermedia* (Howchin) spinose variety; x 50.
Fig. 4.—*Elphidium pseudonodosum* Cushman; x 70.

PLATE VII

Lower Miocene Mollusca of the Cadell Marl Lens

Type Section—Natural Size, Unless Otherwise Stated (Tate Collection, University of Adelaide)

Fig. 1.—*Turritella (Maoricolpus) murrayana* Tate. Holotype T1400-B.
Fig. 2.—*Triton radialis* Tate. Holotype T462D.
Fig. 3.—*Murex basicinctus* Tate. Holotype T417A.
Fig. 4.—*Triton tortirostris* Tate. Paratype T510C.
Fig. 5.—*Austrovoluta antiscalaris* (McCoy). South Australian Department of Mines collection.
Fig. 6.—*Murex pachystirus* Tate. Holotype T410.
Fig. 7.—*Peristernia morundiana* Tate. Holotype T574B.
Fig. 8.—*Glycymeris subtrigonalis* (Tate). Topotype.
Fig. 9.—*Glycymeris subtrigonalis* (Tate). Topotype South Australian Department of Mines collection.
Fig. 10.—*Corbula ephamilla* Tate. Paratype T335A.

PLATE VII—*continued*

Fig. 11.—*Corbula ephamilla* Tate. Paratype T335B.

Fig. 12.—*Cucullaea corioensis* McCoy.

Fig. 13.—*Cucullaea corioensis* McCoy. South Australian Department of Mines collection.

Fig. 14.—*Verticordia rhomboidea* Tate. Holotype T1082; x 8.

Fig. 15.—*Verticordia rhomboidea* Tate; x 8.

PLATE VIII

EOCENE, OLIOGOCENE, AND MIOCENE ECHINOIDS AND MOLLUSCA

Natural Size, Unless Otherwise Stated

Figs. 1 and 2.—*Australanthus longianus* Gregory. F148/52; section 13, hundred of Sherlock; 252-254ft.; Upper Eocene, Buccleuch A.

Figs. 3 and 4.—*Monostychia australis* Laube. F107/55; section 229E, hundred of Anna; Morgan Limestone.

Figs. 5 and 6.—*Lovenia forbesi* T. Woods. Section 5, hundred of Bowhill; Mannum Formation.

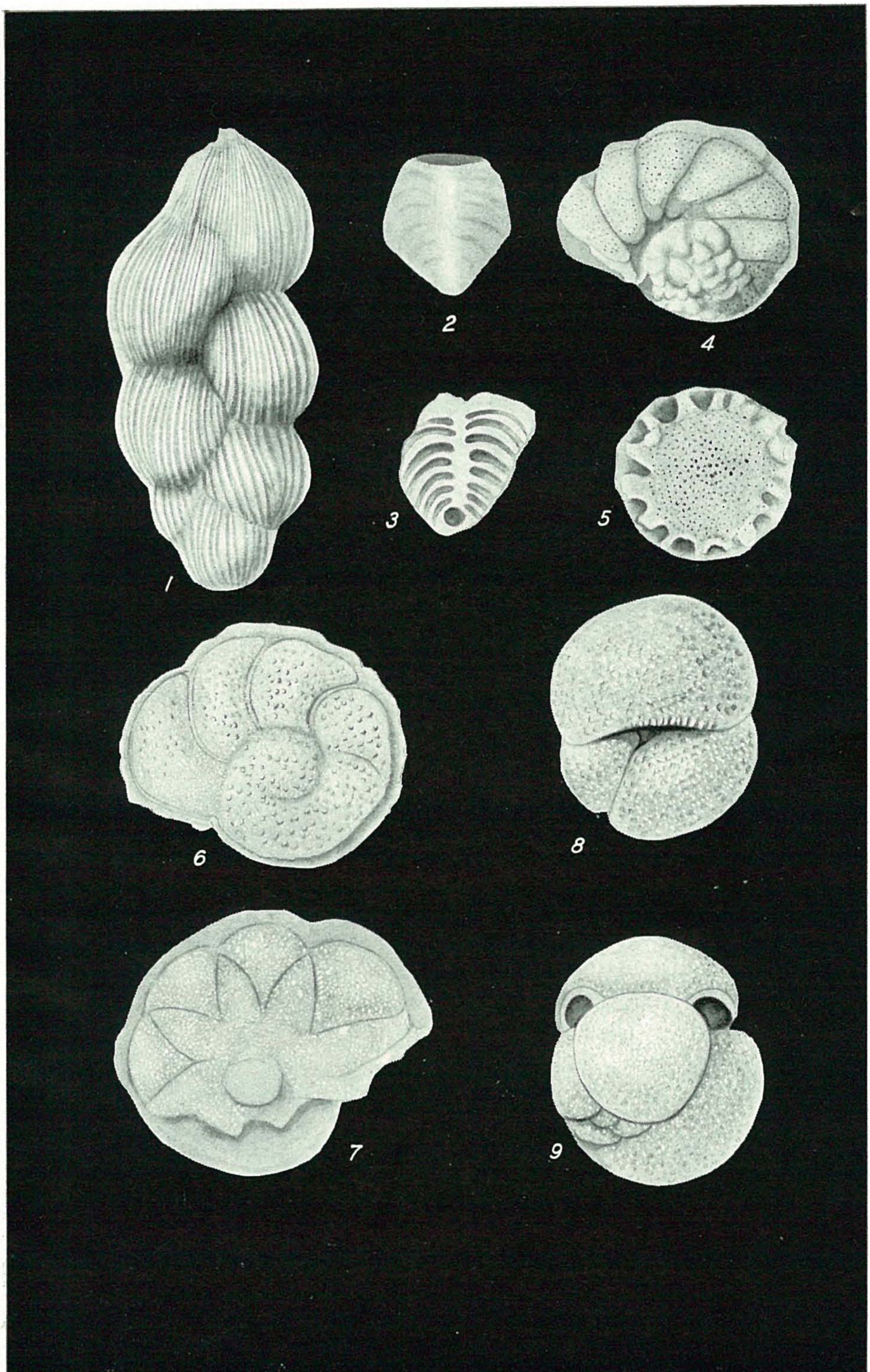
Fig. 7.—*Chlamys gambierensis* (T. Woods). Right valve.

Fig. 8.—*Chlamys gambierensis* (T. Woods). Left valve; Naracoorte Limestone, type section.

Fig. 9.—*Turritella aldingae* Tate. Highways and Local Government Department bore No. 2, Coombe Siding; 306-320ft.; Eocene; Knight Group.

Fig. 10.—*Dentalium* (*Gadilina*) *tatei* Sharp and Pilsbry. Section 56, hundred of Coneybeer; 388-391ft.; Eocene; Knight Group.

Drawings on plates I to VI were made by the author, with the aid of a camera lucida. Most of the drawings on plates VII and VIII were made by Miss G. E. Num.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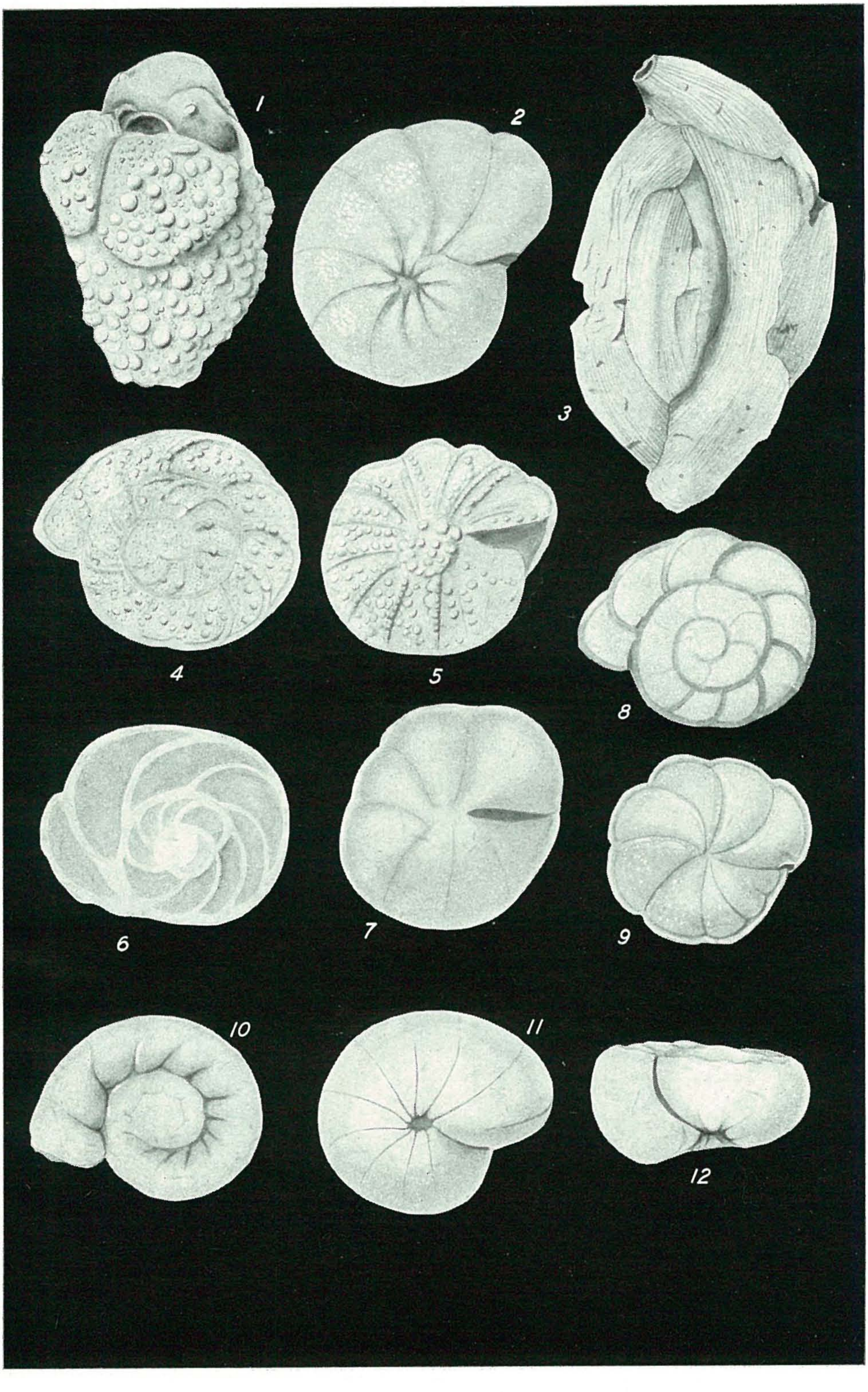
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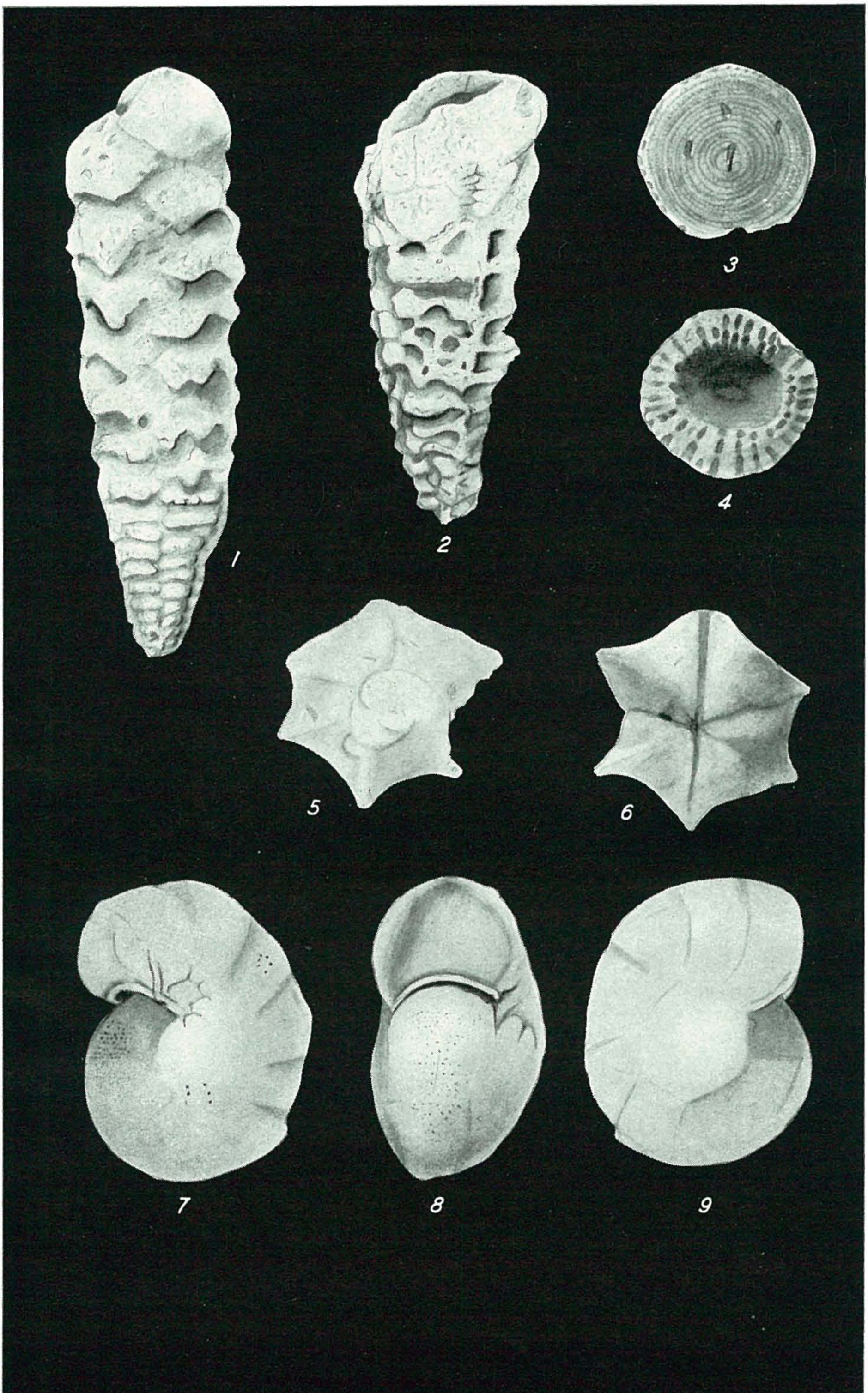
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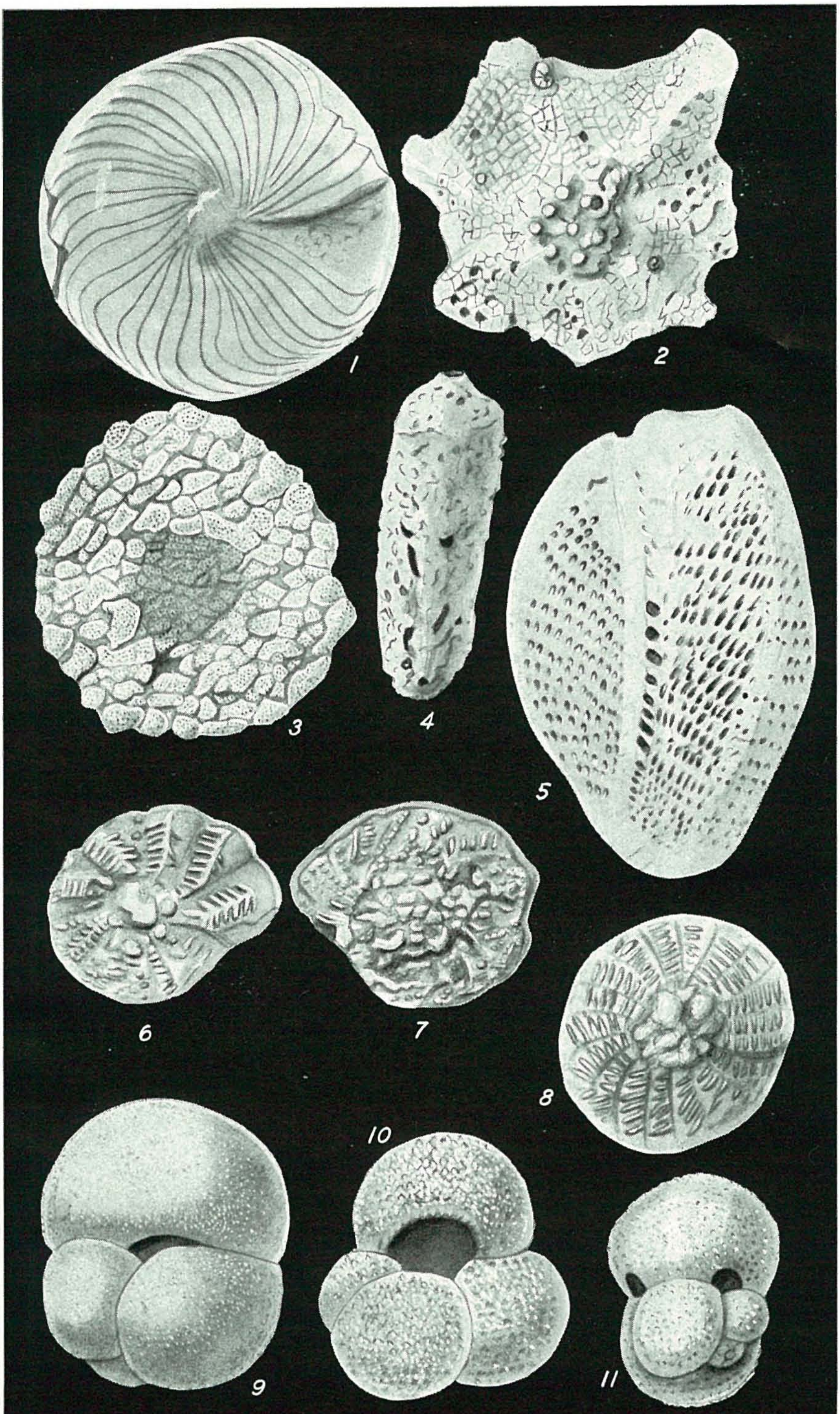
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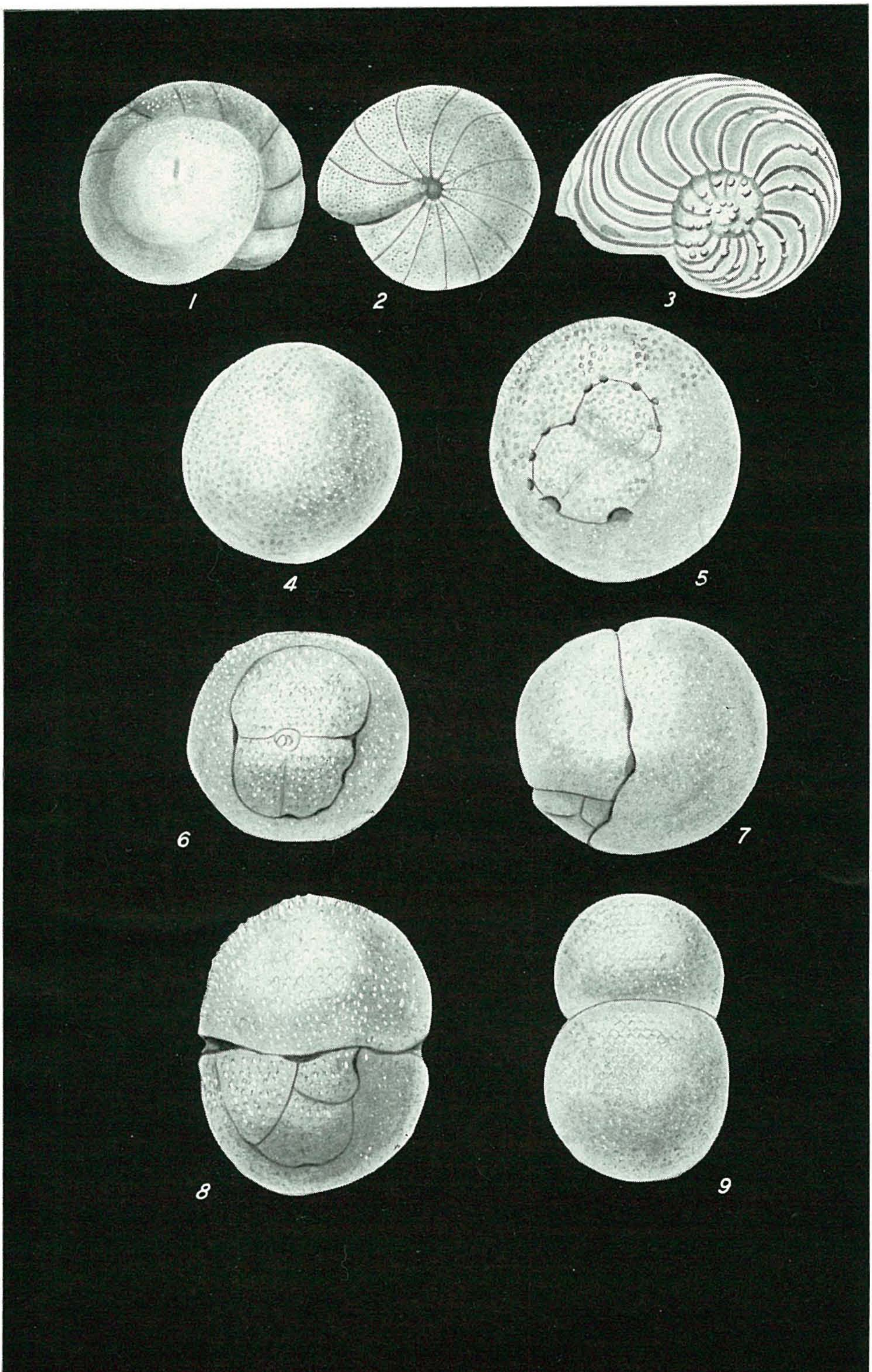
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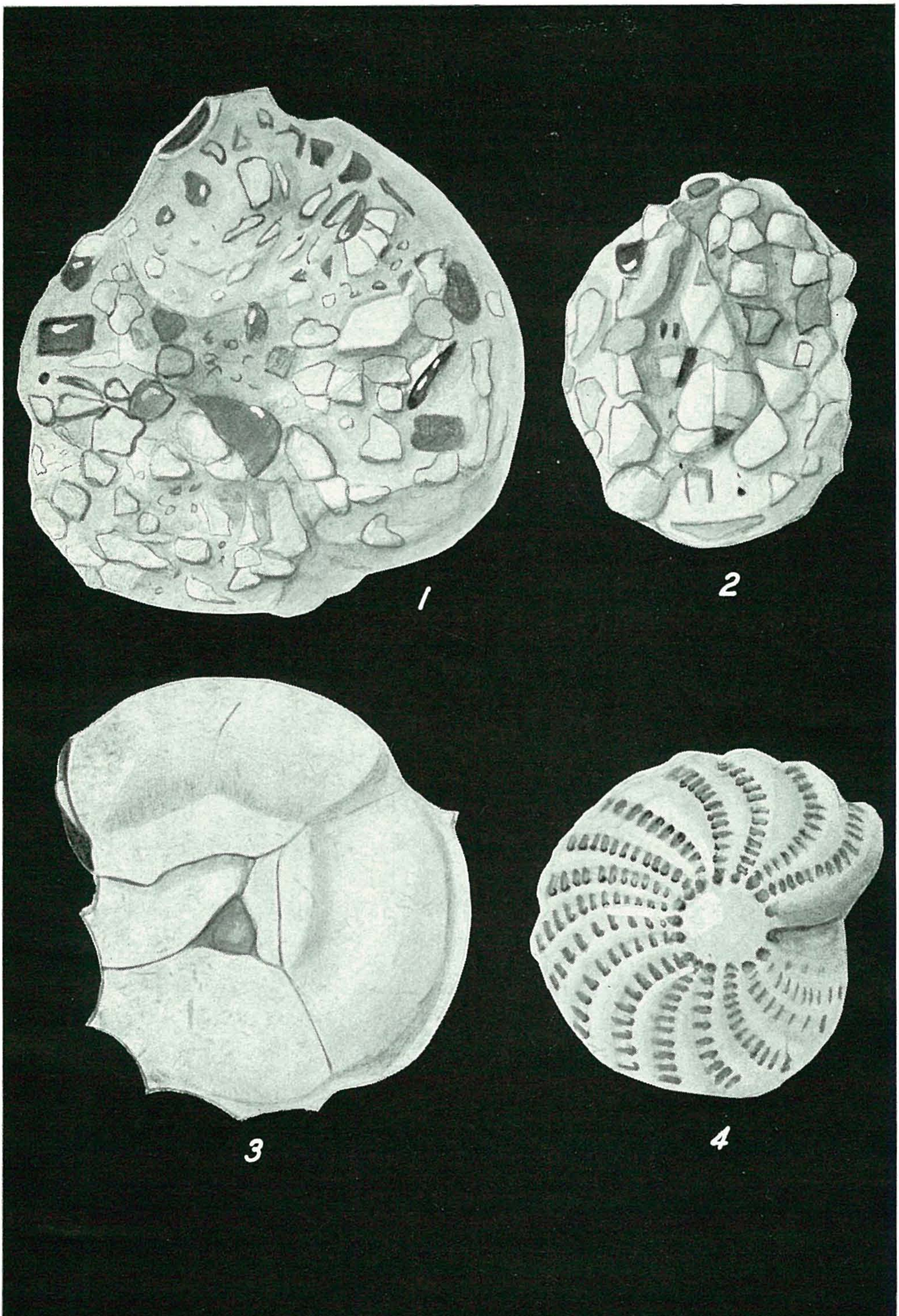
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PLATE VII

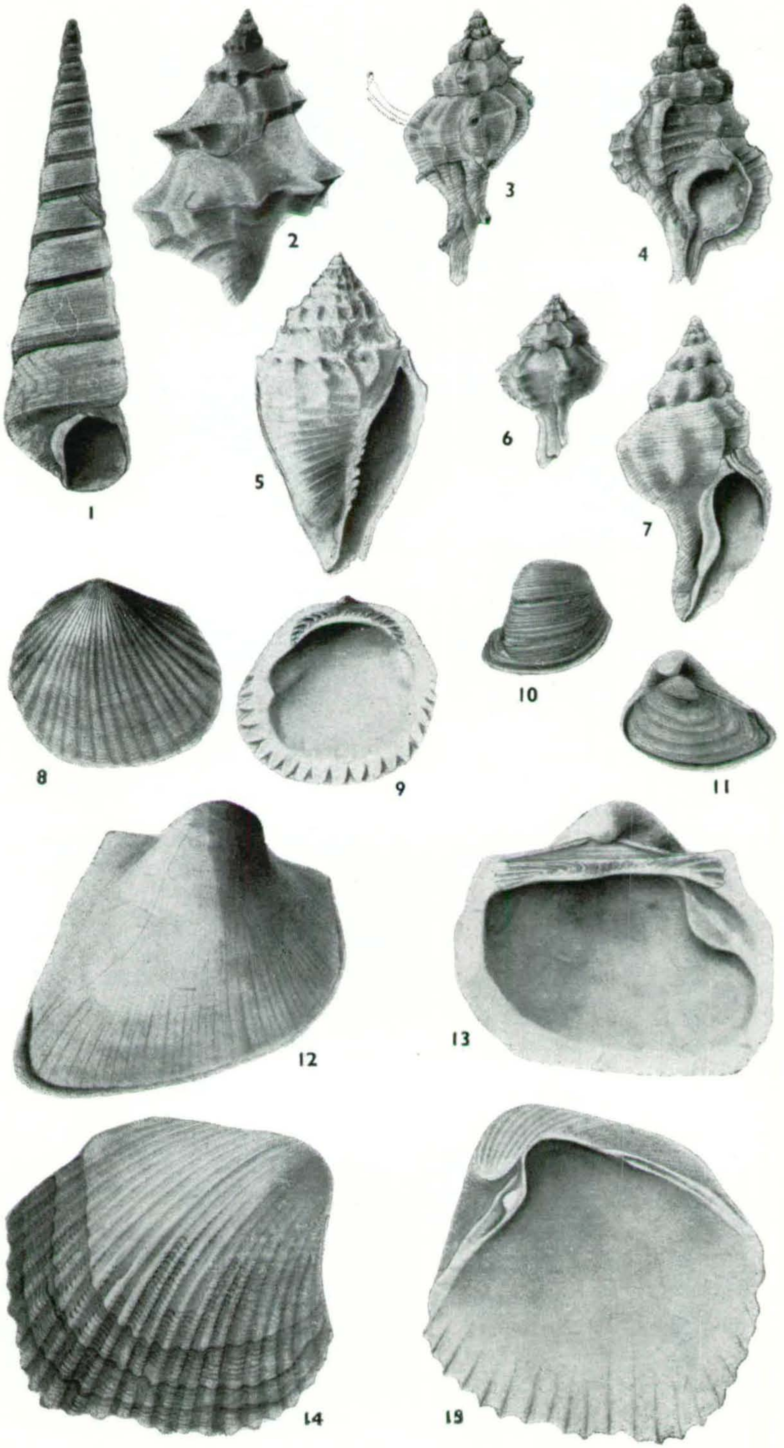
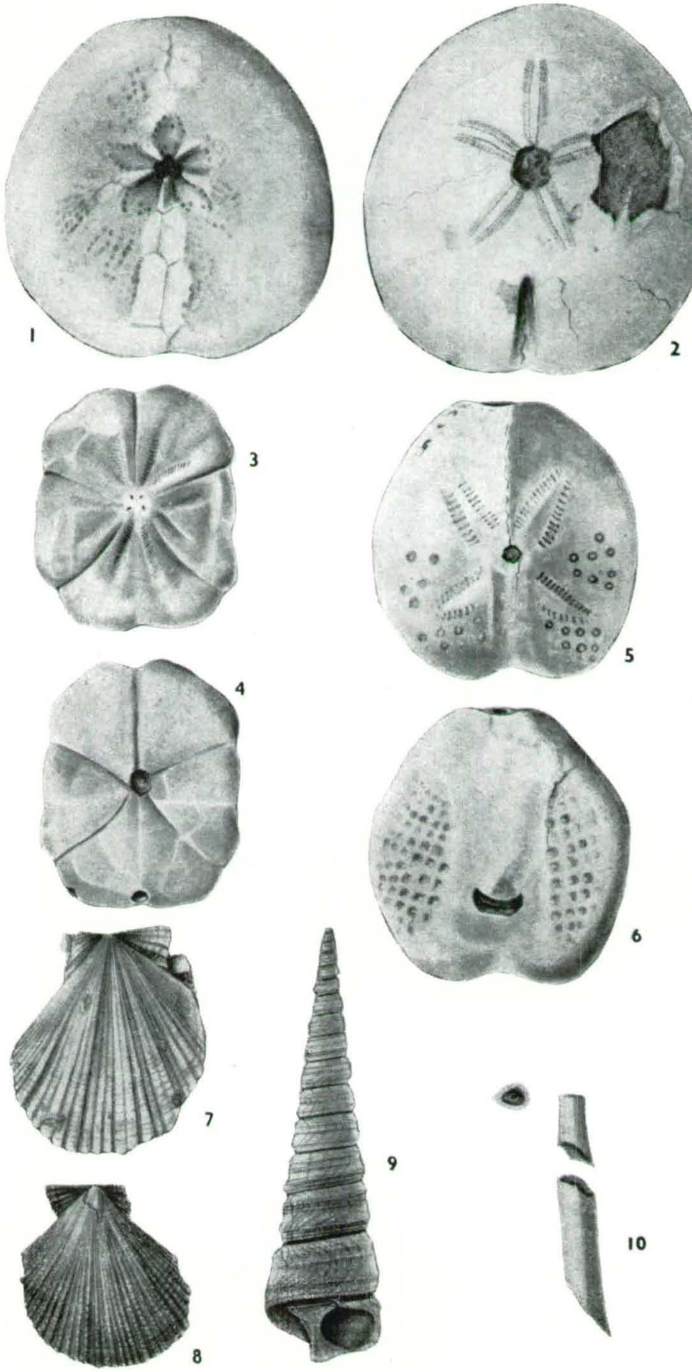


PLATE VIII



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