DEPARTMENT OF MINES
SOUTH AUSTRALIA

Geological Survey of South Australia

BULLETIN No. 42

Cainozoic Foraminifera and Stratigraphy of the Adelaide Plains Sub-Basin, South Australia

by

J. M. LINDSAY
ASSISTANT SENIOR PALAEONTOLOGIST

Issued under the authority of
THE HON. R. C. DEGARIS, M.L.C.
MINISTER OF MINES

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Letter of Transmittal

Geological Survey Office,
Department of Mines,
Adelaide,
South Australia 5000

3*rd November,* 1969

To the Hon. the Minister of Mines,

Usage of groundwater from the Adelaide Plains Sub-Basin of the St. Vincent Basin has grown so rapidly over recent years, as to require legislation for its control, introduced in 1967. *Departmental activities on the Northern Adelaide Plains have involved studies of old bore data and drilling of many observation bores.*

Palaeontological studies of the many samples arising from this work have largely been the responsibility of J. M. Lindsay of the Department's Palaeontological Section. The present report is the result of six years intermittent work and represents a significant contribution to the subsurface stratigraphy of the area, and to a fuller understanding of the groundwater problems.

Approval is now sought to print the report as a Bulletin of the Geological Survey.

T. A. BARNES, Government Geologist

Approved,

R. C. DeGARIS, Minister of Mines

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Cainozoic Foraminifera and Stratigraphy of the Adelaide Plains Sub-Basin, South Australia

SUMMARY

Summarised stratigraphic data are presented for 93 bores in the Adelaide Plains Sub-Basin of the St. Vincent Basin from hundred of Dublin to hundred of Noarlunga, including the Adelaide City area on the Para Fault Block. For the purposes of this Bulletin, the Cainozoic succession (Middle Eocene to Recent) is divided into 14 units which are primarily rock units or (particularly in the Pliocene and Quaternary) groupings of rock units. The maximum total thickness exceeds 2,000ft. (610 m.). Characteristic lithologies and microfaunas are outlined, and units are related to their type sections. The emphasis is on Eocene to Miocene stratigraphy in marine facies.

A new formation name *Carisbrooke Sand* is proposed for the usually unfossiliferous ?Plio-Pleistocene quartz sands between the fossiliferous Pliocene beds and the Pleistocene Hindmarsh Clay in the Sub-Basin, particularly in the eastern part.

Aggregate-range charts are presented for the planktonic foraminifera (42 species or varieties), and for 53 selected species of benthonic foraminifera. Notwithstanding the relatively impoverished nature of the planktonic microfaunas (numbers, diversity), a considerable measure of local planktonic zonation is possible for the Upper Eocene to ?Middle Miocene succession. *Flosculinella bontangensis* (Rutten) is recorded for the first time from the St. Vincent Basin.

INTRODUCTION

During the past six years the author has examined nearly 3,000 samples from about 100 bores in the St. Vincent Basin (mostly Adelaide Plains) which have been submitted by other Sections of the Geological Survey of South Australia for palaeontological and stratigraphic report. That this represents only a fraction of the total drilling in the Adelaide Plains by the Department of Mines and private agencies, serves to emphasize the degree to which the underground water resources of this area have been tapped. In 1967, a census showed that pumping from the pressure aquifers alone was about 7 x 10^9 gallons per year (32 x 10^9 litres per year) and it has been recently concluded that "the continued deepening and widening of the cone of drawdown indicates that the overpumping rates still far exceed the intake" (Department of Mines, 1969). Legislation to control drilling and pumping in Proclaimed Areas of the Adelaide Plains has been in force since 1967. It is against such a background that urgent and continuing hydrogeological studies by the Department of Mines have needed and used the results of detailed stratigraphic micropalaeontology.

Most publications of the past 15 years which have dealt with the regional stratigraphy of the Adelaide Plains have done so only in the form of generalised review. With the data now available (at March, 1969), a more specific detailed stratigraphic summary and interpretation is both possible and desirable.

The bores plotted on the Locality Plan, Fig. 1, are identified in Appendix 1, and a stratigraphic summary of each is given in Appendix 2. Figs. 2, 3, and 4 name and briefly describe the units used, and by means of eight cross-sections show correlations from bore to bore, and illustrate structure. Lithological symbols have not been used, for to be sufficiently meaningful at this scale they would have overcrowded the Figures. Figs. 5 and 6 respectively show summational ranges (drawn between limits of aggregated local occurrences) of most of the planktonic foraminifera encountered, and of selected benthonic species.

The text discusses some of the issues raised by the Tables and Figures, and is an explanatory extension of them.

The stratigraphic usefulness of foraminiferal microfossils lies in their general abundance in marine sediments, their preservation in cable-tool sludges and rotary cuttings, and in the rapid and well-documented advance of foraminiferal studies in recent years. As their stratigraphic ranges have become better known, many species can now be used for correlation with more confidence. Schemes of local planktonic foraminiferal zonation proposed by Lindsay (1967) and Ludbrook and Lindsay (1969) have been used where possible to subdivide, correlate, and date the Upper Eocene to ?Middle Miocene part of the Cainozoic succession in the area. It is proposed to deal with the systematics of these prolific foraminiferal faunas in subsequent papers, but some of the species referred to in the text are illustrated in Plates 1 and 2.

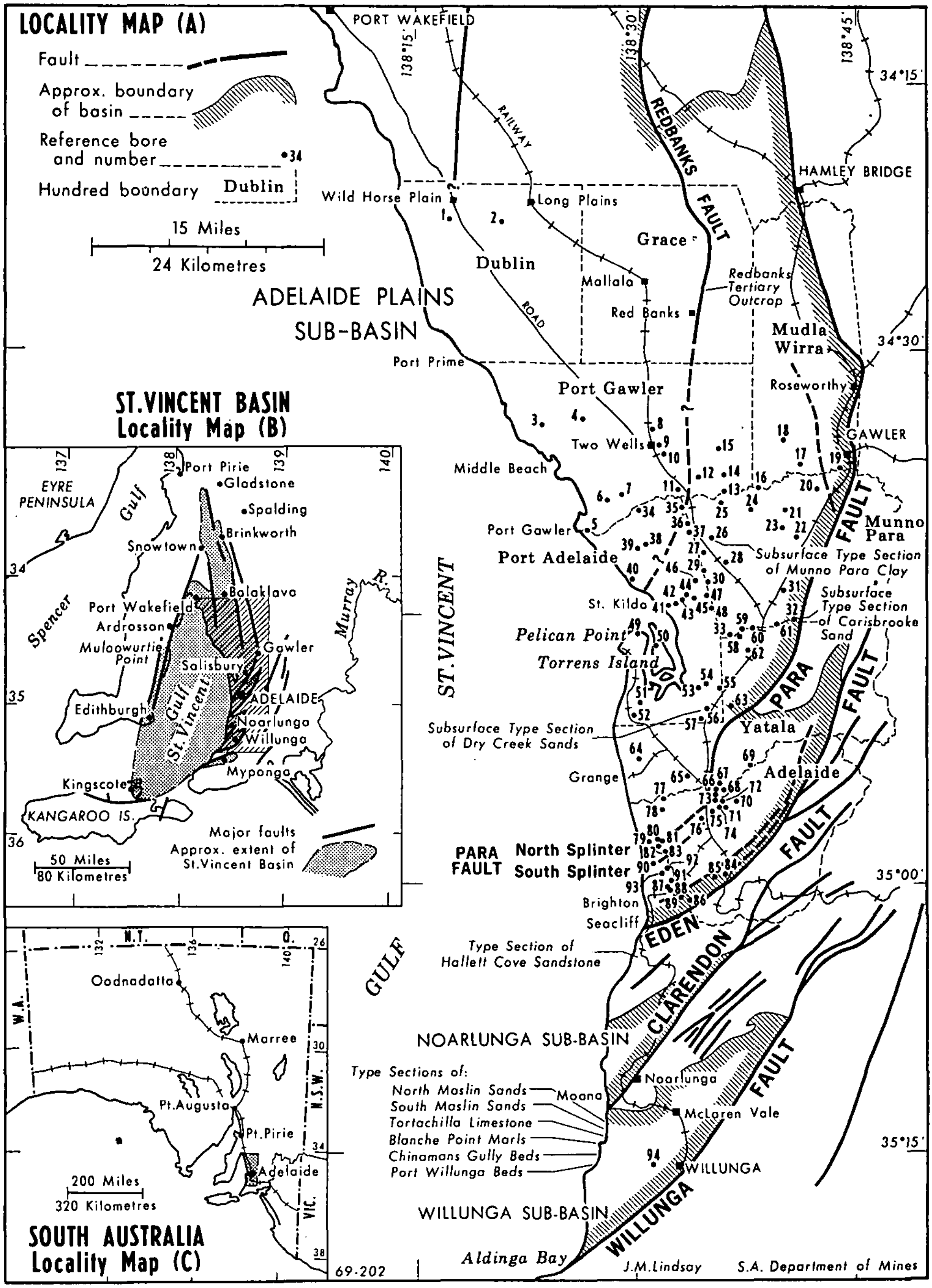

Fig. 1. Locality maps, and plan showing bore locations, Adelaide Plains Sub-Basin.

METHODS

Most of the bores examined are water bores or stratigraphic and observation bores drilled by the Department of Mines. Bores 3 and 64 were drilled during petroleum exploration. A number are foundation test bores for buildings in the Adelaide City area. In most cases the bore materials have been examined personally by the writer for lithology, foraminifera, and stratigraphic interpretation. Only logs of some important bores are now available, but the writer accepts responsibility for the interpretations shown.

Unwashed bore sludges, cuttings, and cores, are stored in the Department of Mines Core Laboratory. All washed residues, microfaunal preparations, and palaeontological record cards are held by the Palaeontology Section of the Geological Survey of South Australia. All available information on each bore is systematically filed in the Records Section of the Department of Mines.

Heavy liquid flotations of planktonic foraminifera were frequently made from the washed residues. Carbon tetrachloride was used for many years, but in view of its high toxicity a change was made recently to the use of bromoform diluted with dehydrated alcohol to a Specific Gravity of 1.8-2.0 (Gibson and Walker, 1967).

Washed residues were sieved to coarse, medium and fine size grades, and each fraction was picked with reasonable thoroughness. Relative abundance of species is indicated in the text thus:

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

The photographs of foraminifera in Plates 1 and 2 were taken with a Leitz Laborlux microscope. For those photographed in incident light (darkfield illumination), a Leitz Ultropak lighting unit was used in combination with a 6.5X or 3.8X objective and relief condenser. For the sections of *Flosculinella* and *Lepidocyclina* a Leitz Photar objective (f = 63 mm.) was used with transmitted light and substage condenser. Adox KB 14 film was used and prints were made on Agfa Brovira paper.

The "Reference Numbers" used for the bores are *ad hoc* and are not related to other schemes such as the "Index Numbers" of Miles (1952).

The "State Number" in Appendix 1 refers to the State Bore Numbering System devised by the Department of Mines to number uniquely each bore in the State. For the Adelaide Plains, the numbers variously involve hundred and section control, Metropolitan 10-Chain Plan control, Adelaide City 4-Chain Plan control (Town Acres, Parklands) and numerical order of recognition.

THE ADELAIDE PLAINS SUB-BASIN

Fig. 1 will show that the writer agrees with Glaessner and Wade (1958), and Ludbrook (1967a, 1969a), rather than with Shepherd (1968), on the extent and nature of the St. Vincent Basin. Shepherd recognised the St. Vincent Basin as extending only from the Eden Fault northwards to Port Wakefield and beyond Snowtown. This is in fact the Adelaide Plains Sub-Basin. It is clear that the St. Vincent Basin must also include the Cainozoic strata along the east coast of Yorke Peninsula, those in the Kingscote-Cygnet Sub-Basin on Kangaroo Island, those in the Myponga and Meadows Valleys, and those in the Willunga and Noarlunga Sub-Basins, besides the Cainozoic strata assumed to underlie Gulf St. Vincent itself and penetrated by Beach Petroleum N.L. Troubridge No. 1 Well, on Troubridge Shoal east of the "heel" of Yorke Peninsula.

From Fig. 1, it is evident too that the Adelaide Plains Sub-Basin contains most of the onshore strata of the St. Vincent Basin. It also contains the thickest and best-developed Cainozoic section east of Gulf St. Vincent, a section over 2,000ft. (610 m.) thick in bore 65.

Subsurface structure is illustrated by Figs. 1-4. Very gently-dipping strata which thin to the north and thicken towards the Para Fault, are cut by a series of arcuate, steep, normal faults with measurable displacements. A basement high and an associated fault in the vicinity of the River Light, mark a prominent hinge zone. The Redbanks Fault (*cf.* Shepherd, 1968) fractures a broadly anticlinal structure, but there are insufficient subsurface data to enable the fault and its displacements to be drawn more confidently. The sequences in bores 84, 85, 86 and 89, demand a continuation of the Burnside Fault as shown. The marginal lignitic sands intersected in bore 19 near Gawler (Appendix 2), represent restricted deposition on an intermediate fault block formed by a splinter of the Para Fault. This structure was first recognized by Rowan (1964 unpub.) on geophysical evidence.

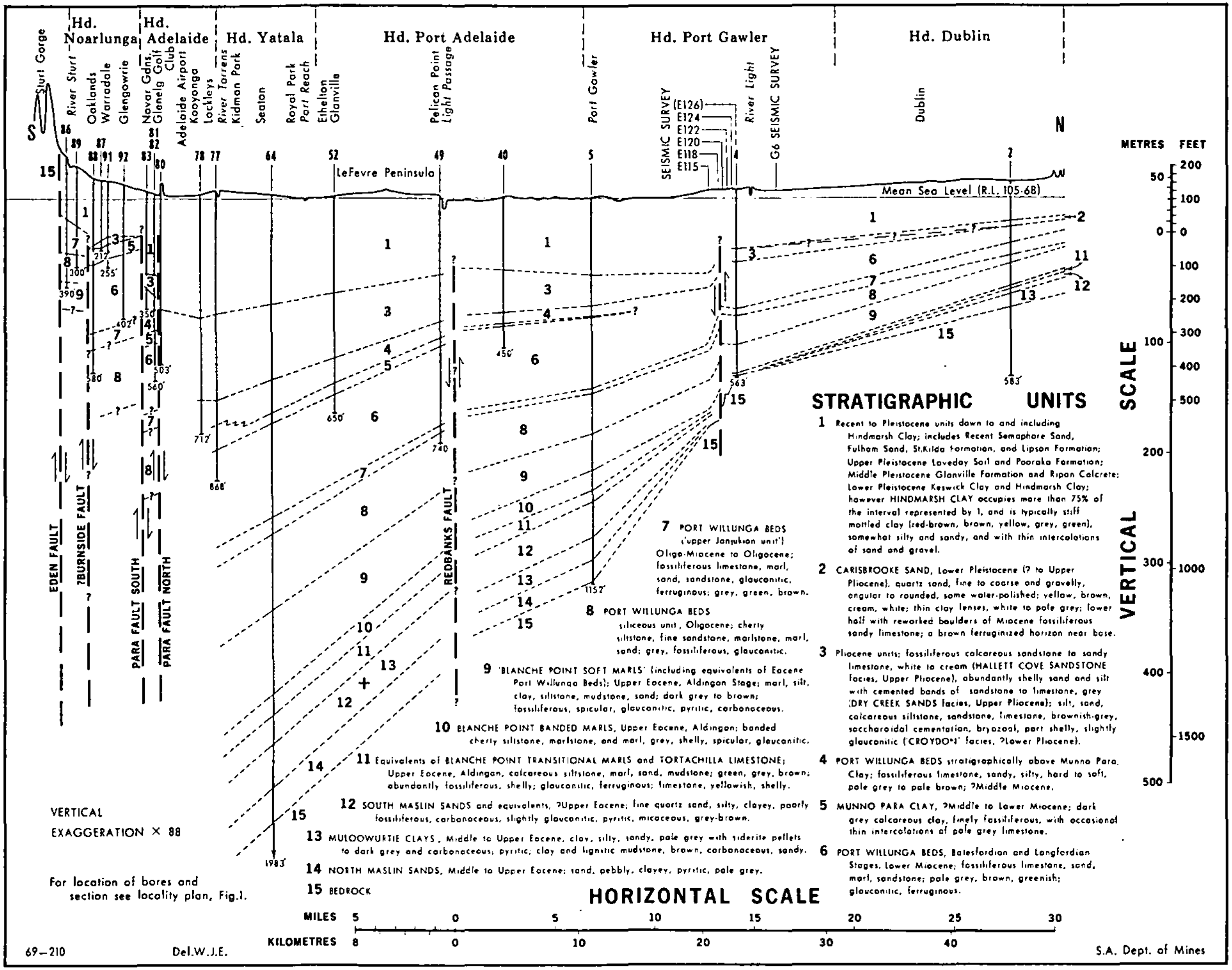

Fig. 2. South-North section through western part of Adelaide Plains Sub-Basin.

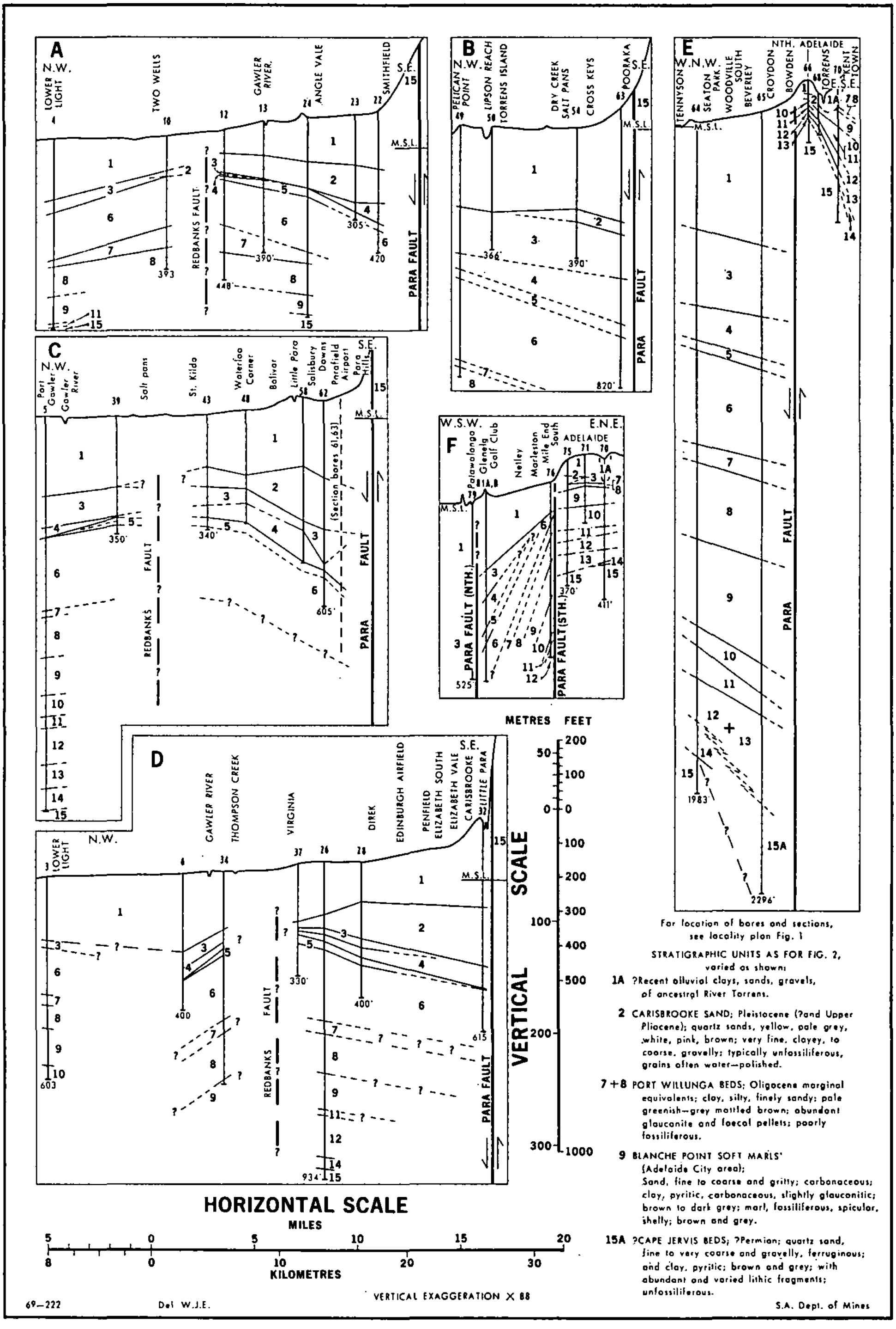

Fig. 3. Transverse sections through Adelaide Plains Sub-Basin.

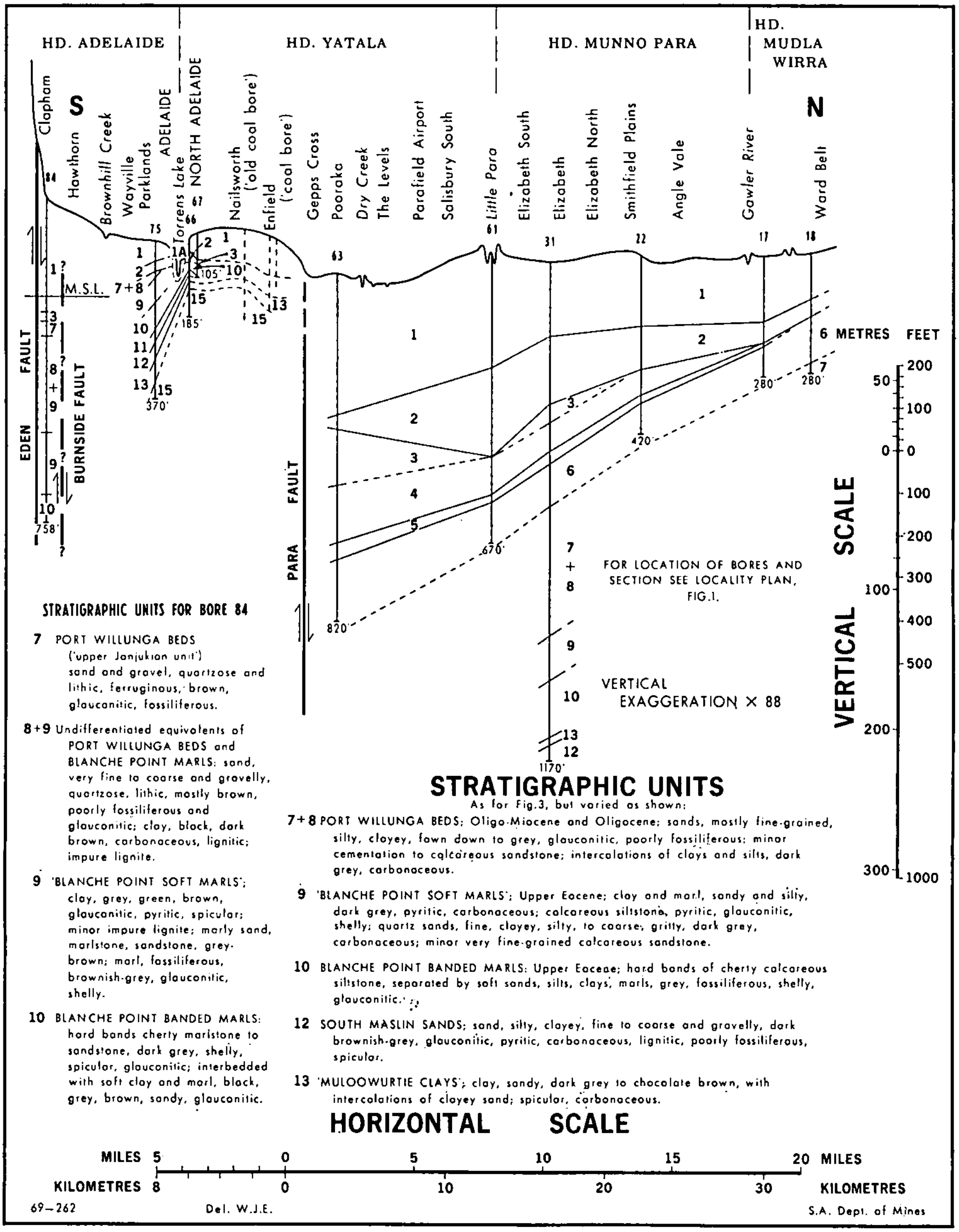

Fig. 4. South-North section through eastern part of Adelaide Plains Sub-Basin.

PREVIOUS WORK

In the 90 years since Scoular's work on Quaternary stratigraphy and water supply in the hundred of Munno Para (Scoular, 1879), many earth scientists have contributed to the stratigraphy and palaeontology of the Cainozoic succession in the Adelaide Plains. The stimulus has often been a hydrogeological problem such as inadequate water quality or supply, which has led to deeper, more intensive, or more widespread subsurface exploration, which in turn has needed and thus stimulated stratigraphic and palaeontological advance. Miles (1952, pp. 14, 15) and Ludbrook (1954) contain references to most of the significant papers on the geology and palaeontology of the Adelaide Plains for the period 1879-1951.

It is logical to consider contributions pre-1952 and post-1952, for in that year, its production necessitated both by a decade of growing crisis in Adelaide's water supply and by the data of intensive drilling to meet the need, appeared Bulletin 27, the best-documented account of the geology and underground water resources of the Adelaide Plains which has yet been published (Miles, 1952). Table XIX in Appendix I of this compilation provided a summary of a wide range of factual information on the strata and waters of 404 reference bores. The Bulletin still is the main published compilation of bore data on the Adelaide Plains despite subsequent advances and changes in dating and stratigraphic interpretation.

Appendix III (Crespin and Cotton, 1952) and Appendix IV (Cotton, 1952) supplied the palaeontological basis for the age datings used in the Bulletin, but biostratigraphic advances since then, foreshadowed by Glaessner (1951), have rendered these datings unacceptable to the following extent:

(1) Eocene strata, undoubtedly present in some of the bores then available, were not recognized (*e.g.* bore 70, Miles Index No. 216).

(2) Beds with Crespin and Cotton's lowest zone, the "zone of *Massilina torquayensis*", were dated—correctly it seems now —as Janjukian, but the Janjukian Stage of the Australian Tertiary is Oligocene and Oligo-Miocene, not middle Miocene in age (*cf.* Glaessner's *Victoriella* zone, 1951).

(3) Beds with their middle zone, the "zone of *Sherbornina atkinsoni*" are of early Miocene age (Longfordian Stage), not middle Miocene.

(4) For their topmost zone they used Glaessner's Lower Miocene (1951) "zone of *Austrotrillina howchini*", but dated beds containing it as "upper middle Miocene". These beds are of Lower to ?Middle Miocene age.

(5) The Pliocene beds ("Adelaidean" is no longer used) are now considered to be mostly Upper Pliocene (Ludbrook 1963, 1969a), and not all Lower Pliocene.

Following publication of this Bulletin, there was a productive period of seven years in which the following contributions were made to the stratigraphy and palaeontology of the Adelaide Plains.

Reynolds (1953) described the coastal Tertiary outcrops in the Willunga Sub-Basin and by recognizing and formalizing a succession of distinctive rock units set a rock-stratigraphic standard for the St. Vincent Basin. The locations of his type sections are shown in Fig. 1.

Following her consultative work for Bulletin 27, Crespin (1954) presented an independent account of the foraminifera and stratigraphy of the Adelaide Plains, Noarlunga, and Willunga Sub-Basins. However her stratigraphic nomenclature has had to yield priority to that of Reynolds, and her term "Oaklands Limestone" (= Longfordian and Batesfordian Port Willunga Beds + Munno Para Clay) has not found general acceptance. Her definition of *Hallett Cove Sandstone* named a facies of the Pliocene complementary to Glaessner's Dry Creek Sands (1951).

Ludbrook (1954) first contributed a general study of the molluscan fauna of the Adelaide Plains Pliocene in its stratigraphic setting; then monographed these Pliocene shells (1955, 1956b, 1957, 1958); and finally (1959b) indicated something of the characteristics and widespread nature of the Pliocene marine transgression.

Glaessner and Wade (1958), using much original material, compiled an informative and still highly relevant chapter on the development and stratigraphy of the St. Vincent Basin and its Sub-Basins.

A further seven-year period, 1962-1969, has seen published the following contributions which have significant bearing on the subsurface stratigraphy of the Adelaide Plains, and which will be mentioned specifically in later sections: Steel (1962), Ludbrook (1963, 1967a, 1969a), Firman (1963, 1966, 1967a, 1967b, 1969), Wade (1964), Miller (1965), Lindsay and Shepherd (1966), Lindsay (1967, 1968), Stuart (1967), Allchurch (1967a, 1967b), Shepherd (1968), and Department of Mines (1969).

During 1964-1967, in a series of unpublished Departmental reports involving stratigraphic and foraminiferal studies, the writer described:

(1) deep foundation test bores for structures in the Adelaide City area (Lindsay, 1964a, 1964b; 1965a),
and

(2) other bores in the Adelaide Plains, mostly water, stratigraphic, and observation bores (Lindsay, 1965b, 1965c, 1965d; 1966a, 1966b; 1967).

These and other unpublished reports referred to herein are listed separately after the list of published references.

At the culmination of an intensive drilling programme, and with a view to providing realistic answers to pressing questions involving underground water resources and exploitation, a comprehensive study (Department of Mines, 1968 unpub.) was made by a team of Department of Mines specialists. The writer contributed a stratigraphic and micropalaeontological Appendix (Lindsay, 1968 unpub.), much of whose detail cannot be included here, but is available in Department files.

LOCAL PLANKTONIC FORAMINIFERAL ZONES

INTRODUCTION

The planktonic zones used here and shown in Fig. 5 are essentially those proposed by Lindsay (1967) and Ludbrook and Lindsay (1969), which in turn were adapted where possible from those of Jenkins (1965, 1967).

However in the Adelaide Plains Sub-Basin, zones below the *Turborotalia aculeata* Zone have not been identified; nor have the *Globoquadrina dehiscens dehiscens* Zone and the *Orbulina universa* Zone. Because of the rarity of *Globigerina labiacrassata* Jenkins and *G. angiporoides angiporoides* Hornibrook in Oligocene Port Willunga Beds, the alternative *Chiloguembelina cubensis* Zone is used instead.

Some correlations between these local planktonic zones and those of Trinidad, Venezuela, or East Africa, were outlined by Ludbrook and Lindsay (1969) and Ludbrook (1969a).

EOCENE ZONES

Turborotalia aculeata Zone

This Zone was first adapted by the writer (1967) from Jenkins' *Globorotalia inconspicua inconspicua* Zone (1965), and was further defined by Ludbrook and Lindsay (1969). The lower boundary of the Zone is put at the top of the range of *Acarinina primitiva* (Finlay), but this species has not yet been found in the St. Vincent Basin. The *aculeata* Zone, in the absence of evidence to the contrary, is therefore carried down to the base of stratigraphic unit 11 in Fig. 5. This is the lowest level in the Adelaide Plains Sub-Basin from which *T. aculeata* has been found. The upper boundary of the *aculeata* Zone is the extinction of the zone species. *T. aculeata* (Jenkins) from the Adelaide City area is figured in Pl. 1, Figs. 28, 32.

Two subzones of the *aculeata* Zone were recognized by Ludbrook and Lindsay, one of the distinguishing criteria being the presence of *Truncorotaloides collactea* (Finlay) only in the lower of the subzones. In the area studied, only two specimens of *T. collactea* have been recovered by the writer, one from low in Blanche Point Banded Marls (bore 64), and the other (the specimen figured in Pl. 1, Figs. 6, 11) from "Blanche Point Soft Marls" in bore 20, where however, sandy facies could mean poor development of Banded Marls. These two instances thus indicate the presently-known extent of the lower subzone in the Adelaide Plains Sub-Basin.

The *Hantkenina alabamensis* Zone shown in Fig. 5, was proposed by Glaessner (1951) in the sense of a total-range zone, but was not included in the main scheme of Ludbrook and Lindsay because although *Hantkenina alabamensis compressa* Parr "is locally common in the Adelaide Plains Sub-

Basin of the St. Vincent Basin, its occurrence elsewhere is extremely rare, and its utility as a zone fossil consequently restricted." In the St. Vincent Basin and the Gambier Embayment it was shown to occur within the *T. aculeata* Zone. The statement also made that "it occurs near the base of the upper subzone of the *T. aculeata* Zone" must now however be corrected, at least in regard to the St. Vincent Basin, to read "occurs in the lower subzone of the *T. aculeata* Zone", for in this Basin *Hantkenina* is known only from a stratigraphic level below that of the latest *Truncorotaloides collactea,* in either Blanche Point Transitional Marls, as at Maslin Bay, or in undifferentiated unit 11, as in bore 94 (Glaessner and Woodard, 1956; Lindsay, 1966c unpub.) and in the Adelaide City area (bores 66A, 67, 68A, 68B, 72, 73A-C). Where it is present, *Hantkenina* establishes a useful, thin marker zone.

The question arises on morphological grounds as to whether the *Hantkenina* of the St. Vincent Basin is in fact *H. alabamensis compressa,* especially in view of the occurrences of *Truncorotaloides collactea* noted above. Studies have begun on the ontogeny of South Australian *Hantkenina* by plotting Ramsay's pattern of measurements relating diameter of test to the ratio:

$$\frac{\text{height of aperture}}{\text{height of apertural face}}$$

(Ramsay, 1962). Results from some 40 specimens show that all the forms from Adelaide, Maslin Bay (*e.g.,* Wade, 1964, pl. 1, fig. 1) and Kingston S.E. (Ludbrook, 1963), plot as one rather variable species, and are con-specific with topotypes of *H. alabamensis compressa* from Brown's Creek, Victoria (Parr, 1947). The plot also shows a close and in fact overlapping relationship between the parameters of this species, and those of *Hantkenina australis* Finlay and *H. primitiva* Cushman and Jarvis. There is a more distant relationship to *H. liebusi* Shokhina despite a first impression of close morphological resemblance. When specimen size and ontogeny are considered as well as the morphology of chambers and tubulospines, Parr's suggestion remains adequate—that the early stages of the South-East Australian species show some of the characters of more "primitive" types than *H. alabamensis.* Pl. 1, Fig. 22 shows a mature topotype specimen of *H. alabamensis compressa,* and for comparison Pl. 1, Fig. 37 an immature specimen from the same sample. The specimen figured in Pl. 1, Figs. 35, 36, is from the Adelaide City area. For the present, all are accepted as *H. alabamensis compressa.*

The *T. aculeata* Zone was shown (Lindsay, 1967) to occur in the basal 22ft. (6.7 m.) of the type section of Port Willunga Beds, overlain by the *Subbotina linaperta* Zone, and together with it spanning the Aldingan and Upper Eocene portion of type Port Willunga Beds. In the Adelaide Plains, subsurface litho- and biostratigraphic correlatives of Aldingan Port Willunga Beds are so difficult to distinguish lithologically from Blanche Point Soft Marls that they are combined to form the working unit "Blanche Point Soft Marls." The top of the *aculeata* Zone is usually found high in this unit.

Subbotina linaperta Zone

The lower boundary of the *"Globigerina" linaperta* Zone, in the sense of Lindsay (1967) and Ludbrook and Lindsay (1969), is marked by the extinction of *Turborotalia aculeata,* and the upper boundary by the extinction of *Subbotina linaperta* (Finlay). The genus *Subbotina* is used for the reasons outlined by Srinivasan (1968). In the outcrop of type Port Willunga Beds, where sample control is best, *Guembelitria stavensis* Bandy ranges upwards from about 7ft. (2 m.) below the extinction of *S. linaperta.* Beneath the Adelaide Plains, *S. linaperta* is extremely rare at this stratigraphic level, whereas *G. stavensis* (which is clearly more tolerant and persistent environmentally) is generally present within its range. Because of this, the earliest *G. stavensis* is a good alternative indicator that we are close to the top of the Eocene. The small specimen of *S. linaperta* figured (Pl. 1, Figs. 13, 14) is from core in the *S. linaperta* Zone, slightly below the earliest *G. stavensis.*

Although in Fig. 5 the top of the *S. linaperta* Zone (and the top of the Eocene) is drawn at the top of "Blanche Point Soft Marls", it is known to extend up slightly into the "siliceous unit" of type Port Willunga Beds.

OLIGOCENE ZONES

Globigerina angiporoides angiporoides Zone

As adapted by Ludbrook and Lindsay, the lower boundary of this Zone is the extinction of *S. linaperta,* and the upper boundary is the extinction of the zone fossil. Above the extinction of *S. linaperta, G. angiporoides angiporoides* Hornibrook is represented only by occasional doubtful examples in the "siliceous unit" of Port Willunga Beds both at Port Willunga and beneath the Adelaide Plains. In such cases, use of the alternative *Chiloguembelina cubensis* Zone is preferred for this interval. However the figured specimen of *G. angiporoides angiporoides* (Pl. 1, Fig. 21), from low in the "siliceous unit", is identifiable even though small.

Globigerina labiacrassata Zone

Ludbrook and Lindsay defined the lower boundary of this Zone by the extinction of *G. angiporoides angiporoides,* and the upper boundary by the extinction of *Chiloguembelina cubensis* (Palmer). However, at least in the eastern St. Vincent Basin the extinction of *G. angiporoides angiporoides* is indefinite, *G. labiacrassata* Jenkins is extremely rare, and the extinction of *C. cubensis* marks the upper boundary of the alternative *C. cubensis* Zone. Fig. 5 shows that the *G. labiacrassata* Zone is probably equivalent to the uppermost part of the *C. cubensis* Zone, near the top of the "siliceous unit" and the base of the "upper Janjukian unit" of Port Willunga Beds.

Chiloguembelina cubensis Zone

By definition (Lindsay, 1967) the lower boundary of the *C. cubensis* Zone is marked by the extinction of *S. linaperta* and the upper boundary by the extinction of the zone fossil. The level of earliest *Guembelitria stavensis* is a useful alternative approximation to the lower boundary. The *C. cubensis*

Zone is equivalent to the *G. angiporoides angiporoides* Zone plus the *G. labiacrassata* Zone. It usually occupies at least the lower half of the "siliceous unit" of subsurface Port Willunga Beds, but at the type section occupies all but the base of the "siliceous unit", and also extends up slightly into the "upper Janjukian unit" (Lindsay, 1967, pl. 1, figs. 2, 3). The specimen of *C. cubensis* figured herein (Pl. 1, Fig. 30) is however from unit 11.

Guembelitria stavensis **Zone**

As defined by the writer (1967), the lower boundary is marked by the extinction of *C. cubensis* and the upper boundary by the extinction of the zone fossil. At Port Willunga the Zone although incompletely exposed is in the "upper Janjukian unit", but beneath the Adelaide Plains it more usually occupies the upper part of the "siliceous unit" and the lower part of the "upper Janjukian unit". The *G. stavensis* Zone occupies an interval equivalent to the basal part of the *Globigerina euapertura* Zone (Ludbrook and Lindsay, 1969). The specimen figured (Pl. 1, Fig. 34) is from the "upper Janjukian unit".

Globigerina euapertura **Zone**

This Zone was adapted for local use by Ludbrook and Lindsay from Jenkins (1965), to have as its base the extinction of *C. cubensis* and as its top the initial appearance of *Globoquadrina dehiscens dehiscens* (Chapman, Parr and Collins). In the Adelaide Plains Sub-Basin the latter species has not been found, and *G. euapertura* Jenkins is a rarity, so that the Zone is only identified with some hesitation. However in view of the zone fossil's presence in the "upper Janjukian unit" (bore 89; type section of Port Willunga Beds) and in the early Longfordian part of Port Willunga Beds (bore 85), the Zone is adapted to occupy the interval between the extinction of *Guembelitria stavensis* and the initial appearance of *Globigerina woodi woodi* Jenkins. As shown in Fig. 5, the lower part of this Zone is considered by the writer to be only doubtfully Oligocene in age, for reasons which will be discussed later. The upper part of the Zone as used here is of early Longfordian, Lower Miocene age.

MIOCENE ZONES

Globigerina woodi woodi **Zone**

This early Longfordian Zone of Ludbrook and Lindsay spans the interval between the first appearance of the zone fossil and the first appearance of *Globigerinoides trilobus trilobus* (Reuss). However, the latter is extremely rare in the Adelaide Plains Sub-Basin, and the presence of the Zone is emphasized rather than its boundaries. The figured specimen (Pl. 1, Fig. 1) is from the *bisphericus* Zone, Munno Para Clay.

Globigerinoides trilobus trilobus **Zone**

This Zone of Ludbrook and Lindsay occupies the interval in the *Orbulina* bioseries (Blow, 1956) between the emergence of *Globigerinoides trilobus trilobus* and the emergence of *Globigerinoides bisphericus* Todd.

However, again in view of the rarity of the zone fossil, the suggested presence of the Zone in middle to upper Longfordian Port Willunga Beds is emphasized rather than its boundaries.

Globigerinoides bisphericus **Zone**

This Zone as defined by Ludbrook and Lindsay occupies the interval in the *Orbulina* bioseries between the appearance of *G. bisphericus* and the appearance of *Praeorbulina glomerosa curva* (Blow). The latter event has been noted in the upper part of Munno Para Clay. The zone fossil is sufficiently present to enable recognition of the Zone in late Longfordian and Batesfordian Port Willunga Beds, including the lower part of the Munno Para Clay.

Praeorbulina glomerosa curva **Zone**

The Zone as defined by Jenkins (1967) is for that interval in the *Orbulina* bioseries between the emergence of the zone fossil and the emergence of *Orbulina suturalis* Bronnimann. It is characterised by *Praeorbulina* species with increasingly embracing final chambers, but without the development of the areal apertures diagnostic of *Orbulina*. These forms are very rare in the Adelaide Plains Sub-Basin but when present are found either high in the Munno Para Clay (bores 24A, 31, 34, 62) or in Balcombian Port Willunga Beds just above Munno Para Clay (bores 32, 81B).

Orbulina suturalis **Zone**

The Zone as used by Ludbrook and Lindsay is for the penultimate stage of the *Orbulina* bioseries between the first appearance of *O. suturalis* (spheroid shape with both sutural and areal apertures) and the first appearance of *Orbulina universa* d'Orbigny (spherical shape, areal apertures). The only direct evidence of this Zone in the Adelaide Plains Sub-Basin is a solitary example of *O. suturalis* in bore 49, Core 1, from 45ft. (14 m.) above the top of Munno Para Clay in Balcombian Port Willunga Beds.

Orbulina universa **Zone**

O. universa has not yet been found in the Adelaide Plains Sub-Basin.

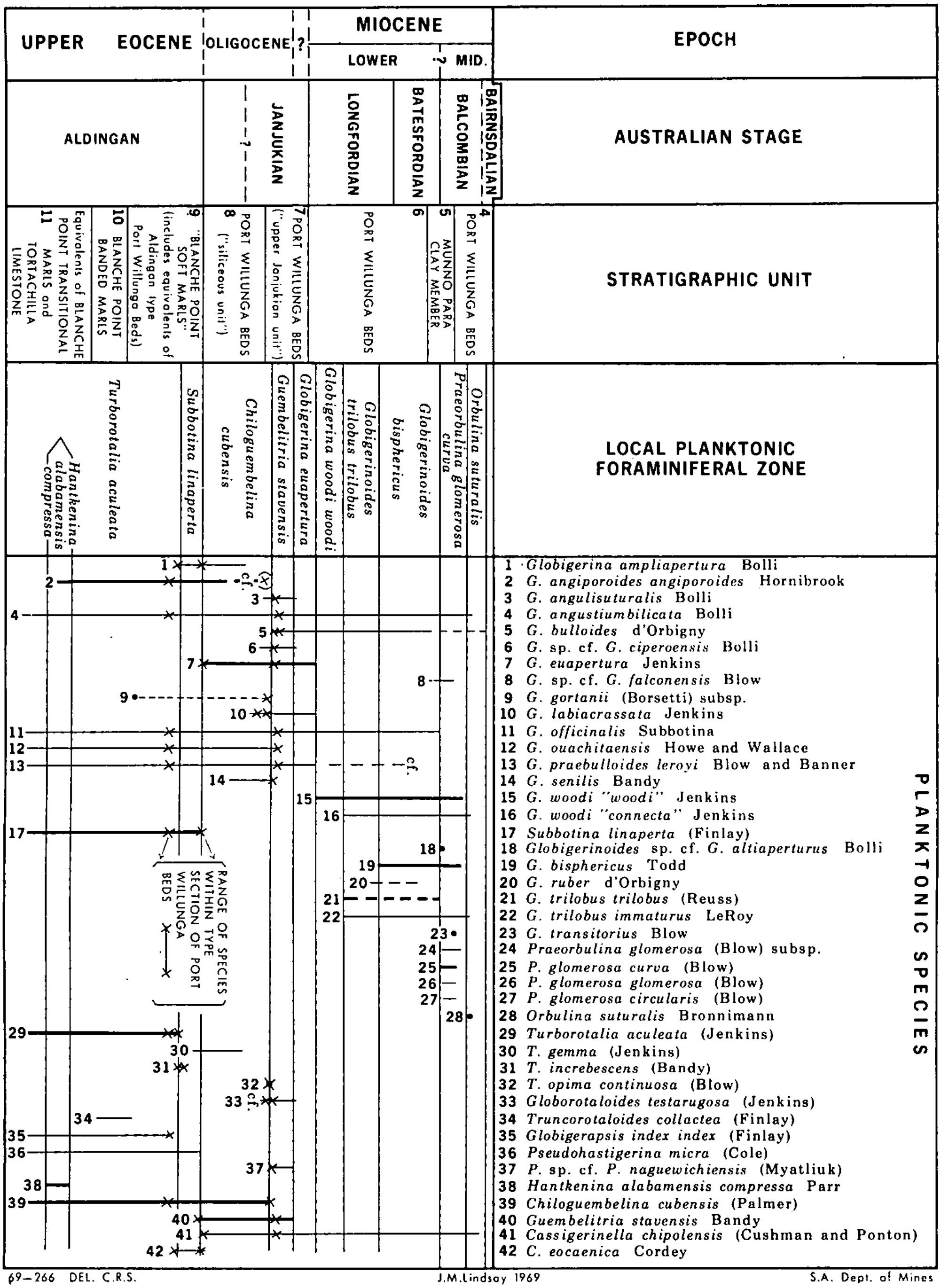

Fig. 5. Aggregated local stratigraphic ranges and zonation of planktonic foraminifera.

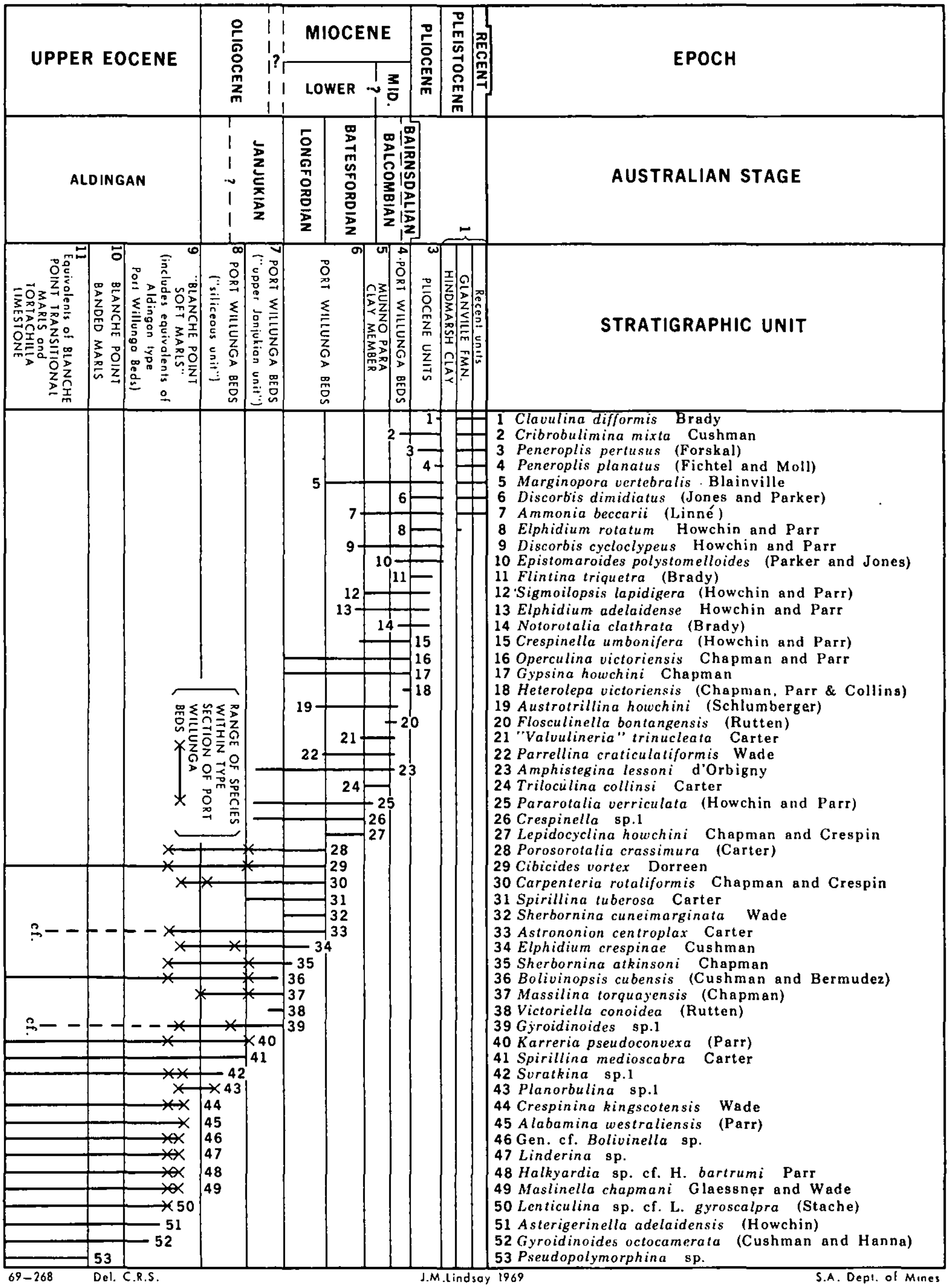

Fig. 6. Aggregated local stratigraphic ranges of selected benthonic foraminifera.

AUSTRALIAN STAGES

Figs. 5 and 6 relate Australian Stages Aldingan through Bairnsdalian to epochs, stratigraphic units, and foraminiferal biostratigraphy for the eastern part of the St. Vincent Basin.

Ludbrook and Lindsay (1966) reviewed the use of the name Aldingan, and redefined it "in the restricted time-rock sense as representing the time interval required for the deposition at Aldinga and Maslin Bays of the Tortachilla Limestone, the Blanche Point Marls, the Chinaman's Gully Beds, and the lower half of the Port Willunga Beds", all being of Eocene and probably all of Upper Eocene age.

The Aldingan Stage contains the *Turborotalia aculeata* Zone (as at present known in the eastern St. Vincent Basin), the *Hantkenina alabamensis compressa* Zone, and at the top the *Subbotina linaperta* Zone. At Port Willunga, the top of the *S. linaperta* Zone is in the basal marker bed of the "siliceous unit" of Port Willunga Beds, approximately 45ft. (14 m.) above the base of the formation (Lindsay, 1967).

The Janjukian Stage, in the restricted sense of Raggatt and Crespin (1955), represents the time interval required for the deposition of the Jan Juc Formation in the Bell's Headland—Torquay area of southern Victoria. Carter (1964), Ludbrook (1967a), and Lindsay (1967) have variously discussed usage of the Stage in Victoria and South Australia. The writer showed that at Port Willunga most of the "siliceous unit" of type Port Willunga Beds is post-Aldingan and pre-Janjukian. In the eastern St. Vincent Basin, the Janjukian is represented in Port Willunga Beds by the uppermost part of the "siliceous unit", and by the "upper Janjukian unit". The Stage contains the uppermost part of the *Chiloguembelina cubensis* Zone, the *Guembelitria stavensis* Zone, and the greater part of the *Globigerina euapertura* Zone as used here. It is Oligocene and Oligo-Miocene in age.

The Longfordian, Batesfordian, Balcombian, and Bairnsdalian Stages are similarly used in the time-rock, and biostratigraphic sense of Carter (1964). All are of Miocene age, and all are represented in Port Willunga Beds which extend above the stratigraphic level of the type section. The relationships between *woodi* to *suturalis* Zones and Longfordian to Balcombian Stages are drawn in Fig. 5.

The presence of the Bairnsdalian Stage is suggested by isolated occurrences of *Heterolepa victoriensis* (Chapman, Parr and Collins) in bores 64 and 83.

EPOCHS AND TIME-CORRELATIONS

THE EOCENE-OLIGOCENE BOUNDARY

Boundary problems still plague the definition and mutual relationships of the Eocene, Oligocene and Miocene Epochs in the classical European sections. The problems are compounded by projection into the antipodean Australasian region. A note of encouragement however was sounded by Glaessner (1967) with his emphasis on correlation between carefully-studied and zoned fossil sequences, particularly using planktonic foraminifera. Despite the limitations of relatively poor planktonic facies or of temperate assemblages in South Australia, zonal sequences here show recognisable points of similarity with those in New Zealand, Africa, the Middle East and beyond.

In a recent attempt to deal with Eocene boundary problems a Colloquium on the Eocene was held at Paris in May 1968 under the auspices of the Comité Francais de Stratigraphie (1968). It was generally agreed that at least for basins of the Mesogean domain (circum-Mediterranean, Middle East, Asia) the Eocene-Oligocene boundary should be put (*inter alia*) between the planktonic foraminiferal Zones of *Globigerina gortanii gortanii,* and *Pseudohastigerina micra-Cassigerinella chipolensis* (or Zone of *Globigerina sellii*), a position first adopted by Blow and Banner (1962). It was agreed at the Colloquium that this boundary is situated at the top of the Priabonian Stage.

Blow and Banner's work in Tanganyika on planktonic assemblages of tropical aspect, also and importantly demonstrated the extinction of the tropical-temperate species *Subbotina linaperta* at the top of the *Globigerina gortanii gortanii* Zone. It is no doubt an over-simplification to equate the time of extinction of *S. linaperta* everywhere with the Eocene-Oligocene boundary, but there is a widespread suggestion of close relationship between the two by authors such as Blow and Banner, Wade (1964) Jenkins (1965), Reiss and Gvirtzman (1966), McTavish (1966), Hornibrook (1968), and Srinivasan (1968).

This datum was recognised in the type section of Port Willunga Beds (Lindsay, 1967) and was there related to the earliest range of the even more tolerant planktonic *Guembelitria stavensis.* Thus indirectly the datum can be traced through the Adelaide Plains Sub-Basin despite the rarity of *S. linaperta* there.

In reference bore 4, core 1, 458-470ft. (139.6-143.3 m.) some stratigraphic relationships can be demonstrated between the ranges of *S. linaperta, G. stavensis, Turborotalia gemma* (Jenkins), and an interesting lineage involving *Cassigerinella eocaenica* Cordey ("*C.* sp. cf. *C. chipolensis*" of Lindsay, 1967; and Ludbrook and Lindsay, 1969) and *Cassigerinella chipolensis* (Cushman and Ponton). *Chiloguembelina cubensis* is present throughout the core. At 460ft. (140.2 m.), the earliest *G. stavensis* and *C. chipolensis* are accompanied by the latest *C. eocaenica,* the latter represented by forms (Pl. 1, Figs. 5, 10, 16, 17) which display the prominent planispiral chambers, compressed test, and small size described by Cordey (1968). The base of the dark grey cherty siltstones forming the "siliceous unit" of Port Willunga Beds is at 465ft. (141.7 m.). *Turborotalia gemma* is present below 466ft. (142.0 m.), and the small but recognisable figured specimen of *Subbotina linaperta* was found at 467ft. (142.3 m.), in dark grey-green-brown siltstones, greensands, and marls at the top of "Blanche Point Soft Marls". The latest *Turborotalia aculeata* are at the bottom of the core. The sequence is probably Eocene below 460ft. (140.2 m.).

THE OLIGOCENE-MIOCENE BOUNDARY

The third meeting of the Committee on Mediterranean Neogene Stratigraphy was held in Berne, Switzerland, in June, 1964. Papers, discussions, and resolutions, were published in "Proceedings of the Third Session in Berne" (*Ed.* Drooger *et al.*, 1966). A resolution of the Committee recommended that for the present the Chattian remain the final Stage of the Oligocene (and the Palaeogene), and the Aquitanian the earliest Stage of the Miocene (and the Neogene). After a study of the planktonic foraminifera from the type Aquitanian-Burdigalian of France, Jenkins (1966) suggested "that the Oligocene-Miocene boundary be placed between the *G. opima opima* Zone and *G. ciperoensis ciperoensis* Zone as defined by Bolli (1957)".

A specimen of the distinctive species *Globigerina angulisuturalis* Bolli was found by Jenkins in the lower part of the stratotype Aquitanian. Bolli (1957) recorded this species from *opima* Zone to *ciperoensis* Zone in Trinidad, and Jenkins (1965) from a comparable range in New Zealand, *euapertura* Zone to *woodi woodi* Zone, that is, late Oligocene to early Miocene according to Jenkins.

An alternative approach was made by Banner and Blow (1965), who proposed a series of Neogene planktonic Zones N.1 to N.23. They recognized that their Zones N.1 to N.3 are older than the holostratotype Aquitanian described by Jenkins, but they extended the Aquitanian downwards by parastratotypes broadly equivalent to the Bormidian Stage. By definition *Turborotalia opima opima* (Bolli) occurs in, and does not range above, Zone N.2. *Globigerina angulisuturalis* appears in the definition of Zones N.1 to N.3. Zone N.1 is pre-*angulisuturalis* and post-*Pseudohastigerina,* Zone N.2 is defined by the concurrence of *G. angulisuturalis* and *T. opima opima,* and Zone N.3 has that part of the range of *G. angulisuturalis* which is post-*T. opima,* and pre-*T. kugleri* (Bolli). According to this approach, *G. angulisuturalis* is entirely Neogene.

In the eastern St. Vincent Basin *G. angulisuturalis* is found rarely but consistently in the "upper Janjukian unit" of Port Willunga Beds. The specimen figured (Pl. 1, Figs. 20, 25) is from this unit in the Adelaide Plains Sub-Basin. A specimen has also been found in this unit at the type section of

Port Willunga Beds, where Sample F145/66 (Lindsay, 1967) contains *G. angulisuturalis* (v), *Guembelitria stavensis* (c), the latest *Chiloguembelina cubensis* (v), and significantly, a specimen of *Pseudohastigerina* sp. cf. *P. naguewichiensis* (Myatliuk) which by itself would make the sample pre-N.1 and Palaeogene by Banner and Blow's own definition.

In bore 64, core in grey sandy silty and marly limestone of the "upper Janjukian unit" yielded *G. angulisuturalis* (v) at 983ft. (299.6 m.), and at 985ft. (300.2 m.) an example of *Pseudohastigerina* sp. cf. *P. naguewichiensis* at the top of the *Guembelitria stavensis* Zone.

Core from bore 12 in the "upper Janjukian unit" has the top of the *G. stavensis* Zone at 330ft. (101 m.), and *Globigerina angulisuturalis* (v) at 340ft. (103.6 m.), both in grey fossiliferous silty quartz sand. The top of the *Chiloguembelina cubensis* Zone is at 341ft. (103.9 m.), and a specimen of *Pseudohastigerina* sp. cf. *P. naguewichiensis* was found at 348ft. (106 m.), both in grey sandy and muddy foraminiferal limestone which is partly dolomitized (Kelly, 1969 unpub.).

In bore 65, pale grey-green limestone, sandstone and sand of the "upper Janjukian unit" has *Victoriella conoidea* (Rutten) (r) and *G. angulisuturalis* (v) at 1,040-1,045ft. (317-319 m.) while the top of the *Guembelitria stavensis* Zone is at 1,070ft. (326 m.).

V. conoidea and *G. angulisuturalis* occur in adjoining samples in bore 49, where in the "upper Janjukian unit" the former species is found at 690-700ft. (210-213 m.) and the latter at 700-710ft. (213-216 m.), both in pale grey, echinoidal, bryozal and foraminiferal, sandy limestone.

In bore 20, the "upper Janjukian unit" at 375ft. (114 m.), here a grey fossiliferous quartz sand, contains *G. angulisuturalis* (v) and *G. ouachitaensis* Howe and Wallace (v) at the top of the *Guembelitria stavensis* Zone.

Thus in the eastern St. Vincent Basin, *G. angulisuturalis* in the lower part of its range is associated with Palaeogene elements such as *Pseudohastigerina, Guembelitria,* and *Chiloguembelina.* But whether less or more of the "upper Janjukian unit" is Oligocene, really depends on whether the Bormidian "Aquitanian parastratotypes" are recognized as Aquitanian or not. That part of unit 7 which is above the *stavensis* Zone is at present dated "Oligo-Miocene".

STRATIGRAPHIC UNITS

INTRODUCTION

Fourteen Cainozoic units, one ?Permian unit (only in bore 65), and a Proterozoic-?Cambrian bedrock "unit" have been used as shown in Figs. 2 to 6 and Appendix 2. They variously comprise formations or (particularly in the Pliocene and Quaternary) groupings of formations; members, and several informal subdivisions. They are primarily rock stratigraphic in character, but Nos. 6, 7 and 11 have biostratigraphic connotation.

Several trends in lithofacies can be recognized. Towards the basin margins there is a general, converging trend to coarser clastic facies. Even there however, the units often retain recognizable characteristics, and so can be distinguished to some extent, a broad interpretation of the unit and its variants being taken. An important conclusion from this study is that most of the units appear to be time-concordant on biostratigraphic grounds, but diachronism in units 2, 7 and 8 is discussed below.

Only one new formation is formally defined. This is unit 2 *Carisbrooke Sand.* Units 7 and 8 are distinct but informal. They were first recognized by the writer in type Port Willunga Beds (1967), and have now been traced through the Adelaide Plains subsurface. The formations described by Reynolds (1953) are adapted for use in this area wherever possible.

The descriptions of units 1 to 14 are intended to supplement, rather than repeat or replace accounts such as those of Glaessner and Wade (1958), Ludbrook (1963, 1969a), Stuart (1967), and Firman (1966, 1967b, 1969).

15. BEDROCK

The Proterozoic to Cambrian succession exposed in the Mount Lofty Ranges, and described most recently in Parkin (1969), extends beneath the adjoining Adelaide Plains. Unfossiliferous bedrock (Proterozoic-?Cambrian) of several types described below was intersected in bores 2, 4, 5, 24B, 26B, 64, 66B, 70 and 75, as shown in Appendix 2 and in the cross-sections.

Bore 4 cored bedrock of hard pale grey banded quartzite suggested to be of Torrensian Series by Cornish (1964 unpub.). The configuration of the bedrock high near bore 4 (Fig. 2) is derived from seismic data (Seedsman, 1967).

Bore 5 cored unfossiliferous Proterozoic or Cambrian carbonates consisting of grey dolomite and dolomitic limestone (Townend, 1964 unpub.; Lindsay, 1965b unpub.).

From bore 64, Steel (1962 unpub.) described red-brown shales and thin quartzites (Marinoan Series) underlain by grey slates and quartzites (Sturtian Series) in which a core was taken.

Bore 2 intersected unfossiliferous hard grey calcareous siltstone and dolomitic limestone comparable with bedrock in bore 5.

Cuttings suggest bedrock of hard grey phyllitic siltstone and fine sandstone in bore 24B, and of white to dark grey weathered phyllite in bore 26B.

Intersections in bores 66B, 70 and 75 (Adelaide City area) indicate dip of the bedrock surface at about 2 deg. to the south-southeast.

Continuous tube-cores of bedrock in bore 66B yielded completely to highly-weathered orange-brown siltstone with occasional quartz veinlets.

Bore 70 also intersected a deeply decomposed bedrock profile of white, grey, and brown gritty quartzose clay veined with seams of siderite, calcite, and quartz. Remnant lithologies include highly-weathered shale and the "decomposed feldspathic quartzite" noted by Tate (1882).

A deeply-weathered bedrock profile was also encountered in bore 75, where white clay with siderite granules and joint-fillings, occurs with remnants of dark grey calcareous shale and white to brown sideritic limestone.

? PERMIAN

15A. ? Cape Jervis Beds

Sands and clays with varied lithic fragments, in bore 65, may well be Permian on lithological grounds as suggested by Steel (1962), and in such case would be Cape Jervis Beds of Ludbrook (1967b). However despite further search, there is still no palaeontological evidence for this.

EOCENE

14. North Maslin Sands

North Maslin Sands (Reynolds, 1953) were penetrated in bores 5, 26B, 64, and 70, in each case resting on bedrock.

The formation in bore 5 is pale grey pebbly quartz sand, slightly clayey, pyritic, and with a thin intercalation of grey carbonaceous clay. The unit here is 63ft. thick (19 m.), almost identical with Reynolds' figure for the type section at Maslin Bay.

Similar sands occur in bore 26B, and in bore 64 they have the maximum known thickness of 102ft. (31 m.). By contrast, the unit is only a thin basal sand in bore 70.

A means of accurately dating North Maslin Sands is provided by a lens of clay with abundant, varied, and beautifully-preserved plant remains, which has recently been exposed in the A.B.M. Noarlunga Sand Co. quarry, within the lower half of type North Maslin Sands. Black and highly carbonaceous in the middle but decarbonized to brown and pale grey towards its margins, the lens is up to 9ft. thick (2.7 m.), elongate in plan, about 50yds. (46 m.) in breadth, and at least the same in length. It represents the deposits of a swamp-filled riverine pond.

W. K. Harris has examined the lens palynologically and reports (pers. comm.) "a microflora comparable with that from the Burrungule Member (Middle Eocene) in the Otway Basin. In particular both units contain the zone species "*Proteacidites*" aff. *pachypolus* Cookson and Pike, together with

P. pachypolus. Other elements in the Maslin Bay assemblage reinforce this correlation. However no microplankton are present, and the depositional environment appears to have been non-marine in contrast to the distinctly marine Burrungule Member".

The Burrungule Member (Harris, 1966; Ludbrook, 1969a) contains the early Middle Eocene planktonic foraminiferal Zone of *Planorotalites australiformis* (*Globorotalia australiformis* Zone of Ludbrook and Lindsay, 1969). There is no direct evidence that the age of type North Maslin Sands extends into the Upper Eocene. Ludbrook (1962, 1969b) has reported but not described arenaceous foraminifera from the top of North Maslin Sands at Christie's Beach, in the adjoining Noarlunga Sub-Basin. A more definite commencement of marine transgression produced the fossiliferous South Maslin Sands, which at Maslin Bay disconformably follow North Maslin Sands and have a small fauna of Upper Eocene molluscs (Ludbrook, 1963, 1969a).

13. "Muloowurtie Clays"

Relatively thin intercalations of clay are typically developed in North Maslin Sands, but a number of bores in the Adelaide Plains (see Appendix 2) have penetrated a much thicker clay unit of apparently wide extent. It generally overlies bedrock or North Maslin Sands and precedes South Maslin Sands. It is here called "Muloowurtie Clays", denoting not an informal name but doubtful identification with the formation described by Tepper (1879), and more recently noted by Glaessner and Wade (1958) and Crawford (1965).

Bore 2 has unit 13 as white, pale grey, and bluish or greenish clay with dark brown siderite granules, small pyritic aggregates, and rare pyritized lignitic fragments.

In bore 5, 21ft. (6 m.) of pale grey pyritic clay are followed by 49ft. (15 m.) of dark brown to grey carbonaceous clay, mudstone, and lignite, with one or two small shell fragments in core. This upper interval compares with the middle-upper Eocene phase of Clinton Coal Measures (Harris, 1966).

Unit 13 attains its greatest known thickness in bore 65 where it is white to grey sandy silty clay with pyrite, ferruginous nodules, and variable but mostly low carbonaceous content. Steel (1962 unpub.) assigned the interval to North Maslin Sands.

Within the Adelaide City area, bores 66B, 70, and 75 penetrated unit 13. Continuous tube-cores in bore 66B reveal pale grey and brown plastic clays with pyrite, abundant granules of siderite (Scott, 1966 unpub.), and brown to black lignitic fragments. The unit is here topped by a thin coaly horizon which separates it from South Maslin Sands. A very similar sequence was cut in bore 70. Bore 75 has 15ft. (5 m.) of white clay with abundant siderite granules and pyrite, followed by 40ft. (12 m.) of dark brownish-grey clay which is sandy, pyritic, carbonaceous, and lignitic.

Compared with this 40-mile long (64 km.) development of unit 13 in the Adelaide Plains Sub-Basin, bore 2 is about 28 miles (45 km.) from Muloowurtie Point on Yorke Peninsula (Fig. 1) the type area for Muloowurtie Clays. The type section has been discussed by the authors previously noted. It consists mainly of yellow and white fossiliferous sandy clays, followed by *Turritella* beds with siliceous nodules correlated with Blanche Point Marls by Glaessner and Wade, and Crawford. The type-section rests directly on Cambrian Kulpara Limestone.

The contrast is obvious between the marine and brackish (Glaessner and Wade, 1958) depositional environments of typical Muloowurtie Clays on Yorke Peninsula, and the clearly non-marine environments which produced "Muloowurtie Clays" to the east. However since no other name is at present applicable to these Eocene clays, and since a westward change to increasingly marine facies (not necessarily of the same age) is quite feasible, the identification is tentatively made pending more facts from both sides of Gulf St. Vincent.

Fossiliferous glauconitic marls which are here included in unit 11 also correlate with part of Muloowurtie Clays (Ludbrook, 1967a, 1969a).

12. South Maslin Sands

Type South Maslin Sands (Reynolds, 1953) are at least 100ft. thick (30 m.), and are thus comparable in thickness with the type sections of Blanche Point Marls and Port Willunga Beds. Representing an early phase of the Upper Eocene marine transgression, they consist of poorly fossiliferous sands which in their exposed and oxidized state are coloured brown, purple, and green, with many ferruginous grains and coatings, some at least being oxidized glauconite. Some weak calcareous and ferruginous cementation is developed. Animal remains include rare foraminifera, echinoid spines, sponge spicules, Bryozoa, and a small fauna of Upper Eocene molluscs (Ludbrook, 1963, 1969a).

South Maslin Sands therefore contrast both with the preceding North Maslin Sands which typically lack animal remains, and with the overlying richly fossiliferous Tortachilla Limestone.

It is instructive to note the different appearance of unoxidized South Maslin Sands at depth in bore 94 only three miles (5 km.) inland from their type section (Cochrane, 1956). A re-examination of bore 94 (Lindsay, 1966c unpub.) convinced the writer that the interval below 618ft. (188 m.) correlates with South Maslin Sands rather than with North Maslin Sands (Glaessner and Woodard, 1956) or Tortachilla Limestone (Ludbrook, 1956a). It consists of dark grey carbonaceous and pyritic quartz sands followed by greenish-brown and grey carbonaceous sandy silts. Ludbrook demonstrated the fossiliferous nature of the interval, recording sponge spicules and rare, small, but persistently present foraminifera increasing in abundance and variety upwards. This marginal marine facies is typical of subsurface South Maslin Sands in the Adelaide Plains Sub-Basin.

Bores 2, 5, 26B, 65, 66B, 68A, 70 and 75, penetrated the formation, in each case beneath correlatives of Blanche Point Transitional Marls and Tortachilla Limestone.

In bore 26B, several tube-cores were taken in unit 12. Towards the base it is a fine to medium-grained quartz sand, silty and clayey, grey-brown in colour, glauconitic pyritic and carbonaceous, with lignitic splinters, clay faecal pellets, occasional shell fragments, and a small foraminifer *Fissurina* sp. In the middle, the unit is grey green or brown glauconitic and pyritic sand and silt with a little weak and lumpy cementation to calcareous sandstone and siltstone. Animal remains are more varied, with common sponge spicules, and rare fish-bone fragments, ostracodes, casts of small gastropods, and small foraminifera which include *Lenticulina* sp., *Guttulina* sp., *Cibicidoides* sp., and *Globocassidulina* sp. This is an impoverished but marine fauna. The upper part of the unit is a dark green to dark brown quartzose greensand with minor calcareous sandstone, and a similar microfauna.

In a very comparable development of unit 12, bore 5 has a microfauna which expands from rare small *Cibicidoides* spp. near the base, to an assemblage with *Crespinina kingscotensis* Wade, *Maslinella chapmani* Glaessner and Wade, *Linderina* sp., *Pseudopolymorphina* sp., and Gen. cf. *Bolivinella* sp., near the top.

The unit reaches its greatest-known thickness in bore 65, as dark greenish-grey glauconitic clayey sands, which are micaceous, pyritic, and carbonaceous.

Bore 75 typifies the development of unit 12 in the Adelaide City area, as a black to dark brownish-grey carbonaceous pyritic and glauconitic quartz sand with minor cementation to pyritic sandstone. There are occasional molluscan, bryozoal, echinoid, ostracode, and fish-bone fragments, with small and rare *Cibicidoides* sp. near the top of the unit.

11. Undifferentiated Tortachilla Limestone and Blanche Point Transitional Marl

The three members which Reynolds (1953) distinguished in this interval at Maslin Bay are all notably fossiliferous, and range in lithology from brown bryozoal limonitic sand, through hard pink white and green limestones with marly pockets and grains of limonite and quartz, up to green and dark grey glauconitic marl. The total thickness is less than 17ft. (5 m.). The combined interval, with varying proportions of these lithologies, is widely recognizable in the St. Vincent Basin, but in the Adelaide Plains Sub-basin it has proved impractical to differentiate the individual members. Even in bore 94, only 3 miles (5 km.) from the type exposure, the equivalent interval, 8ft. thick (2.4 m.) has a mixture of lithologies ranging from greenish and brownish-grey glauconitic ferruginous sandy marl, to yellow-grey and brown sandy marly limestone, and brown ferruginous pelletal sand. Here as elsewhere the extinction of a distinctive, striate, *Pseudopolymorphina* sp. (Pl. 2, Fig. 8) is a good marker for the top of unit 11.

The unit thickens southwards from 9ft. (2.7 m.) in bore 2, to 90ft. (27 m.) in bore 64 (see Fig. 2), with the following facies changes:

In bore 2 it occurs as a greenish-brown pyritic, ferruginous, and very glauconitic pebbly quartz sand, stained ferrous-green. Prolific molluscan, bryozoal, brachiopod, coral, and fish fragments accompany a varied foraminiferal microfauna which includes *Pseudopolymorphina* sp., *Globigerapsis index* (Finlay), *Subbotina linaperta* (Finlay), and *Lamarckina airensis* Carter.

Bore 64 has a thick development of yellowish, brownish and greenish-grey glauconitic silty sandy limestones, which are hard and compact to soft friable and marly. *Pseudopolymorphina* sp., *Pseudohastigerina micra* (Cole), and *Turborotalia aculeata* are present.

Unit 11 in bore 5 is intermediate in location, thickness and lithology, between bores 2 and 64. Green grey and brown richly fossiliferous and glauconitic marl, limestone, siltstone, sandstone, and sand are developed, and contain most of the species shown as ranging through unit 11 in Figs. 5 and 6.

On a bedrock high, unit 11 rests on and fills fissures in Proterozoic quartzite at the bottom of bore 4. Here the unit is green-grey-brown to black carbonaceous siltstone and mudstone, which is marly, sandy, glauconitic, pyritic, shelly and still has *Pseudopolymorphina* sp.

In the Adelaide City area, unit 11 is a greenish-grey glauconitic shelly silty marl to greensand. Bores 73A-C have the *Hantkenina* Zone well-represented in the upper half of unit 11, through a cored thickness of 7ft. (2 m.). The top of the *Hantkenina* Zone is close to the top of the range of *Pseudopolymorphina* sp. in these cores.

Greensands at North Adelaide (Ludbrook, 1963, p. 8) (*e.g.* bores 68A, B), and the comparable interval in the historic Kent Town Bore (Bore 70), are all unit 11. A topotype of *Asterigerinella adelaidensis* (Howchin) from the latter bore is figured (Pl. 2, Figs. 2, 4).

Blanche Point Marls

10. *Blanche Point Banded Marls Member*

At Blanche Point (Reynolds, 1953) this Member of Blanche Point Marls consists of 37ft. (11 m.) of alternating bands of grey glauconitic silty marls and hard cherty marlstones or siltstones, all characteristically spicular. In the type section as elsewhere it is stratigraphically well separated from the later "siliceous unit" of Port Willunga Beds.

Stuart (1967) recognized a persistent thickness of about 40ft. (12 m.) of Banded Marls through at least the coastal part of the Willunga and Noarlunga Sub-Basins. In the Adelaide Plains Sub-Basin a similar constancy is illustrated by identical thicknesses of 60ft. (18 m.) in bores 5 and 64; and in the Adelaide City area comparable thicknesses of between 64 and 69ft. (19.5-21 m.) in bores 70, 72, and 75. The unit is thicker however in the eastern and south-eastern parts of the fault-blocks (*e.g.*, bores 31, 65, 76, and 94).

In bore 31, "hard bars" of cherty calcareous sandy siltstone are separated by sands silts and clays. The lower part of the unit here displays marginal facies and an impoverished fauna.

Figure 2 shows that unit 10 is not present on the bedrock high at bores 4 and 2. Banded Marls are also absent in bore 26B, Virginia.

The scaphopod *Dentalium* (*Gadilina*) *tatei* Sharp and Pilsbry (Ludbrook, 1959a) does not occur stratigraphically above Banded Marls.

9. *Blanche Point Soft Marls Member*

Unit 9 includes not only rock and time-correlatives of the Blanche Point Soft Marls Member (Reynolds, 1953), but also in its upper part (for reasons stated earlier) time-equivalents of Chinaman's Gully Beds (Reynolds, *op. cit.*), and of the Aldingan part of the type-section of Port Willunga Beds (Lindsay, 1967).

At Maslin and Aldinga Bays this succession consists of: 57ft. (17 m.) of grey, shelly, glauconitic, and spicular calcareous marl, silt, clay, soft siltstone and marlstone (Soft Marls); 7ft. (2 m.) of vari-coloured and thinly bedded clays, silts, and sands, in regressive facies (Chinaman's Gully Beds); and a sequence about 40ft. thick (12 m.) of basal gravelly sand, cross-bedded bryozoal sands and sandstones, green clays with white limy nodules, and brown bryozoal limestones silts and marls (Aldingan Port Willunga Beds).

In bore 94, nearby, the equivalent succession is: 94ft. (29 m.) of dark grey spicular clays and marls, 17ft. (5 m.) of black lignitic clay and grey fine carbonaceous sand, and 38ft. (12 m.) of black gravelly carbonaceous sand, and dark grey glauconitic carbonaceous clays silts and sands with an impoverished microfauna. The contrast with the coastal section is due to marginal facies and unoxidized subsurface preservation.

Unit 9 is thickest in bore 65 (Lindsay, 1968) where grey shelly silts, soft siltstones, and marls, enclose a thin intermediate bed of dark brown and black lignitic silt and clay.

Bore 64 has unit 9 as grey spicular pyritic shelly marl and carbonaceous mudstone, overlain by calcareous clayey siltstone. The comparable interval in bore 5 consists of dark brown carbonaceous clays with pyrite and glauconite, followed by dark brownish-grey glauconitic shelly clay. Bores 4 and 31 show unit 9 in similar clayey lithology but with a basal sandy phase.

In the Adelaide City area, unit 9 was penetrated in bores 70, 71, 74, and 75. In bore 71, continuous tube-cores show the unit as brown to dark grey clayey silts and fine-grained to gravelly quartz sands. The interval is carbonaceous, spicular, glauconitic and pyritic.

The lithological contrast between units 8 and 9 is well shown in electric logs of bores 4, 24B, 26B, and 64.

OLIGOCENE

Port Willunga Beds

8. *Port Willunga Beds "siliceous unit"*

Almost half of the type section of Port Willunga Beds is occupied by a sequence 50ft. (15 m.) thick, characterized by prominent bands of hard fawn and grey fossiliferous cherty nodules in bryozoal impure limestones, marls, silts, and sands (Lindsay, 1967). At Maslin and Aldinga Bays, this distinct "siliceous unit" of Port Willunga Beds is separated from the earlier cherty unit (Blanche Point Banded Marls) by 107ft. (33 m.) of Blanche Point Soft Marls, Chinaman's Gully Beds, and Aldingan Port Willunga Beds.

The two cherty units are similarly distinct in bore 94 and beneath the Adelaide Plains. In increasingly marginal sandy facies, the cherty phase of unit 8 was developed intermittently (bore 94), only slightly (bore 31) or not at all (bore 84). As shown in Figure 4 it then merges with units 7 or 9 in part or whole. Unit 10, on the other hand, is more persistent and still quite typically developed in these bores.

A petrographic study by Kelly (1969 unpub.) of cores from unit 8 in bore 12 revealed up to 50 per cent opaline silica in the cherty bands and nodules. Opaline sponge spicules are common. Zeolitisation in the lower part of the unit was also reported by Kelly, who described a core with 65 per cent matrix of opaline silica and zeolite, the latter being identified by X-ray diffraction as "similar to heulandite".

Massilina torquayensis, described from the Janjukian Stage, occurs rarely but consistently through unit 8. A distinctive *Planorbulina* sp. (Pl. 2, Fig. 6) has a restricted range above and below the base of the unit and is often associated with *Textularia* sp. aff. *T. pseudomiozea* Finlay.

At Port Willunga, the basal bed of unit 8 contains *Subbotina linaperta* and is uppermost Eocene. In bore 2, a specimen of *Globigerina* sp. aff. *G. ampliapertura pseudoampliapertura* Blow and Banner (Pl. 1, Figs. 18, 23, 27) was recovered from the upper part of unit 8, and would also suggest a late Eocene age (Blow and Banner, 1962; Srinivasan, 1968). The same sample yielded a small specimen of *G. ampliapertura* Bolli (Pl. 1, Figs. 2, 7). Fig. 2 suggests that the non-cherty facies of unit 7 was developed in bore 2 at the expense of unit 8. Unit 8 may thus be diachronous, from mostly Oligocene in the south, to mostly Eocene in the north.

7. *Port Willunga Beds, "upper Janjukian unit"*

Only the lower part of this unit is exposed at the top of the type section of Port Willunga Beds where it is "about 12ft. (3½ m.) thick, consisting of yellow-brown, fawn, and pale grey bryozoal beds including hard limestone bands, softer impure limestone, silty sands, and at the top of the exposure cross-bedded calcarenitic sandstones" (Lindsay, 1967). The unit is here Oligocene in age, containing the top of the *Chiloguembelina cubensis* Zone and the bottom of the *Guembelitria stavensis* Zone.

The base of unit 7 is determined lithologically by contact with the uppermost cherty phase of the underlying "siliceous unit". However the top of unit 7 is at least partly drawn on biostratigraphic grounds, at the extinction of *Victoriella conoidea* (Rutten), *Massilina torquayensis, Gyroidinoides* sp. 1, or *Bolivinopsis cubensis* (Cushman and Bermudez), benthonic species which typically do not range above Janjukian Stage. The first three have been figured by Ludbrook (1961, pl. II) from the Janjukian Ettrick Formation of the Murray Basin.

In bore 94, unit 7 comprises yellow and grey fossiliferous quartz sands which grade into the overlying basal Longfordian sands. Here, the top of unit 7 is marked by *Gyroidinoides* sp. 1.

Bore 2 cut a development of unit 7 with lithologically distinct top and bottom contacts. It is here a bluish-green and brown fossiliferous marl beneath Longfordian limestone and above dark grey cherty siltstone and sandstone of unit 8.

Southwards from bore 2 along the present coast, a gradual change of facies associates the marl component increasingly with limestone. By bore 5 the lithology is greenish and brownish-grey glauconitic rubbly limestone and marl. Bore 49 has pale greenish-grey glauconitic sandy limestone with rare *Victoriella conoidea.* Bore 64 similarly cut glauconitic sandy and marly limestone. Eastwards in bore 65, sandier facies of glauconitic limestone sandstone and sand also contain *Victoriella.* Towards marginal situations, the content of sandy clastics increases, reaching a notable thickness on the Burnside Fault Block, where unit 7 consists of brownish ferruginous and glauconitic fossiliferous quartz sands, with some sandstone and limestone beds.

Similar fossiliferous sands with hard calcareous cemented bands were cored through unit 7 in bore 12. Kelly (1969 unpub.) found that hard bands low in the unit had been wholly or partly dolomitized.

Unit 7 contains the *Guembelitria stavensis* Zone in bore 2, whereas in bore 5 the unit is post-*stavensis* Zone. From this and other observations it becomes apparent that unit 7 thickens marginally at the expense of unit 8 and is therefore diachronous. In the case of bore 31 (Fig. 4) time-equivalents of units 7 and 8 are mostly sands with only slight development of cherty unit 8.

The "Oligo-Miocene" age of upper unit 7 was discussed earlier.

MIOCENE

Port Willunga Beds

6. *Port Willunga Beds (Longfordian and Batesfordian Stages)*

Longfordian

Port Willunga Beds which are Longfordian in the sense of Carter (1964), while not exposed in the type section are developed in sandy facies nearby, bore 94 cutting yellow and brown fossiliferous sands (with sporadic cementation to calcareous sandstone or sandy limestone) which have a Longfordian microfauna and which extend up in continuous sequence above the stratigraphic level of the type section. A feature of the lower part of this Longfordian sequence is the abundant, part-oxidized, glauconite pellets and foraminiferal casts. Comparable Longfordian beds with varying proportions of sand, sandstone, and limestone, in places becoming marly, are widely developed beneath the Adelaide Plains.

Similar Longfordian Port Willunga Beds crop out in an isolated and small exposure near Redbanks and adjacent to the Redbanks Fault (Fig. 1). Samples collected by Mr. N. Alley of the University of Adelaide, and examined by the writer, consist of yellow brown and red very sandy fossiliferous limestone which is ferruginous and glauconitic (part-oxidized). Foraminifera in addition to those listed by Ludbrook (1959b) include *Sherbornina atkinsoni* Chapman (r), *Astrononion centroplax* Carter (r), *Cibicides vortex* Dorreen (v), *Elphidium crespinae* Cushman (r), *Crespinella* sp. 1 (v), *Planorbulinella inaequilateralis* (Heron-Allen and Earland) (v), and the planktonics *Globigerina officinalis* Subbotina (v), and *G.* sp. cf. *G. euapertura.* This is early Longfordian.

Longfordian unit 6 as cored by bore 12 consists of brown and grey compact to friable sandy limestones marls and quartz sands, with echinoids, Bryozoa and foraminifera. The lower part is muddy and glauconitic.

In general, one-half to two-thirds of unit 6 is Longfordian. The boundary with the Batesfordian phase is usually a biostratigraphic one. The ranges of a number of benthonic foraminifera stratigraphically useful at this level, are shown in Fig. 6.

Batesfordian

Extending up in continuity with the Longfordian sequence, the Batesfordian (in the sense of Carter, 1964) phase of unit 6 is commonly a bryozoal and foraminiferal sandy silty limestone, compact to friable, and pale grey to cream in colour. Marginally, a more variable and sandy lithology is developed. For example in bore 31 the Batesfordian part of unit 6, from 469 to 514ft. (143-157 m.), consists of fossiliferous limestones, sandstones, sands, silts, and marls.

Batesfordian (and younger) Miocene beds are not known to crop out in the area studied, but have been intersected in many bores, where they comprise an important part of Aquifer "B" (Department of Mines, 1969).

Lepidocyclina howchini Chapman and Crespin, an indicator of the Batesfordian climatic optimum, has been found as shown in the following table:

Reference bore No.	Depth (feet)	(metres)
12 (core)	151	(46)
18	180	(55)
31	470-495	(143-151)
32	491-560	(150-171)
62	555-605+	(169-184)

A median section is figured (Pl. 2, Fig. 10). The exterior of a specimen from Morgan Limestone, Murray Basin, has been figured by Ludbrook (1961, pl. IV). The observed internal features of the species agree well with descriptions by Carter (1964) and Wade (1964). On the evidence of internal structure, these authors supported Crespin (1943) in suggesting an uppermost Burdigalian age for *Lepidocyclina howchini*. In the Adelaide Plains Sub-Basin this is *bisphericus* Zone, pre-Munno Para Clay.

Continuous core from bore 12, besides demarcating the *Lepidocyclina* horizon, shows that *Marginopora vertebralis* Blainville commenced its range only a little above the base of the Batesfordian interval. According to Eames *et al.* (1962, fig. 2), this event is an indicator of the Burdigalian-Vindobonian boundary, which suggests an age no older than late Burdigalian for the Batesfordian Stage.

5. *Munno Para Clay Member*

This marker bed of dark grey foraminiferal clay was described and named by Lindsay and Shepherd (1966). The subsurface type section is in bore 26A. Later references to the unit include Lindsay (1968), Shepherd (1968), and Ludbrook (1969a).

Cores (*e.g.*, bores 12 and 64) and electric logs (*e.g.*, bores 24B, 26A, and 64) show that the unit typically comprises beds of clay separated by two or three bands of white brown or grey foraminiferal limestone.

Compared with the adjacent limestones, the higher planktonic ratio of the clay (*Cassigerinella chipolensis* is often abundant), its variety of well-preserved fragile species, and its fine-grained clastic content all indicate deposition during a period of oscillating marine transgression. However enclosed and reducing conditions are suggested by a significant content of fine carbonaceous material, by occasional pyrite, and by the restricted variety of planktonic species.

4. *Port Willunga Beds (Balcombian and Bairnsdalian Stages)*

Bore 63 (Figs. 3B, 4) contains the greatest known thickness of unit 4. A core of the unit in bore 49, 40ft. (12 m.) above Munno Para Clay, yielded grey, compact to friable, fine-grained, foraminiferal sandy limestone with abundant *Ditrupa* worm-tubes. The diverse, Balcombian, microfauna includes *Orbulina suturalis* (v), large *Marginopora vertebralis* (f), *Epistomaroides polystomelloides* (Parker and Jones) (f), *Elphidium adelaidense* Howchin and Parr (r), *Crespinella umbonifera* (Howchin and Parr) (r), *"Valvulineria" trinucleata* Carter (v), and *Ammonia beccarii* (r).

Flosculinella bontangensis (Rutten) has now been found in this unit in bores 31, 32, 46, 47B, and 81B, extending the distribution of this warm-water Burdigalian species eastwards from its previous records in Nullarbor Limestone of the Eucla Basin (Crespin, 1956; Ludbrook, 1963, 1969a). The *Flosculinella* zone is thus distinctly younger than the *Lepidocyclina* zone. The figured specimens of *Flosculinella bontangensis* (Pl. 2, Figs. 1, 3) are from well above the Munno Para Clay.

The later members of the *Orbulina* bioseries occur only very rarely in the Adelaide Plains Sub-Basin but consistently indicate that the *Orbulina*-surface is in unit 4. This is supported by the finding of single specimens of *Heterolepa victoriensis* (Chapman, Parr and Collins) in the upper part of the unit in bores 64 and 83. This benthonic species was not found below the Bairnsdalian *Orbulina universa* Zone by Ludbrook (1961), Carter (1964), or Reed (1965).

3. PLIOCENE

The Pliocene is represented by three separate lithological units which for ease of representation and because of intertonguing facies relationships are numbered as a single unit.

Unit 3 attains its greatest known thickness in bore 77, west of Adelaide. At the other extreme, cores in bore 12, north of the Gawler River, penetrated 1ft. only (0.3 m.) of marginal Dry Creek Sands, represented by brown and grey shelly foraminiferal clayey and gravelly quartz sand.

Dry Creek Sands

This was the first formation-name to be given to Pliocene beds in the St. Vincent Basin. It was proposed by Glaessner (1951) for "the fossiliferous subsurface strata first observed in the Dry Creek bore from 320 to 410ft." (98-125 m.), a reference to Tate's historic recognition (1890) of a Pliocene fauna in this bore (bore 56). Records of this old bore are unfortunately meagre. A brief log (Miles, 1952, Table XIX, No. 178) records "mainly sands" (presumably unfossiliferous) for 200ft. (61 m.) above the fossiliferous Dry Creek Sands. The surrounding bores 54, 55, and 57 however, have fuller logs, and samples of bore 54 have been examined. It can be said that in their type area, Dry Creek Sands are overlain by Carisbrooke Sand with apparently conformable contact, and that besides shelly sands they may also contain cemented bands of fossiliferous calcareous sandstone and sandy limestone.

Dry Creek Sands facies is well-known as a shelly aquifer, and it is the typical facies of the Pliocene within the Dry Creek-Elizabeth-Virginia area. Ludbrook (1954-1959) has monographed the molluscan fauna. Miocene material is often recycled into the basal beds of Dry Creek Sands.

Hallett Cove Sandstone

The name Hallett Cove Sandstone (Crespin, 1954) fits relatively thin developments of typically-hard fossiliferous sandstone-limestone facies either in high-level situations or in the upper part of the subsurface Pliocene of the Adelaide Plains. On the Para Fault Block (*e.g.*, bore 87), the Pliocene is all or mostly of this type. It is the predominant facies of Pliocene beds beneath the City of Adelaide, where it has an irregular karst-weathered surface (Allchurch, 1967b), but there is also interbedding with loose sands, and a brown shelly sand of Dry Creek Sands facies typically occurs at the base.

In bore 4, the top 16ft. (5 m.) of unit 3 are Hallett Cove Sandstone facies; in bore 7 the top 10ft. (3 m.); in bore 49 the top 20ft. (6 m.); in bore 64 most of the top 40ft. (12 m.), and in bore 83 most of the top 33ft. (10 m.). The lower part may be interbedded with Dry Creek Sands facies.

"Croydon facies"

Steel (1962) recorded still another phase of the Pliocene beneath Dry Creek Sands in the Croydon and Kooyonga bores. He noted "a very fine grey silt with a poor fauna" which Ludbrook (1963) referred to informally as "silts, Croydon", dating it as Lower Pliocene. Closer study of the interval in bore 65 (Lindsay, 1968) shows it to consist of pale grey glauconitic bryozoal silt, fine quartz sand, and somewhat saccharoidal calcareous sandstone, with a total thickness of 66ft. (20 m.). In bore 78, the facies is prominently developed in the bottom 173ft. (53 m.) of the Pliocene section as grey-brown beds of clayey sand, silt, saccharoidal sandstone, and siltstone, with bryozoa, shell fragments, glauconite, and a little pyrite. An intercalation of grey shelly sand is Dry Creek Sands facies.

Similar "Croydon facies", occupying the lower part of the Pliocene section, is developed in bore 5, with a thickness of 42ft. (13 m.); in bore 39, 35ft. (11 m.); in bore 40, 55ft. (17 m.); in bore 49, 58ft. (18 m.); in bore 64, 150ft. (46 m.); and in bore 81B, 30ft. (9 m.).

Elphidium adelaidense is well-developed at this level, with *Ammonia beccarii, Epistomaroides polystomelloides,* and *Notorotalia clathrata* (Brady).

In the lower part of bore 50, 19ft. (6 m.) of "Croydon facies" are underlain by 46ft. (14 m.) of Dry Creek Sands facies. It is apparent that the latter facies may intertongue with the former as well as with Hallett Cove Sandstone.

In the bores studied, "Croydon facies" is only developed within about 4 miles (6½ km.) of the present coast, and from Glenelg to Port Gawler.

? PLIO-PLEISTOCENE

2. Carisbrooke Sand

The name *Carisbrooke Sand* is here proposed for the unit in the Adelaide Plains Sub-Basin known informally until now as "?Plio-Pleistocene sands" (Lindsay and Shepherd, 1966; Allchurch 1967a; Shepherd, 1968). It represents a prominent phase of typically unfossiliferous sand deposition which followed the deposition of fossiliferous Upper Pliocene Dry Creek Sands or Hallett Cove Sandstone, and preceded the deposition of Pleistocene Hindmarsh Clay.

Carisbrooke Sand is not known to crop out in the Adelaide Plains. The subsurface type section is in bore 32, between 250 and 425ft. (76-130 m.). This bore is in Carisbrooke Reserve, adjacent to the property and subdivision of Carisbrooke, from whence the name of the formation. The name has been approved by the Central Registry of Stratigraphic Names, Canberra.

Comparing Appendix 2 with Fig. 1 it can be seen that unit 2 is developed throughout the Sub-Basin except for a strip a few miles wide near the present coast. Figs. 3A to 3D suggest that fossiliferous Pliocene thickens westwards at the expense of unit 2. Other possible time-equivalents of part of unit 2 are fossiliferous basal beds of Hindmarsh Clay (see below), and fossiliferous "sands at Lockleys" (not encountered in the bores studied) of Ludbrook (1963, 1969a). The age of unit 2 thus appears to range from ?uppermost Pliocene to early Pleistocene.

In bore 32, unit 2 consists of fine to medium-grained quartz sands with some poorly-sorted and gravelly intervals. Colour varies from white, through pale grey, cream and yellow, to pale brown. Constituent sand grains vary from angular to rounded, and are often clear and water-polished. The lower part of the unit displays minor cementation to brown ferruginous sandstone.

In bore 32 as in other marginal situations such as bores 2 (Fig. 2) and 61, there is some reworking of Miocene material into the basal part of Carisbrooke Sand. Apart from this, organic remains are typically limited to occasional lignitic fragments.

The type-section of Carisbrooke Sand is overlain by Hindmarsh Clay, and underlain by a thin brown ferruginous gravelly and sandy clay which may represent marginal Pliocene deposition. *Ammonia beccarii,* and *Elphidium macellum* (Fichtel and Moll) are present in this clay, with a little recycled Miocene material.

Continuous tube-cores from bore 12 show a conformable relationship between unit 2, and both unit 3 (mentioned earlier) and unit 1. Unit 2 here consists of unfossiliferous slightly clayey quartz sands which are pale grey mottled yellow, orange, brown, pink, or red. The sands are poorly sorted, and pebbly at the base, where there is also minor patchy ferruginous cementation.

Comparable sands in bore 94 are at least correlatives of unit 2.

Allchurch (1967a) described from an excavation at North Adelaide the relationship between Carisbrooke Sand, Hallett Cove Sandstone, Hindmarsh Clay, and Torrens valley alluvial deposits (unit 1A in Figs. 3, 4).

PLEISTOCENE TO RECENT

1. Hindmarsh Clay to St. Kilda Formation

A number of separate Quaternary lithological units are for ease of representation grouped together as "unit 1". These formations, listed in Fig. 2, have been described by Firman (1963, 1966, 1967a, 1967b, 1969).

Hindmarsh Clay

Near the coast, from Port Gawler southwards, a basal phase of subsurface Hindmarsh Clay contains fragments patches or lenses of white to brown marly limestone which sometimes yield rare small recrystallized foraminifera (*Discorbis* spp., *Elphidium* spp.) At least some are considered to be indigenous. In bore 64, similar limestone and sandy clay above Hallett Cove Sandstone contain a more diverse microfauna with *Clavulina multicamerata* Chapman, *Discorbis mira* (Cushman), *D. cycloclypeus* Howchin and Parr, *D.* sp. cf. *D. dimidiatus* (Parker and Jones), *Ammonia beccarii,* and *Epistomaroides polystomelloides.* Green-grey sandy clays at the base of unit 1 in bore 65 also yielded *Marginopora vertebralis, Peneroplis pertusus* (Forskal), *Spirolina arietina* (Batsch), *Elphidium advenum* (Cushman), *E. macellum* (Fichtel and Moll), and *Discorbis acervulinoides* Parr. Definite marine influence is apparent. Comparable beds which crop out south of the Adelaide Plains Sub-Basin were considered to be early Pleistocene by Firman (1967b), and Twidale, Daily and Firman (1967, p. 239), on the basis of published and unpublished palaeontological work by N. H. Ludbrook.

Glanville Formation

The lime-crusted "*Anadara* beds" described by Firman (1966, 1967b) and dated by him as Middle Pleistocene (1969), are recognized in bores 3, 5, and 49, and in foundation borings in the Port Adelaide area. At Port Adelaide, rubbly lime-cemented silts sands and marls up to 27ft. thick (8 m.) are abundantly fossiliferous. *Marginopora vertebralis* is predominant, and the associated microfauna is of Recent aspect.

St. Kilda Formation

These shelly sands and muds of Recent age, described by Firman (1966, 1967b), and encountered near the coast at the top of bores 3 and 39, are characterized by a microfauna with predominant *Peneroplis planatus* (Fichtel and Moll) rather than *Marginopora vertebralis*.

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REFERENCES

Allchurch, P. D., 1967a. A buried scarp of Torrens River Valley, North Adelaide. *Quart. geol. Notes geol. Surv. S. Aust.* **22**: 1-4.

Allchurch, P. D., 1967b. Karst topography on Hallett Cove Sandstone in the Adelaide City area. *Quart. geol. Notes geol. Surv. S. Aust.* **24**: 1-4.

Banner, F. T., and Blow, W. H., 1965. Progress in the planktonic foraminiferal biostratigraphy of the Neogene. *Nature, Lond.*, **208** (5016): 1164-1166.

Blow, W. H., 1956. Origin and evolution of the foraminiferal genus *Orbulina* d'Orbigny. *Micropaleontology,* **2** (1): 57-70.

Blow, W. H., and Banner, F. T., 1962. The Mid-Tertiary (Upper Eocene to Aquitanian) Globigerinacea. Part 2 *in* Eames *et. al.* (1962).

Bolli, H. M., 1957. Planktonic foraminifera from the Oligocene-Miocene Cipero and Lengua Formations of Trinidad, B.W.I. *Bull. U.S. natn. Mus.* **215**: 97-123, pls. 22-29.

Bolli, H. M., 1966. Zonation of Cretaceous to Pliocene marine sediments based on planktonic foraminifera. *Boln. inf. Asoc. Venez. Geol. Min. Petrol.* **9** (1): 3-32, Tables 1-4.

Carter, A. N., 1964. Tertiary foraminifera from Gippsland, Victoria, and their stratigraphical significance. *Mem. geol. Surv. Vict.*, **23**: 154 p., pls. 1-17.

Cochrane, G. W., 1956. The geology and hydrology of the Willunga Basin. *Rep. Invest. geol. Surv. S. Aust.* **8**: 1-10, Tables 1-5, pls. 1, 2.

Comité Francais de Stratigraphie, 1968. Colloque sur l'Eocène. *Geol. Newsl. Int. Un. Geol. Sci.* for 1968 (4): 60-68.

Cordey, W. G., 1968. A new Eocene *Cassigerinella* from Florida. *Palaeontology,* 11 (3): 368-370.

Cotton, B. C., 1952. The mollusca of the Adelaidean Stage. Appendix IV, 239-249, *in* Miles (1952).

Crawford, A. R., 1965. The geology of Yorke Peninsula. *Bull. geol. Surv. S. Aust.* **39**: with Appendix, 96 p.

Crespin, Irene, 1943. The genus *Lepidocyclina* in Victoria. *Proc. R. Soc. Vict.* **(N.S.)**, **55** (2): 157-180.

Crespin, Irene, 1954. Stratigraphy and micropalaeontology of the marine Tertiary rocks between Adelaide and Aldinga, South Australia. *Rep. Bur. Miner. Resour. Geol. Geophys. Aust.* **12**: 65p.

Crespin, Irene, 1956. Fossiliferous rocks from the Nullarbor Plains. *In* Papers on Tertiary micropalaeontology. *Rep. Bur. Miner. Resour. Geol. Geophys. Aust.* **25**: 27-42.

Crespin, Irene, and Cotton, B. C., 1952. The stratigraphy and palaeontology of the subsurface deposits of the Adelaide Plains. Appendix III, 227-238, *in* Miles (1952).

Department of Mines, 1969. "Northern Adelaide Plains. Progress information on the groundwater situation January, 1969." Government Printer: Adelaide.

Drooger, C. W., Reiss, Z., Rutsh, R. F., and Marks, P., (Eds.), 1966. "Proceedings of the Third Session in Berne, 8-13 June 1964, International Union of Geological Sciences, Commission on Stratigraphy, Committee on Mediterranean Neogene Stratigraphy." E. J. Brill: Leiden.

Eames, F. E., Banner, F. T., Blow, W. H., and Clarke, W. J., 1962. "Fundamentals of Mid-Tertiary stratigraphical correlation." Cambridge University Press.

Firman, J. B., 1963. Quaternary geological events near Port Adelaide. *Quart. geol. Notes geol. Surv. S. Aust.* **7**:

Firman, J. B., 1966. Stratigraphic units of Late Cainozoic age in the Adelaide Plains Basin, South Australia. *Quart. geol. Notes geol. Surv. S. Aust.* **17**: 6-9.

Firman, J. B., 1967a. Late Cainozoic units in South Australia. *Quart. geol. Notes geol. Surv. S. Aust.* **22**: 4-8.

Firman, J. B., 1967b. Stratigraphy of Late Cainozoic deposits in South Australia. *Trans. R. Soc. S. Aust.* **91**: 165-178, pl. 1.

Firman, J. B., 1969. Quaternary Period. *In* Parkin (*ed.*) (1969). Pp. 204-233.

Gibson, T. G., and Walker, W. M., 1967. Flotation methods for obtaining foraminifera from sediment samples. *J. Paleont.* **41** (5): 1294-1297.

Glaessner, M. F., 1951. Three Foraminiferal Zones in the Tertiary of Australia. *Geol. Mag.* LXXXVIII (4): 273-283.

Glaessner, M. F., 1967. Time scales and Tertiary correlations, pp. 1-5, "11th Pacific Science Congress, Tokyo, 1966. Symposium No. 25, Tertiary correlations and climatic changes in the Pacific." Sasaki Printing and Publishing Co. Ltd.: Sendai, Japan.

Glaessner, M. F., and Parkin, L. W., (ed.), 1958. The geology of South Australia. *J. geol. Soc. Aust.*, **5** (2): 1-163.

Glaessner, M. F., and Wade, Mary, 1958. The St. Vincent Basin, 115-126, *in* Glaessner and Parkin (*ed.*) (1958).

Glaessner, M. F., and Woodard, G. D., 1956. The micropalaeontological examination of the Willunga Bore. Appendix, 11-14, pl. III, *in* Cochrane (1956).

Harris, W. K., 1966. New and redefined names in South Australian Lower Tertiary stratigraphy. *Quart. geol. Notes geol. Surv. S. Aust.* **20**: 1-3.

Hornibrook, N. de B., 1968. A handbook of New Zealand microfossils (Foraminifera and Ostracoda). *Inf. Ser. Dep. scient. ind. Res. N.Z.* **62**: 136 p., Table II.

Jenkins, D. G., 1965. Planktonic foraminiferal zones and new taxa from the Danian to Lower Miocene of New Zealand. *N.Z. J. geol. geophys.* **8** (6): 1088-1126.

Jenkins, D. G., 1966. Planktonic foraminifera from the type Aquitanian-Burdigalian of France. *Contr. Cushman Fdn. foramin. Res.* XVII (1): 1-15, pl. 3.

Jenkins, D. G., 1967. Planktonic foraminiferal zones and new taxa from the Lower Miocene to the Pleistocene of New Zealand. *N.Z. J. geol. geophys.* **10** (4): 1064-1078, Fig. 2.

Lindsay, J. M., 1967. Foraminifera and stratigraphy of the type section of Port Willunga Beds, Aldinga Bay, South Australia. *Trans. R. Soc. S. Aust.*, **91**: 93-110.

Lindsay, J. M., 1968. Notes on foraminifera and stratigraphy of the Grange and Croydon bores. *Quart. geol. Notes, geol. Surv. S. Aust.* **26**: 1-3.

Lindsay, J. M., and Shepherd, R. G., 1966. Munno Para Clay Member. *Quart. geol. Notes, geol. Surv. S. Aust.* **19**: 7-11.

Ludbrook, N. H., 1954. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Part I. *Trans. R. Soc. S. Aust.* **77**: 42-64.

Ludbrook, N. H., 1955. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Part II. Pelecypoda. *Trans. R. Soc. S. Aust.*, **78**: 18-87.

Ludbrook, N. H., 1956a. Supplementary note on Willunga Basin sediments. *Rep. Invest. geol. Surv. S. Aust.* **8**. Appendix *in* Cochrane (1956), 15-18.

Ludbrook, N. H., 1956b. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Part III. Scaphopoda, Polyplacophora, Gastropoda (Haliotidae to Tornidae). *Trans. R. Soc. S. Aust.* **79**: 1-36, pls. 1, 2.

Ludbrook, N. H., 1957. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Part IV. Gastropoda (Turritellidae to Struthiolariidae). *Trans. R. Soc. S. Aust.* **80**: 17-58, pls. 1-4.

Ludbrook, N. H., 1958. The molluscan fauna of the Pliocene strata underlying the Adelaide Plains. Part V. Gastropoda (Eratoidae to Scaphandridae). *Trans. R. Soc. S. Aust.* **81**: 43-111, pls. 1-6.

Ludbrook, N. H., 1959a. Revision of the Tate Molluscan Types—Scaphopoda. *Trans. R. Soc. S. Aust.* **82**: 141-149, pls. 1, 2.

Ludbrook, N. H., 1959b. A widespread Pliocene molluscan fauna with *Anodontia* in South Australia. *Trans. R. Soc. S. Aust.* **82**: 219-233, pls. 1-5.

Ludbrook, N. H., 1961. Stratigraphy of the Murray Basin in South Australia. *Bull. geol. Surv. S. Aust.* **36**: 96 p., pls. I-VIII.

Ludbrook, N. H., 1962. Palaeontology Section Report, p. 22, *in Rept. Dir. Min. S. Aust.* for 1960-61.

Ludbrook, N. H., 1963. Correlation of the Tertiary rocks of South Australia. *Trans. R. Soc. S. Aust.*, **87**: 5-15.

Ludbrook, N. H., 1967a. Correlation of the Tertiary rocks of the Australasian region, pp. 7-19. *In* "11th Pacific Science Congress, Tokyo, 1966. Symposium No. 25, Tertiary correlation and climatic changes in the Pacific." Sasaki Printing and Publishing Co. Ltd.: Sendai, Japan.

Ludbrook, N. H., 1967b. Permian deposits of South Australia and their fauna. *Trans. R. Soc. S. Aust.* **91**: 65-92.

Ludbrook, N. H., 1969a. Tertiary Period. *In* Parkin, (*ed.*) (1969). Pp. 172-203.

Ludbrook, N. H., 1969b. Permian of South Australia, Review. *In* Symposium on the Permian of Australia. *geol. Soc. Aust. Spec. Publ.* (in press).

Ludbrook, N. H., and Lindsay, J. M., 1966. The Aldingan Stage. *Quart. geol. Notes, geol. Surv. S. Aust.* **19**: 1-2.

Ludbrook, N. H., and Lindsay, J. M., 1969. Tertiary foraminiferal zones in South Australia. *In* "Proceedings of the First International Conference on Planktonic Microfossils, Geneva, 1967" (Brönnimann and Renz *ed.*) Vol. II. E. J. Brill: Leiden (in press).

McTavish, R. A., 1966. Planktonic foraminifera from the Malaita Group, British Solomon Islands. *Micropaleontology,* **12** (1): 1-36.

Miles, K. R., 1945. Noarlunga sand deposit. *Min. Rev., Adelaide,* **81**: 85-89.

Miles, K. R., 1952. Geology and underground water resources of the Adelaide Plains area. *Bull. geol. Surv. S. Aust.* **27**: 257 p. with appendices.

Miller, P. G., 1965. Investigation into the effects of the increasing utilization of the pressure groundwaters of the Northern Adelaide Plains. Progress Report. *Min. Rev., Adelaide,* **118**: 16-31.

Olliver, J. G., and Weir, L. J., 1967. The construction sand industry in the Adelaide Metropolitan Area. *Rep. Invest., geol. Surv. S. Aust.* **30**: 106 p., pl. 1.

Parkin, L. W. (*ed.*), 1969. *Handbook of South Australian Geology.* Government Printer: Adelaide. 261 p.

Parr, W. J., 1947. An Australian record of the foraminiferal genus *Hantkenina. Proc. R. Soc. Vict.* (N.S.), LVIII (I-II): 45-47.

Raggatt, H. G., and Crespin, Irene, 1955. Stratigraphy of Tertiary rocks between Torquay and Eastern View, Victoria. *Proc. R. Soc. Vict.* (N.S.), **67** (1): 75-142, pls. IV-VII.

Ramsay, W. R., 1962. Hantkenininae in the Tertiary rocks of Tanganyika. *Contr. Cushman. Fdn. foramin. Res.* XIII (3): 79-89.

Reed, K. J., 1965. Mid-Tertiary smaller foraminifera from a bore at Heywood, Victoria, Australia. *Bull. Am. Paleont.* **49** (220): 39-104.

Reiss, Z., and Gvirtzman, G., 1966. Subsurface Neogene stratigraphy of Israel, 312-346 *in* Drooger *et. al.* (*ed.*) (1966).

Reynolds, M. A., 1953. The Cainozoic succession of Maslin and Aldinga Bays, South Australia. *Trans. R. Soc. S. Aust.* **76**: 114-140.

Scoular, G., 1879. The geology of the hundred of Munno Para, Part 1. The Newer Tertiary rocks. *Trans. Proc. Rep. phil. Soc. Adel.* for 1878-1879, 60-70.

Seedsman, K. R., 1967. Reflection seismic survey—Northern Adelaide Plains, 1964. *Min. Rev., Adelaide,* **121**: 56-69.

Shepherd, R. G., 1968. The hydrogeology of the Northern Adelaide Plains Basin. *Min. Rev., Adelaide,* **125**: 8-20.

Srinivasan, M. S., 1968. Late Eocene and early Oligocene planktonic foraminifera from Port Elizabeth and Cape Foulwind, New Zealand. *Contr. Cushman Fdn. foramin. Res.* XIX (4): 142-159.

Steel, T. M., 1962. Subsurface stratigraphy in the western suburbs of Adelaide. *Quart. geol. Notes geol. Surv. S. Aust.* **2**.

Stuart, W. J., 1967. Sedimentation in the St. Vincent Basin. A.N.Z.A.A.S. 39th Congress Melb. Jan. 1967. Sect. C Abstracts, pp. A5-A6.

Tate, R., 1882. Notes on the Tertiary strata beneath Adelaide. *Trans. R. Soc. S. Aust.* **5**: 40-43.

Tate, R., 1890. On the discovery of marine deposits of Pliocene age in Australia. *Trans. R. Soc. S. Aust.* **13** (2): 172-180.

Tate, R., 1898. On deep-seated Eocene strata in the Croydon and other bores. *Trans. R. Soc. S. Aust.* **22** (II): 194-199.

Tepper, J. G. O., 1879. Introduction to the cliffs and rocks at Ardrossan, Yorke's Peninsula. *Trans. Proc. Rep. phil. Soc. Adel.* for 1878-1879, **2**: 71-79.

Twidale, C. R., Daily, B., and Firman, J. B., 1967. Eustatic and climatic history of the Adelaide area, South Australia: A Discussion. *J. Geol.* **75** (2): 237-242.

Wade, Mary, 1964. Application of the lineage concept to biostratigraphic zoning based on planktonic foraminifera. *Micropaleontology,* **10** (3): 273-290.

UNPUBLISHED REPORTS

Cornish, B. E., 1964. Light No. 1 Well completion report. Dept. of Mines. Rep. Bk. 59/113.

Department of Mines, 1968. Northern Adelaide Plains groundwater study to May, 1968. Vols. I and II. Dept. of Mines. Rep. Bk. 67/123.

Kelly, A., 1969. Petrography of twenty-five sandy limestones from the Two Wells area, South Australia, Observation bore "N". Aust. Miner. Devel. Lab. Rep. MP 2404-69.

Lindsay, J. M., 1964a. New Government Building, Victoria Square, foundation stratigraphy. Dept. of Mines. Pal. Rep. 3/64, Rep. Bk. 58/126.

Lindsay, J. M., 1964b. Morphett Street and Victoria Bridges, foundation stratigraphy. Dept. of Mines. Pal. Rep. 5/64, Rep. Bk. 59/34.

Lindsay, J. M., 1965a. New A.M.P. Building, Adelaide, foundation stratigraphy. Dept. of Mines. Pal. Rep. 5/65, Rep. Bk. 60/39.

Lindsay, J. M., 1965b. Stratigraphy and micropalaeontology of three deep bores, Hundred of Port Gawler. Dept. of Mines. Pal. Rep. 4/65, Rep. Bk. 60/51.

Lindsay, J. M., 1965c. Immanuel College, Camden Park, bore 1, stratigraphy and micropalaeontology. Dept. of Mines. Pal. Rep. 14/65, Rep. Bk. 61/108.

Lindsay, J. M., 1965d. Adelaide Plains Sub-basin stratigraphy, Summary Report No. 1, Hundred of Port Adelaide. Dept. of Mines. Pal. Rep. 16/65, Rep. Bk. 61/164.

Lindsay, J. M., 1966a. Adelaide Plains Sub-basin stratigraphy, Summary Report No. 2, Hundred of Yatala. Dept. of Mines. Pal. Rep. 1/66, Rep. Bk. 62/4.

Lindsay, J. M., 1966b. Adelaide Plains Sub-basin stratigraphy, Summary Report No. 3, Hundreds of Munno Para, Mudla Wirra, and Port Gawler. Dept. of Mines. Pal. Rep. 2/66, Rep. Bk. 62/47.

Lindsay, J. M., 1966c. Stratigraphy and micropalaeontology of the Willunga Bore W.B.1—a re-examination. Dept. of Mines. Pal. Rep. 8/66, Rep. Bk. 63/73.

Lindsay, J. M., 1967. Adelaide Plains Sub-basin stratigraphy and micropalaeontology, Summary Report No. 4. Dept. of Mines. Pal. Rep. 1/67, Rep. Bk. 64/6.

Lindsay, J. M., 1968. Palaeontology and stratigraphy. Appendix C. Vol. I, *in* Department of Mines (1968) (unpub.).

Rowan, I. S., 1964. First report on gravity survey of the North Adelaide Plains. Dept. of Mines. Rep. Bk. 58/55.

Scott, I. F., 1966. Carbonate pellets from North Adelaide. Aust. Miner. Devel. Lab. Rep. MP 1946-66.

Steel, T. M., 1962. Beach Petroleum Grange No. 1 Well, subsurface stratigraphy. Dept. of Mines. Pal. Rep. 8/62, Rep. Bk. 677.

Townend, R., 1964. Petrology of carbonate core samples from Port Gawler. Aust. Miner. Dev. Lab. Rep. MP 147-64.

PLATE 1

All figures approximately X96

Fig. 1. *Globigerina woodi woodi* Jenkins. Hypotype Ff 459. Bore 12, core, 138ft. (42 m.), unit 5. Apertural view.

Figs. 2, 7. *Globigerina ampliapertura ampliapertura* Bolli. Hypotype Ff 460. Bore 2, 223-234ft. (68-71 m.), unit 8. Immature specimen. 2. Apertural view. 7. Edge view.

Figs. 3, 8. *Globigerina gortanii* (Borsetti) subsp. Hypotype Ff 461. Bore 74, core, 132ft. (40 m.), unit 9. 3. Spiral view. 8. Apertural view.

Fig. 4. *Cassigerinella eocaenica* Cordey. Hypotype Ff 462. Bore 20, 385ft. (117 m.), unit 9. Edge view showing early planispiral chambers in final whorl.

Figs. 5, 10, 16. *Cassigerinella eocaenica* Cordey. Hypotype Ff 463. Bore 4, core, 460ft. (140 m.), unit 8. 5. Apertural side view showing early planispiral chambers in final whorl. 10. Opposite side view. 16. Edge view.

Fig. 17. *Cassigerinella eocaenica* Cordey. Hypotype Ff 464. Bore 4, as above. Dissected specimen showing initial planispiral whorl.

Figs. 6, 11. *Truncorotaloides collactea* (Finlay). Hypotype Ff 465. Bore 20, as for Ff 462. 6. Spiral view. 11. Umbilical view (final chamber broken).

Figs. 9, 15. *Globorotaloides testarugosa* (Jenkins). Hypotype Ff 466. Bore 2, as for Ff 460. 9. Spiral view. 15. Umbilical view.

Figs. 12, 19, 24. *Globigerina ouachitaensis* Howe and Wallace. Hypotype Ff 467. Bore 34. 440-450ft. (134-137 m.) unit 7. 12. Spiral view. 19. Umbilical view. 24. Side view.

Figs. 13, 14. *Subbotina linaperta* (Finlay). Hypotype Ff 468. Bore 4, core, 467ft. (142 m.), unit 9. 13. Spiral view. 14. Umbilical view.

Figs. 18, 23, 27. *Globigerina ampliapertura aff. pseudoampliapertura* Blow and Banner. Hypotype Ff 469. Bore 2, as for Ff 460. 18. Spiral view. 23. Edge view. 27. Apertural view.

Figs. 20, 25. *Globigerina angulisuturalis* Bolli. Hypotype Ff 470. Bore 34, as for Ff 467. 20. Spiral view. 25. Umbilical view.

Fig. 21. *Globigerina angiporoides angiporoides* Hornibrook. Hypotype Ff 471. Bore 24B, 500-510ft. (152-155 m.) unit 8. Umbilical, apertural view.

Fig. 22. *Hantkenina alabamensis compressa* Parr. Topotype Ff 472. Lower Brown's Creek Clay, type section, Otway Basin, Victoria. Side view.

Figs. 26, 31. *Turborotalia gemma* (Jenkins). Hypotype Ff 473. Bore 4, core, 469ft. (143 m.), unit 9. 26. Spiral view. 31. Umbilical view.

Figs. 28, 32. *Turborotalia aculeata* (Jenkins). Hypotype Ff 474. Bore 71, core, 97ft. (30 m.), unit 9. 28. Spiral view. 32. Umbilical view.

Figs. 29, 33. *Globigerinoides* sp. cf. *G. altiaperturus* Bolli. Hypotype Ff 475. Bore 49, 440-450ft. 134-137 m.), unit 5. 29. View of primary aperture. 33. Spiral view showing secondary aperture.

Fig. 30. *Chiloguembelina cubensis* (Palmer). Hypotype Ff 476. Bore 73C, core, 57ft. (17 m.), unit 11. Oblique apertural view.

Fig. 34. *Guembelitria stavensis* Bandy. Hypotype Ff 477. Bore 2, 184-220ft. (56-67 m.), unit 7. Side view, showing aperture.

Figs. 35, 36. *Hantkenina alabamensis compressa* Parr. Hypotype Ff 478. Bore 73C, as for Ff 476. 35. Side view. 36. Slightly oblique apertural view.

Fig. 37. *Hantkenina alabamensis compressa* Parr. Topotype Ff 479, as for Ff 472. Side view of early chambers of broken specimen.

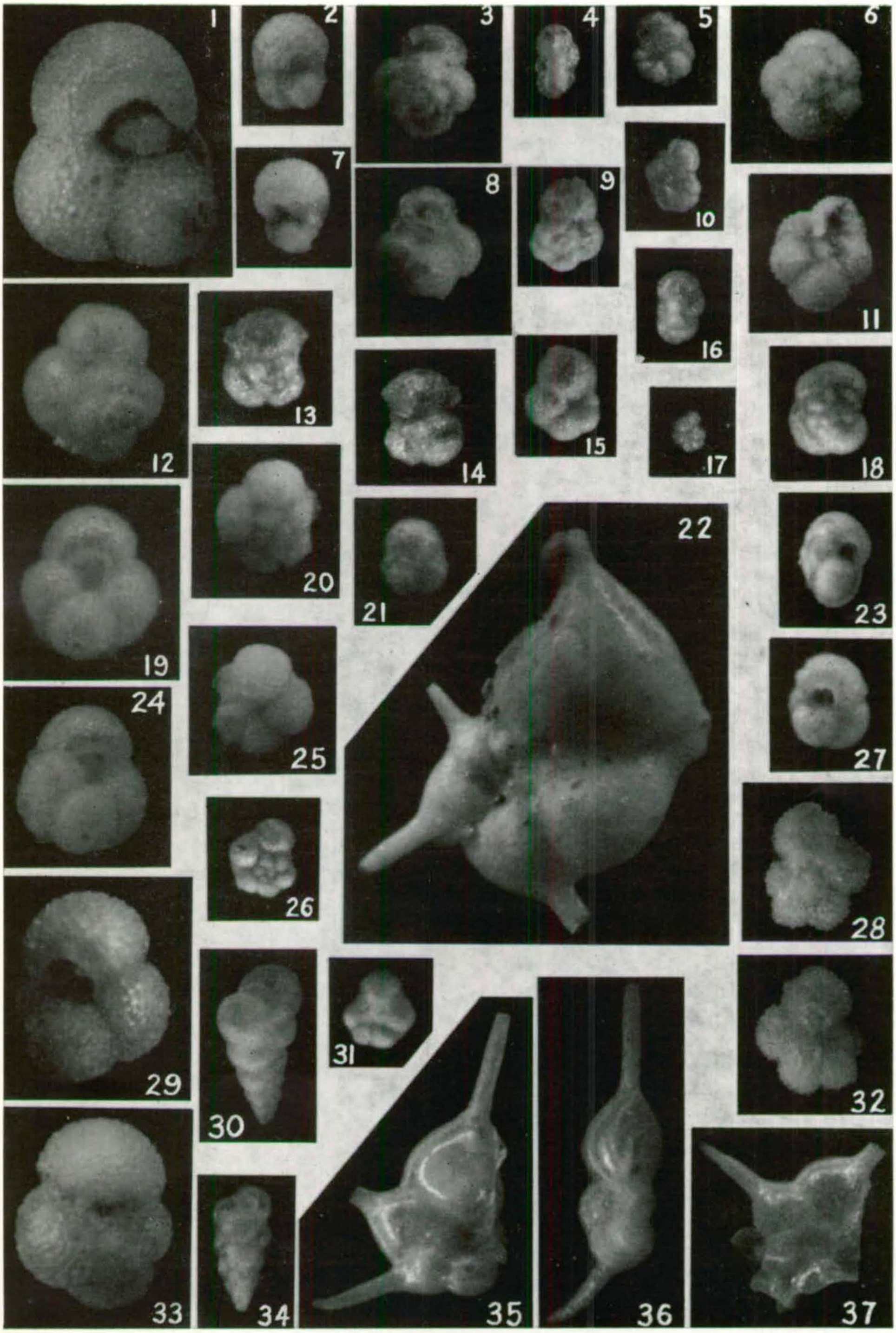

PLATE 1.

PLATE 2

Magnifications as shown

Fig. 1. *Flosculinella bontangensis* (Rutten). Hypotype Ff 480. Bore 31, 370-375ft. (113-114 m.), unit 4. Exterior view. X96.

Figs. 2, 4. *Asterigerinella adelaidensis* (Howchin). Topotype Ff 481. Bore 70, 195-217ft. (59-66 m.), unit 11. 2. Dorsal side. 4. Ventral side. X24.

Fig. 3. *Flosculinella bontangensis* (Rutten). Hypotype Ff 482. Bore 32, 450-455ft. (137-139 m.), unit 4. Axial section. X64.

Figs. 5, 7, 9. *Svratkina* sp. Figured Specimen Ff 483. Bore 5, 810-815ft. (247-248 m.), unit 9. 5. Dorsal, spiral, view. 7. Ventral view. 9. Edge view. X48.

Fig. 6. *Planorbulina* sp. Figured Specimen Ff 484. Bore 4, core, 460ft. (140 m.), unit 8. Dorsal view. X48.

Fig. 8. *Pseudopolymorphina* sp. Figured specimen Ff 485. Bore 70, as for Ff 481. Side view. X24.

Fig. 10. *Lepidocyclina howchini* Chapman and Crespin. Hypotype Ff 486. Bore 31, 469-481ft. (143-147 m.), unit 6. Equatorial section, showing nephrolepidine embryonic apparatus. X24.

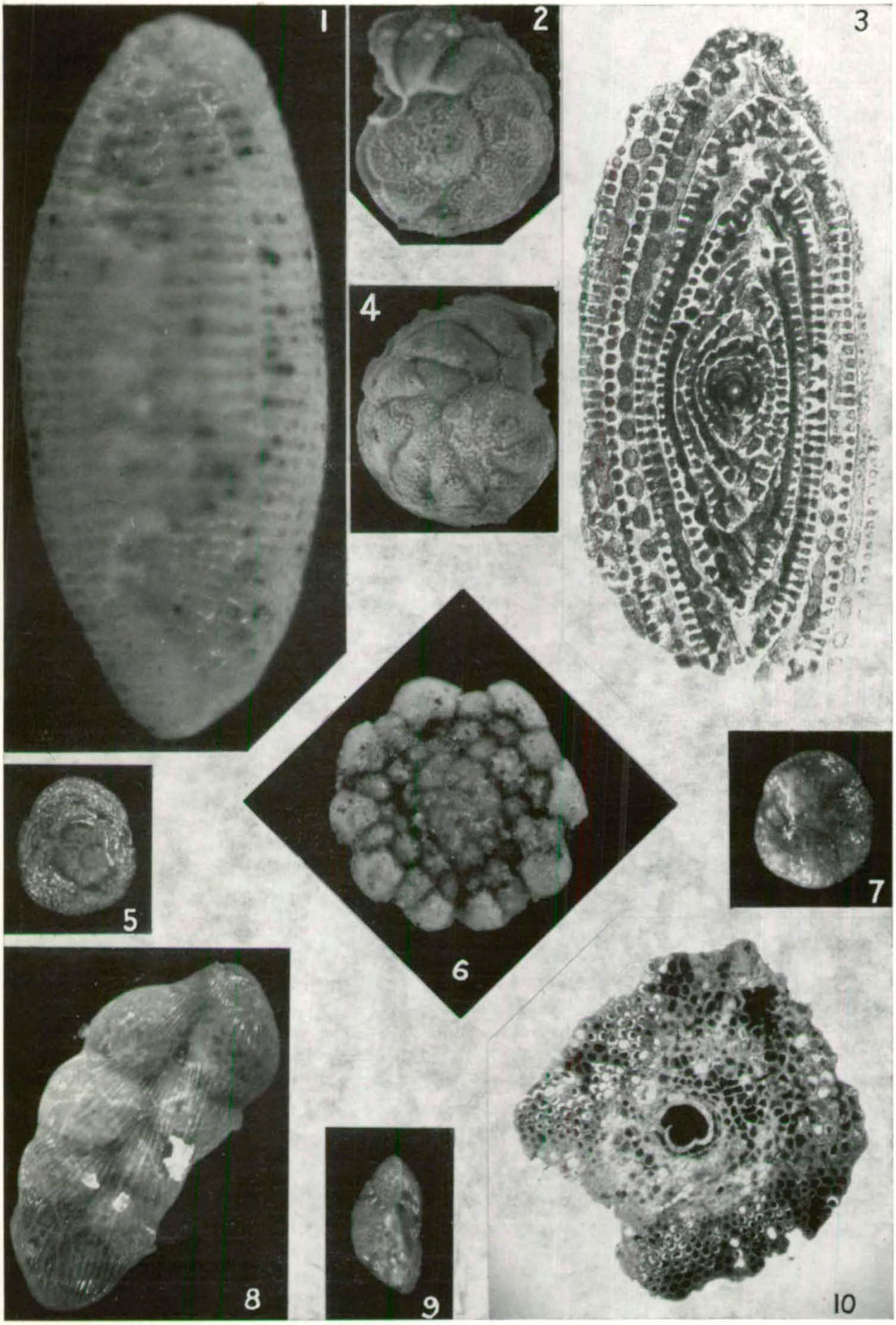

PLATE 2.

APPENDIX 1

REFERENCE BORE DATA

Ref. No.	Hundred	Section	Name of Bore	State Number
1	Dublin	Adj. 505	Dept Mines seismic shothole C. 214	338050504
2	Dublin	97	Engineer-in-Chief's Dept. bore (1887-88)	338009701
3	Port Gawler	733	Beach Petroleum N. L. Hallions No. 2 well	594073302
4	Port Gawler	344	Dept. Mines Light No. 1 bore	594034401
5	Port Gawler	T/A	Dept. Mines Observation bore F, Port Gawler	594999001
6	Port Gawler	28	F. Centofanti, bore 2	594002802
7	Port Gawler	25	K. O'Loan, bore 1	594002505
8	Port Gawler	464	E. Gameau, bore 1, Two Wells	594046401
9	Port Gawler	451	W. J. Gameau, bore 1, Two Wells	594045104
10A	Port Gawler	446	Dept. Mines Observation bore G, Two Wells	594044601
10B	Port Gawler	446	Dept. Mines Observation bore G1, Two Wells	594044602
11	Port Gawler	67	T. Rinaldi, bore 1	594006704
12	Port Gawler	251	Dept. Mines Observation bore N	594025101
13	Port Gawler	78(S)	T. Elliott, bore 1, Gawler River	594007801
14	Port Gawler	58	E. R. Hillwood, bore 1	594005804
15	Port Gawler	174	Dept. Mines Observation bore J	594017401
16	Mudla Wirra	87	H. G. Richardson, bore 1, Gawler River	522008701
17	Mudla Wirra	35	E. L. Koch, bore 1	522003502
18	Mudla Wirra	873	Dept. Mines Observation bore H	522087301
19	Munno Para	118	Merenda Bros., bore 1, Gawler	525011807
20	Munno Para	27	V. Costa, bore 2	525002702
21	Munno Para	4133	C. Costa, bore 1	525413304
22	Munno Para	4099	Smithfield Primary School, bore 1	525409901
23	Munno Para	4102	Metro Meat Co., bore 1	525410201
24A	Munno Para	3889	Dept. Mines Observation bore C, Angle Vale	525388902
24B	Munno Para	3889	Dept. Mines Observation bore C1, Angle Vale	525388903
25	Munno Para	7557	J. Spiers, bore 1	525755702
26A	Munno Para	3036	Dept. Mines Observation bore A, Virginia	525303603
26B	Munno Para	3036	Dept. Mines Observation bore A1, Virginia	525303604
26C	Munno Para	3036	Dept. Mines Observation bore A2, Virginia	525303605
27	Munno Para	3069	A. Bergamin, bore 1	525306901
28	Munno Para	3073	P. and S. Damin, bore 3, Direk	525307305
29	Munno Para	4260	J. Penquitt, bore 1	525426003
30	Munno Para	4249	C. A. Millstead, bore 1	525424901
31	Munno Para	3125	South Australian Housing Trust, Elizabeth Oval bore 1	525312501
32	Munno Para	2020	Dept. Mines Observation bore P3, Carisbrooke	525202002
33A	Munno Para	2272	Dept. Mines Observation bore P1, Bolivar	525227201
33B	Munno Para	2272	Dept. Mines Observation bore P2, Bolivar	525227202
34	Port Adelaide	7526	Dept. Mines Observation bore M, Buckland Park	593752601
35	Port Adelaide	7554	T. H. McKay, bore 2	593755402
36	Port Adelaide	176	Virginia School bore	593017604
37	Port Adelaide	176	T. T. Stoyanoff, bore 1	593017605
38	Port Adelaide	175	Dept. Mines Saline Water Detection bore No. 1, Buckland Park	593017501
39	Port Adelaide	161	Dept. Mines Observation bore E, Buckland Park	593016101
40	Port Adelaide	D	Dept. Mines Observation bore D, St. Kilda	593000D01
41	Port Adelaide	Lot 25 St. Kilda	E. and W. S. Dept., St. Kilda Township bore 1	593999003

REFERENCE BORE DATA

Ref. No.	Hundred	Section	Name of Bore	State Number
42	Port Adelaide......	316	Dept. Mines Saline Water Detection bore No. 1, St. Kilda	593031601
43	Port Adelaide......	185	Dept. Mines Saline Water Detection bore No. 2, St. Kilda	593018502
44	Port Adelaide......	185	Dept. Mines Saline Water Detection bore No. 3, St. Kilda	593018501
45	Port Adelaide......	5021	J. O. Robinson, bore 1....................	593502104
46	Port Adelaide......	5030	A. W. and D. J. Taylor	593503004
47A	Port Adelaide......	5023	Messrs. Hobby, Row and Brown, bore 1 ...	593502302
47B	Port Adelaide......	5023	G. R. Fregona, bore 1	593502315
48	Port Adelaide......	5013	E. G. Perre, bore 1	593501305
49	Port Adelaide......	Block 10 Harbours Board Reserve	Dept. Mines Observation bore L, Pelican Point	593001001
50	Port Adelaide......	861	Dept. Works, Torrens Island Quarantine Station, bore 1	593086101
51	Port Adelaide......	705	Cresco Fertilizers Ltd., bore 1, Birkenhead ..	593070506
52	Port Adelaide......	Adj. 1108	E. and W. S. Dept., Glanville bore	593110801
53	Port Adelaide......	358	I.C.I. Alkali (Aust.) Pty. Ltd., bore 1, Dry Creek	593035801
54	Port Adelaide......	332	I.C.I. Alkali (Aust.) Pty. Ltd., bore 4, Dry Creek	593033201
55	Port Adelaide......	1020	Metro Wholesale Meat Co. Ltd., bore 1	593102001
56	Port Adelaide......	980	The Australian Smelting and Refining Co. Ltd., bore 1, Dry Creek (1890). 'Dry Creek bore'; 'Old Smelters bore'. (Latterly Burfords Ltd.)	593098001
57	Port Adelaide......	920	Fellmongers (S.A.) Ltd. bore 1, Dry Creek..	593092002
58	Yatala	2268	P. Errigo, bore 2	728226802
59A	Yatala	2269	D. Scambiatterra, bore 1	728226905
59B	Yatala	2269	I. Greco (previously P. Errigo)	728226902
60	Yatala	2189	Dept. Mines Observation bore P10, Salisbury	728218903
61	Yatala	2220	Dept. Mines Observation bore P9, Salisbury	728222004
62	Yatala	2235	Dept. Agriculture Parafield Poultry Station bore 1	728223502
63	Yatala	97	Metropolitan Abattoirs bore...............	728009702
64	Yatala	735	Beach Petroleum N.L. Grange No. 1 well ...	755728078
65	Yatala	Adj. 374	E. and W. S. Dept. Croydon bore No. 2	756728026
66A	Yatala	T.A. 749	Proposed Festival Hall site "Carclew", North Adelaide, foundation test bore 1	787074901
66B	Yatala	T.A. 749	Proposed Festival Hall site, "Carclew", North Adelaide, foundation test bore 2	787074902
67	Yatala	T.A. 772	E. F. Marshall and Sons, drainage bore, 168 Ward Street, North Adelaide	787077201
68A	Yatala	T.A. 717	Adelaide Children's Hospital, corner Kermode Street and Sir Edwin Smith Avenue, foundation test bore 1	787071705
68B	Yatala	T.A. 717	Adelaide Children's Hospital, corner Kermode Street and Sir Edwin Smith Avenue, foundation test bore 5	787071704
69	Yatala	478	H. and L. G. Dept. Vale Park Bridge, foundation test bore 2	757728044
70	Adelaide	N.E. Parklands No. 13	Old E. and W. S. Dept. Kent Town bore (1890)	791202001
71	Adelaide	T.A. 270	Public Buildings Dept., new Govt. Office Building, Victoria Square, foundation test bore G. 4	202027011

REFERENCE BORE DATA

Ref. No.	Hundred	Section	Name of Bore	State Number
72	Adelaide	T.A. 16	New A.M.P. Building, North Terrace, foundation test bore 4A, Gresham Street	202001605
73A	Adelaide	Railway Reserve	Morphett Street and Victoria Bridges, foundation test bore 11, Adelaide Railway Station	787202004
73B	Adelaide	Parklands Reserve	Morphett Street and Victoria Bridges, foundation test bore 12, south bank of Torrens lake	787202001
73C	Yatala	Parklands Reserve	Morphett Street and Victoria Bridges, foundation test bore 14, north bank of Torrens lake	787728007
74	Adelaide	T.A. 199	P.M.G. proposed building, Waymouth Street, foundation test bore 1	790019901
75	Adelaide	West Parklands	Australian Postal Institute, bore 1	789202002
76	Adelaide	5	S.A. Farmers Union bore, Mile End........	761202163
77	Adelaide	145	D. J. Hayman, bore 3	761202003
78	Adelaide	2028	Kooyonga Golf Club, bore 6	761202077
79	Adelaide	Adj. 186	E. and W. S. Dept., Glenelg North bore, Patawalonga Creek	765202003
80	Adelaide	186	Glenelg Golf Club, bore 6.................	765202011
81A	Adelaide	170	Glenelg Golf Club, bore 2.................	765202006
81B	Adelaide	170	Glenelg Golf Club, bore 5.................	765202007
82	Adelaide	186	Glenelg Golf Club, bore 3.................	765202004
83	Adelaide	152	Immanuel College bore 1, Camden Park	766202078
84	Adelaide	262	E. and W. S. Dept. Springbank bore........	772202004
85	Adelaide	8	Daws Road High School, bore 1	772202022
86	Adelaide	78	Flinders University, Bedford Park, water bore 1	774202020
87	Noarlunga	178	Warradale Infants School, bore 1	771547037
88	Noarlunga	Adj. 144	Oaklands bore (S.A.R. bore 36)............	771547025
89	Noarlunga	119	Corporation of Marion, Sturt Oval bore 1...	771547034
90	Noarlunga	214	Glenelg Corporation, Glenelg Oval bore 1...	765547006
91	Noarlunga	147	E. and W. S. Dept. Paringa Park bore (Govt. bore 9)	771547012
92	Noarlunga	174	E. and W. S. Dept. Glenelg East bore (Govt. bore 91A)	771547006
93	Noarlunga	Pt. 175	Howard R. Weymouth bore 1, East Glenelg.	770547010
94	Willunga	Adj. 222	Dept. Mines bore W.B.1, Willunga	697022203

APPENDIX 2

STRATIGRAPHIC SUMMARIES OF REFERENCE BORES

KEY:

Stratigraphic units:	numbered as in Figs, 2, 3, 4.
Bore numbers:	"No." represents "reference bore number for the purposes of this Bulletin only".
R.L.:	reduced level of bore with reference to Low Water Ordinary Spring Tides, Port Adelaide. Mean Sea Level =R.L. 105.68 feet (32.21m.)
Unit 1:	the figure in this column denotes the depth to the base of this composite unit.
Unit 2:	interval occupied by Unit 2.
Units 3 to 15:	depth to the top of each unit.
Measurements:	in each bore the upper figure is feet, the lower (**bold**) metres.

Bore No.	R.L.	Total Depth	Stratigraphic Units 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	ca. 136	200	?125	?125	—	—	—	?125	170	at 200							
	(ca. 42)	**(61)**	**(?38)**	**(?38)**	—	—	—	**(?38)**	**(52)**	**(at 61)**							
2	ca. 156	583	120	120-134	—	—	—	134	184	220	245	—	311	320	335	—	376
	(ca. 48)	**(178)**	**(37)**	**(37-41)**	—	—	—	**(41)**	**(56)**	**(67)**	**(75)**	—	**(95)**	**(98)**	**(102)**	—	**(115)**
3	115	603	190	—	190	—	—	211	350	380	?450	?560					
	(35)	**(184)**	**(58)**	—	**(58)**	—	—	**(64)**	**(107)**	**(116)**	**(?137)**	**(?171)**					
4	136	563	180	—	180	—	—	220	360	380	465	—	550	—	—	—	561
	(42)	**(172)**	**(55)**	—	**(55)**	—	—	**(67)**	**(110)**	**(116)**	**(142)**	—	**(168)**	—	—	—	**(171)**
5	110	1152	233	—	233	325	353	355	570	585	705	815	875	910	1015	1085	1148
	(34)	**(351)**	**(71)**	—	**(71)**	**(99)**	**(107.6)**	**(108.2)**	**(174)**	**(178)**	**(215)**	**(248)**	**(267)**	**(277)**	**(309)**	**(331)**	**(350)**
6	120	400	230	—	230	280	314	317.5									
	(37)	**(122)**	**(70)**	—	**(70)**	**(85)**	**(96)**	**(97)**									
7	126	242	210	210-225	225												
	(38)	**(74)**	**(64)**	**(64-69)**	**(69)**												
8	146	200	110	110-150	—	—	—	150									
	(45)	**(61)**	**(34)**	**(34-46)**	—	—	—	**(46)**									
9	146	200	108	108-118	118	—	—	125									
	(45)	**(61)**	**(33)**	**(33-36)**	**(36)**	—	—	**(38)**									
10A	140	393															
	(43)	**(120)**	100	100-120	[120]	—	—	?120	270	330							
10B	140	351	**(31)**	**(31-37)**	**(37)**	—	—	**(?37)**	**(82)**	**(101)**							
	(43)	**(107)**															
11	151	300	80	80-145	—	145	170	180									
	(46)	**(91)**	**(24)**	**(24-44)**	—	**(44)**	**(52)**	**(55)**									

Bore No.	R.L.	Total Depth	Stratigraphic Units 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
12	163	448	73	73-131	131	132	136	151	285	367							
	(50)	(137)	(22)	(22-39.9)	(39.9)	(40.2)	(41.5)	(46)	(87)	(112)							
13	186	390	103	103-169	—	169	172	199———	?								
	(57)	(119)	(31)	(31-51.5)	—	(51.5)	(52.4)	(61)———	?								
14	177	212	64	64-141	—	—	141	158									
	(54)	(65)	(20)	(20-43)	—	—	(43)	(48)									
15	169	300	70	70-115	—	—	—	115	230	270							
	(52)	(91)	(21)	(21-35)	—	—	—	(35)	(70)	(82)							
16	204	260	150	150-183	—	—	183	199									
	(62)	(79)	(46)	(46-56)	—	—	(56)	(61)									
17	231	280	154	154-206	—	—	206	210									
	(70)	(85)	(47)	(47-63)	—	—	(63)	(64)									
18	222	280	110	110-149	—	—	—	149	259								
	(68)	(85)	(34)	(34-45)	—	—	—	(45)	(79)								
19	248	435	121	(undifferentiated Quaternary-Tertiary sands 121-435 feet (37-133m.)													
	(76)	(133)	(37)														
20	238	385	?204	—	—	—	—	?204	?285 ———	———	?						
	(73)	(117)	(?62)	—	—	—	—	(?62)	(?87) ———	———	?						
21	213	354	207	207-225	—	225	253	286	(Samples from 295-354 feet (90-108m.) not available)								
	(65)	(108)	(63)	(63-69)	—	(69)	(77)	(87)									
22	216	420	170	170-270	—	270	330	350									
	(66)	(128)	(52)	(52-82)	—	(82)	(101)	(107)									
23	203	305	145	145-258	—	258	285										
	(62)	(93)	(44)	(44-79)	—	(79)	(87)										
24A	196	275															
	(60)	(84)	130	130-206	—	—	206	232	397	430	524	—	—	—	—	—	580
24B		586	(40)	(40-63)	—	—	(63)	(71)	(121)	(131)	(160)	—	—	—	—	—	(177)
		(179)															
25	183	386	108	108-183	183	—	204	214+									
	(56)	(118)	(33)	(33-56)	(56)	—	(62)	(65+)									
26A	157	525															
	(48)	(160)															
26B	157	934	157	157-195	195	217	238	261	470	510	625	—	730	747	—	870	905
	(48)	(285)	(48)	(48-59)	(59)	(66)	(73)	(80)	(143)	(155)	(191)	—	(223)	(228)	—	(265)	(276)
26C	157	612															
	(48)	(187)															
27	153	335	155	155-203	203	216	247	275									
	(47)	(102)	(47)	(47-62)	(62)	(66)	(75)	(84)									
28	153	400	115	115-225	225	250	280	304									
	(47)	(122)	(35)	(35-69)	(69)	(76)	(85)	(93)									
29	143						at 277										
	(44)						(at 84)										

30	138	375	167	167-209	209	248	289	320							
	(42)	(114)	(51)	(51-64)	(64)	(76)	(88)	(98)							
31	ca. 192	1170	171	171-330	330	370	439	469	571———?)		877	982	—	1133	1116
	(ca. 59)	(357)	(52)	(52-101)	(101)	(113)	(134)	(143)	(174———?)		(267)	(299)	—	(345)	(340)
32	269	615	250	250-425	?425	?427	491	492.5							
	(82)	(187)	(76)	(76-129.5)	(?129.5)	(?130.1)	(149.7)	(150.1)							
33A	159														
	(49)														
33B	153	445	130	130-295	295	?360	442								
	(47)	(136)	(40)	(40-90)	(90)	(?110)	(135)								
34	130	629	170	—	170	210	230	245	440	480	614				
	(40)	(192)	(52)	—	(52)	(64)	(70)	(75)	(134)	(146)	(187)				
35	153	310	160	160-190	—	190	195	200							
	(47)	(94)	(49)	(49-58)	—	(58)	(59)	(61)							
36	149	305	151	151-182	182	191	206	228							
	(45)	(93)	(46)	(46-55)	(55)	(58)	(63)	(69)							
37	149	330	170	170-190	190	199	209	235							
	(45)	(101)	(52)	(52-58)	(58)	(61)	(64)	(72)							
38	119	335	200	200-205	205	292	310	330							
	(36)	(102)	(61)	(61-62)	(62)	(89)	(94)	(101)							
39	115	350	210	—	210	292	298	320							
	(35)	(107)	(64)	—	(64)	(89)	(91)	(98)							
40	114	450	220	—	220	345	380	386							
	(35)	(137)	(67)	—	(67)	(105)	(116)	(118)							
41	113	470	224	224-243	243	321	355	380							
	(34)	(143)	(68)	(68-74)	(74)	(98)	(108)	(116)							
42	114	310	205	—	205	290	306								
	(35)	(94)	(62)	—	(62)	(88)	(93)								
43	117	340	150	150-210	210	265	300	327							
	(36)	(104)	(46)	(46-64)	(64)	(81)	(91)	(100)							
44	119	295	165	165-200	200	251	290								
	(36)	(90)	(50)	(50-61)	(61)	(77)	(88)								
45	127	306	170	170-198	198	256	302								
	(39)	(93)	(52)	(52-60)	(60)	(78)	(92)								
46	ca. 137					at 240-260									
	(ca. 42)					(at 73-79)									
47A	137	526	ca. 125	ca. 125-199	199	260	306	336	?						
	(42)	(160)	(ca. 38)	(ca. 38-61)	(61)	(79)	(93)	(102)	(?)						
47B	137	[310]	?	?	?	260	310								
	(42)	(94)	?	?	?	(79)	(94)								
48	131	333	190	190-230	230	?274	333								
	(40)	(101)	(58)	(58-70)	(70)	(?84)	(101)								
49	117	740	240	—	240	378	426	452	690	710					
	(36)	(226)	(73)	—	(73)	(115)	(130)	(138)	(210)	(216)					

Bore No.	R.L.	Total Depth	Stratigraphic Units 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
50	115	366	253	—	253												
	(35)	(112)	(77)	—	(77)												
51	115	330	300	—	300												
	(35)	(101)	(91)	—	(91)												
52	117	650	290	—	290	?485	558	594									
	(36)	(198)	(88)	—	(88)	(?148)	(170)	(181)									
53	112	394	260	—	260												
	(34)	(120)	(79)	—	(79)												
54	113	390	240	240-280	280												
	(34)	(119)	(73)	(73-85)	(85)												
55	114	407	233	233-340	340												
	(35)	(124)	(71)	(71-104)	(104)												
56	114	450	120+	?-320	320												
	(35)	(137)	(37+)	(?-98)	(98)												
57	115	427	285	285-315	315												
	(35)	(130)	(87)	(87-96)	(96)												
58	168	486.5	200	200-365	365	393	486										
	(51)	(148.3)	(61)	(61-111)	(111)	(120)	(148.1)										
59A	172	474	?	210-384	—	384											
	(52)	(144)	(?)	(64-117)	—	(117)											
59B	ca. 172	487.5	210	210-365	?365	378											
	(ca. 52)	(148.6)	(64)	(64-111)	(?111)	(115)											
60	189	587	320	320-380	380	400	493	522									
	(58)	(179)	(98)	(98-116)	(116)	(122)	(150)	(159)									
61	225	670	260	260-470	—	470	560	575									
	(69)	(204)	(79)	(79-143)	—	(143)	(171)	(175)									
62	158	605	227	227-380	380	484	499	520									
	(48)	(184)	(69)	(69-116)	(116)	(148)	(152)	(158)									
63	167	820	333	333-368	368	500	635	673									
	(51)	(250)	(101)	(101-112)	(112)	(152)	(194)	(205)									
64	120	1983	324	—	324	550	653	680	960	1010	1235	1490	1550	1640———	?	1770	1872
	(37)	(604)	(99)	—	(99)	(168)	(199)	(207)	(293)	(308)	(376)	(454)	(472)	(500———	?)	(539)	(571)
65	153	2296	395	—	395	606	729	760	1025	1090	1319	1623	1710	1770	1905	—	(15A: 2030)
	(47)	(700)	(120)	—	(120)	(185)	(222)	(232)	(312)	(332)	(402)	(495)	(521)	(539)	(581)	—	(15A:(619))
66A	242	85	41	41-56	—	—	—	—	—	—	—	56	67	82			
	(74)	(26)	(12)	(12-17)	—	—	—	—	—	—	—	(17)	(20)	(25)			
66B	246	185	20	20-56	—	—	—	—	—	—	—	56	ca. 70	87	97.5	—	118
	(75)	(56)	(6)	(6-17)	—	—	—	—	—	—	—	(17)	(ca. 21)	(27)	(30)	—	(36)
67	258	105	65	65———	?	—	—	—	—	—	—	73.5	103				
	(79)	(32)	(20)	(20———	?)	—	—	—	—	—	—	(22)	(31)				

68A	206	120	55	—	—	—	—	—	—	—	—	55———?		80	100		
	(63)	(37)	(17)	—	—	—	—	—	—	—	—	(17———(?)		(24)	(30)		
68B	209	82	—	17-51	—	—	—	—	—	—	—	51———?		?82			
	(64)	(25)	—	(5-16)	—	—	—	—	—	—	—	(16)———(?)		(?25)			
69	227	81	[1A: 0-41.5]———			—	—	—	—	—	—	41.5	ca. 65				
	(69)	(25)	(1A: 0-13)		—	—	—	—	—	—	—	(13)	(ca. 20)				
70	239	411	[1A: 0-69]		—	—	—	—	[Equivs. 7+8: 69-80]		80	131	195	218	264	302	305
	(73)	(125)	(1A: 0-21)		—	—	—	—	(Equivs. 7+8: 21-24)		(24)	(40)	(59)	(66)	(80)	(92)	(93)
71	253	200	65	—	65	—	—	—	[Equivs. 7+8: 80-89]		89	150					
	(77)	(61)	(20)	—	(20)	—	—	—	(Equivs. 7+8: 24-27)		(27)	(46)					
72	238	200	33	—	33	—	—	—	—	—	56	81	150	165			
	(73)	(61)	(10)	—	(10)	—	—	—	—	—	(17)	(25)	(46)	(50)			
73A	201	116	48	48-66	—	—	—	—	—	—	—	66	80	97			
	(61)	(35)	(15)	(15-20)	—	—	—	—	—	—	—	(20)	(24)	(30)			
73B	193	90	[1A: 8-53]	—	—	—	—	—	—	—	—	53	66	81			
	(59)	(27)	(1A: 2-16)	—	—	—	—	—	—	—	—	(16)	(20)	(25)			
73C	187	90	[1A: 17-50]	—	—	—	—	—	—	—	—	50	55	71			
	(57)	(27)	(1A: 5-15)	—	—	—	—	—	—	—	—	(15)	(17)	(22)			
74	ca. 254	150	50	—	50	—	—	—	[Equivs. 7+8: 80-91]		91	134					
	(ca. 77)	(46)	(15)	—	(15)	—	—	—	(Equivs. 7+8: 24-28)		(28)	(41)					
75	ca. 237	370	45	45-70	—	—	—	—	[Equivs. 7+8: 70-85]		85	140	205	236	275	—	330
	(ca. 72)	(113)	(14)	(14-21)	—	—	—	—	(Equivs. 7+8: 21-26)		(26)	(43)	(62)	(72)	(84)	—	(101)
76	169	515	87	—	—	—	—	87	113	149	230	338	460	478			
	(52)	(157)	(27)	—	—	—	—	(27)	(34)	(45)	(70)	(103)	(140)	(146)			
77	ca. 135	868	370	—	370	630	700	774									
	(ca. 41)	(265)	(113)	—	(113)	(192)	(213)	(236)									
78	ca. 120	712	371	—	371	612											
	(ca. 37)	(217)	(113)	—	(113)	(187)											
79	113	525	340	—	340												
	(34)	(160)	(104)	—	(104)												
80	ca. 115	503	340	—	340												
	(ca. 35)	(153)	(104)	—	(104)												
81A	128	560	230	—	230	?318	408	448									
	(39)	(171)	(70)	—	(70)	(?97)	(124)	(137)									
81B	119	376	233	—	233	305											
	(36)	(115)	(71)	—	(71)	(93)											
82	ca. 120	340	255	—	255	305											
	(ca. 37)	(104)	(78)	—	(78)	(93)											
83	128	350	247	—	247	291											
	(39)	(107)	(75)	—	(75)	(89)											

Bore No.	R.L.	Total Depth	Stratigraphic Units														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
84	337	758	264	—	?264	—	—	—	285	[Equivs. 8+9: 322]	547	692					
	(103)	(231)	(80)	—	(?80)	—	—	—	(87)	(Equivs. 8+9: 98)	(167)	(211)					
85	258	412	172	172-220	—	—	—	220	300	[Equivs. 8+?9: 378]							
	(79)	(126)	(52)	(52-67)	—	—	—	(67)	(91)	(Equivs. 8+?9: 115)							
86	ca. 235	390	186.5	—	—	—	—	186.5	187	288	375						
	(ca. 72)	(119)	(56.8)	—	—	—	—	(56.8)	(57.0)	(88)	(114)						
87	ca. 164	212	182	—	182	—	205										
	(ca. 50)	(65)	(55)	—	(55)	—	(62)										
88	ca. 168	580	200	—	200	—	210	?260	?460————	?							
	(ca. 51)	(177)	(61)	—	(61)	—	(64)	(?79)	(?140————	?)							
89	ca. 207	300	180	—	—	—	—	180	225								
	(ca. 63)	(91)	(55)	—	—	—	—	(55)	(69)								
90	ca. 130	358	266	—	266												
	(ca. 40)	(109)	(81)	—	(81)												
91	ca. 159	255	166	—	166	—	187	229									
	(ca. 48)	(78)	(51)	—	(51)	—	(57)	(70)									
92	ca. 150	402	155	—	155	—	167	206									
	ca. 46)	(123)	(47)	—	(47)	—	(51)	(63)									
93	ca. 143	256	140	—	140	—	170	210									
	(ca. 44)	(78)	(43)	—	(43)	—	(52)	(64)									
94	ca. 256	680	20	20-110	—	—	—	110	210	286	375	524	610	618			
	(ca. 78)	(207)	(6)	(6-34)	—	—	—	(34)	(64)	(87)	(114)	(160)	(186)	(188)			