

EARLY EOCENE BURRUNGULE MEMBER
(WANGERRIP GROUP, GAMBIER EMBAYMENT)
AND MIDDLE EOCENE STURGESS POINT MEMBER
(NIRRANDA GROUP, PORT CAMPBELL EMBAYMENT)
IN THE OTWAY BASIN, SOUTHEASTERN AUSTRALIA

C. ABELE

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SUMMARY

The Burrungule Member has been recognised in the Gambier Embayment of the Otway Basin in southeastern South Australia and southwestern Victoria. The name has also been applied to a rock unit in the Port Campbell Embayment to the east. Planktonic foraminifers indicate that the strata in the Gambier Embayment are Early Eocene, those to the east late Middle Eocene; spores and pollen also suggest an age difference. The name 'Burrungule' should not be used for the Port Campbell Embayment beds which are best assigned to the Sturgess Point Member. The Early Eocene Burrungule Member in the Gambier Embayment belongs to the uppermost Dilwyn Formation of the Wangerrip Group, the Middle Eocene Sturgess Point Member to the lowermost Mepunga Formation of the Nirranda Group.

INTRODUCTION

The main aim of this report is to briefly describe the few available Early and Middle Eocene planktonic foraminiferal assemblages from subsurface Otway Basin in Victoria (Fig.1), and to discuss their stratigraphic significance (Fig.2). The foraminifers, as well as spores and pollen, indicate that the strata in far southwestern Victoria are distinctly older than those in the Port Campbell Embayment.

The name 'Burrungule' from southeastern South Australia has been applied to a rock unit, regarded as either a formation or a member, in the Port Campbell Embayment. The biostratigraphic evidence supports the use of the name for beds in far southwestern Victoria but not for those in the Port Campbell Embayment.

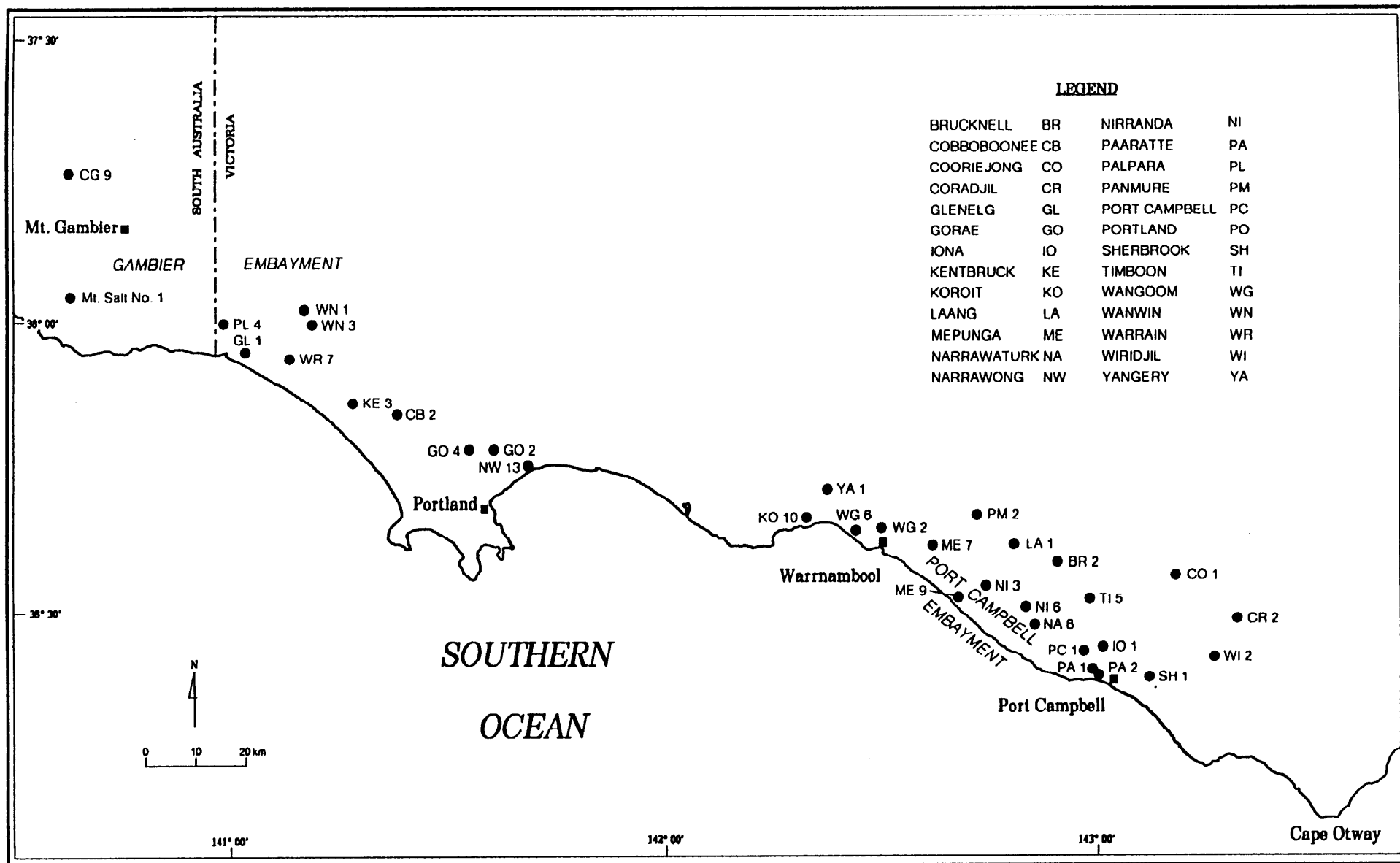


FIGURE 1 . Bore location map, Otway Basin

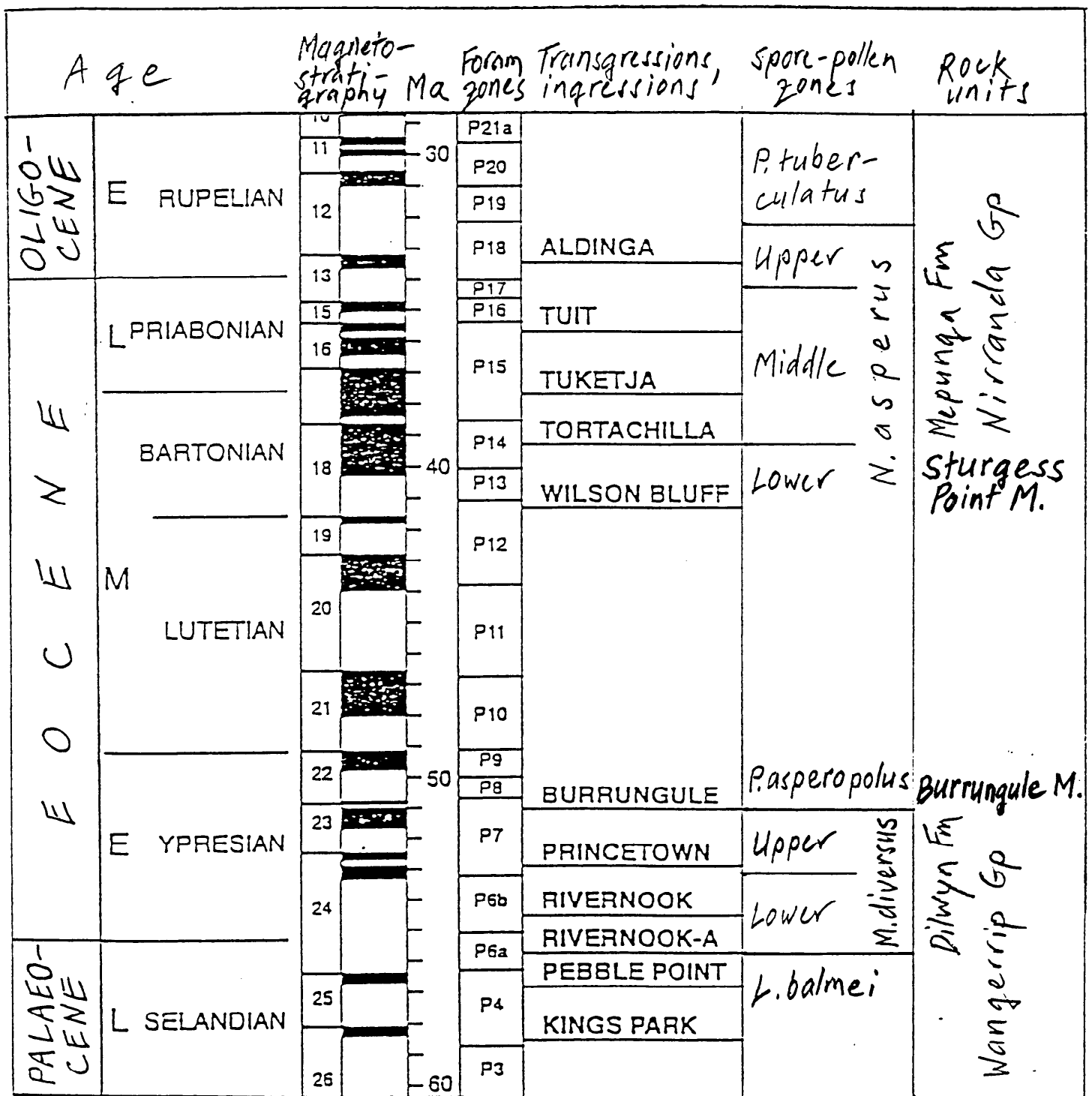


Fig. 2 OTWAY BASIN EOCENE STRATIGRAPHY
(partly after McGowan, 1993)

BURRUNGULE MEMBER

Southeastern South Australia

The Burrungule Member was defined by Harris (1966) as part of the redefined Knight Formation (formerly Knight Group) in southeastern South Australia. Its name is derived from the township of Burrungule 24 km northwest of Mount Gambier. The type section is in the South Australian Department of Mines bore CG 9 (Fig.1). The member was described as comprising up to 27 m of carbonaceous clay with occasional silt and coarse sand interbeds, and as containing brackish water foraminifers but no planktonics. It was regarded as Middle Eocene.

Within a year or two, planktonic foraminifers were found in the member. Ludbrook & Lindsay (1969) and Ludbrook (1969, 1971) recorded *Planorotalites australiformis*, *Pseudohastigerina micra*, *Acarinina collactea*, *A. spinuloinflata*, *Guembelitria columbiana*, '*Globigerina*' *higginsi* and *Subbotina angiporoides minima* (currently accepted names are used here). Ludbrook & Lindsay (1969) recognised the *Planorotalites australiformis* Zone as a total range zone in South Australia. Ludbrook (1971) also recorded the Burrungule Member from the Mount Salt 1 well southwest of Mount Gambier.

McGowran, Harris & Lindsay (1970) and McGowran, Lindsay & Harris (1971) considered that the species in the Burrungule Member is *Pseudohastigerina wilcoxensis* (not *micra*), and also noted *Subbotina* cf. *frontosa*.

Harris (1971) described the Burrungule Member as typically a laminated silty clay with a few sand intercalations, slightly calcareous and very carbonaceous. He defined the *Proteacidites confragosus* zonule (equivalent to the *P. asperopolus* Zone of Stover & Partridge, 1973; Partridge, 1976) on the basis of spores and pollen in the unit.

Both Harris (1971) and Ludbrook (1971) regarded the Knight Formation (renamed the Tartwaup Formation by Ludbrook) and hence the Burrungule Member as Middle Eocene, and as separated by a break spanning all or most of the Early Eocene from the underlying Dartmoor or Dilwyn Formation. Harris considered the Knight Formation as equivalent to the Mepunga Formation in the Port Campbell Embayment.

McGowran, Lindsay & Harris (1971) showed corresponding breaks below the *Planorotalites australiformis* and *Proteacidites confragosus* zones. In contrast, the *P. australiformis* Zone was shown as conformably overlain by the *Acarinina primitiva* Zone, and the *P. confragosus* Zone by the *P. pachypolus* Zone (= Lower *Nothofagidites asperus* Zone). McGowran et al. correlated the *P. australiformis* Zone with the early Middle Eocene intercontinental planktonic foraminiferal Zone P 10 (Fig.2).

McGowran (1978) stated that the age of the Burrungule Member remains unclear, but in his Fig.2 showed it as latest Early Eocene. The unit was still shown as separated by a break from the underlying Dartmoor (=Dilwyn) Formation, but with a more prominent break encompassing most of Middle Eocene intervening between the Burrungule Member and the overlying sediments (Kongorong Sand). Clearly, the member is part of McGowran's (1979) Palaeocene to Early Eocene Sequence One, not Middle to Late Eocene Sequence Two.

The gap between the Burrungule marine ingressions and the later Eocene transgressions (beginning with Wilson Bluff) was even more emphatically shown by McGowran (1989, 1991). In the 1991 paper, McGowran correlated the Burrungule Member with Zone P 8, late but not latest Early Eocene, and stressed that there is a gap of eight or ten million years between the Burrungule ingressions and the next transgression during which no control by means of correlation with the global time scale is available. Although spore - pollen zones are usually shown as spanning the gap, continuous sedimentation cannot always be assumed.

Thus - in the 1960s and early 1970s the Burrungule Member, as part of the Knight or Tartwaup Formation, was considered as associated with the overlying sediments, that is the Nirranda Group, and separated by a break from the underlying Wangerrip Group. Later it became clear that the major break is above, not below, the Burrungule Member which is part of the Wangerrip, not Nirranda, Group.

In the last few years geologists of the South Australian Department of Mines and Energy have discarded many of the local Tertiary rock unit names in favour of names used for the larger Victorian part of the Otway Basin (P.A. Rogers, written comm., 5 May 1993; also Morton et al., 1994). Whether or not the Burrungule Member is considered to be a useful rock unit, the name will live on because of its biostratigraphic and geohistoric connotations, for example as Burrungule ingression.

Southwestern Victoria

Holdgate (1981) recognised the Burrungule Member as comprising well-burrowed grey muddy siltstone with lesser sand in the uppermost part of the Dilwyn Formation in at least eight bores in southwestern Victoria, between the South Australian border and Portland Bay. The member is overlain by the Mepunga Formation or other marine carbonate deposits, exceptionally by Older Volcanics.

Locally the unit contains foraminifers, rarely planktonic species. On the basis of very sparse assemblages obtained after limited picking in 1974 and 1975, I tentatively assigned the Burrungule Member in Warrain 7 and Wanwin 1 bores to the late Middle Eocene *Acarinina collectea* Zone, as stated by Holdgate (1981).

Holdgate (1981) indentified the Burrungule Member in Palpara 4 (wrongly referred to as Palpara 5), Warrain 7, Wanwin 1, Kentbruck 3, Cobboboonee 2, Gorae 4 and 2, and Narrawong 13 bores (Fig.1). Earlier Holdgate (1977) had recognised the unit in Glenelg 1 and later Walker (1984) indentified it in Wanwin 3.

The following intervals of Burrungule Member are taken mostly from well completion reports, but for Cobboboonee 2 and Narrawong 13 the lower limit was estimated approximately from Holdgate's (1981) Fig.5.

Glenelg 1	302 - ca 390 m
Palpara 4	277 - 347.5 m
Warrain 7	235 - 351 m
Wanwin 1	166 - 195 m
3	93 - 251.5 m
Kentbruck 3	531.5 - 651 m
Cobboboonee 2	821 - ca 920 m
Gorae 4	794 - 848 m
2	609 - 670 m
Narrawong 13	556 - ca 615 m

Palynology

Selected core samples of the Burrungule Member were submitted for examination to R. Morgan in 1993. The results (Morgan, 1994), barren samples excepted, are:

Glenelg 1:	302m	<i>P. asperopolus</i> Zone
	390 m	upper <i>Malvacipollis diversus</i> Zone
Warrain 7:	252.3 - 258.35 m	<i>P. asperopolus</i> Zone; <i>Wetzeliella thompsonae</i> dinoflagellate Zone
	343.8 - 348.15 m	upper <i>M. diversus</i> Zone
Wanwin 1:	168.9 - 174.3 m	<i>P. asperopolus</i> Zone
Cobboboonee 2:	886.9 - 891.2 m	upper <i>M. diversus</i> Zone
Narrawong 13:	574 - 580 m	<i>P. asperopolus</i> Zone
	686 - 692 m	<i>P. asperopolus</i> Zone

It appears that in most bores the upper strata in the interval assigned to the Burrungule Member represent the *P. asperopolus* Zone whereas the lower part of the unit falls within the upper *M. diversus* Zone. The only exception is the Narrawong 13 bore where the *P. asperopolus* Zone is more than 100 m thick and appears to extend down into the Dilwyn Formation (or the base of the Burrungule Member has been incorrectly picked). In the Victorian Otway Basin the only other bore where the Dilwyn Formation is known to extend into the *P. asperopolus* Zone is Iona 1 in the east.

According to McGowran (1991, Fig.2), the Burrungule Member or ingressions is restricted to the *P. asperopolus* Zone. The upper *M. diversus* Zone is represented by underlying strata, including the Princetown Member or ingressions.

Planktonic foraminifers

In 1993 and 1994 I processed additional samples of the Burrungule Member from the Warrain 7 and Wanwin 1 bores, and also samples from Palpara 4, Wanwin 3, Kentbruck 3, Gorae 2 and Narrawong 13 bores. These either yielded very sparse foraminiferal assemblages consisting almost wholly of benthonics or did not contain any foraminifers.

Thus - only two assemblages with sparse planktonics are available, from samples processed in 1974 and 1975. One comes from an unspecified level in a core cut between 554 and 572 feet (168.9 and 174.3 m) in Wanwin 1, and the other from the base of a core between 269.2 and 275.1 m in Warrain 7. These assemblages were improved by extensive picking of the washed residues in 1993 and 1994.

The Wanwin 1 core represents the *P. asperopolus* spore-pollen zone which has also been identified 20 m above the Warrain 7 core.

Wanwin 1: 168.9 - 174.3 m

Planorotalites australiformis (9 specimens). Tests rather small, up to 0.18 mm; 4 chambers in last whorl.

P. pseudoscitula (20 specimens). Typically 5 chambers in last whorl. Tests more strongly compressed, with more angular periphery in chambers preceding the last one, than in *P. australiformis*.

Acarinina collactea (more than 70 specimens). Up to 0.22 mm in size. Many resemble *A. rotundimarginata* and *A. spinuloinflata* (see later remarks on *A. collactea*).

Pseudohastigerina wilcoxensis (29 specimens).

Guembelitra cf. *columbiana* (2 specimens).

Acarinina primitiva (1 specimen ?). The ranges of *A. primitiva* and *Planorotalites australiformis* overlap in New Zealand (Jenkins, 1971; Hornibrook, Brazier & Strong, 1989) and on the Naturaliste Plateau (McGowran, 1978) but, as stressed by McGowran (1991), the two have not been recorded together in southern Australia.

There are some contaminants in this assemblage, but the *A. primitiva* specimen does not obviously differ in its state of preservation or colour from the rest. Of course, a single specimen hardly provides a firm base for any conclusions.

Warrain 7: 269.2 - 275.1m

Planorotalites australiformis (1 specimen). The small test, with maximum diameter 0.12 mm, resembles that figured by Ludbrook & Lindsay (1969, pl. 1, figs 4 - 6).

Acarinina collactea (more than 50 specimens). Up to 0.24 mm (as for holotype). Many tests have only 4 chambers in last whorl. In about half a dozen specimens the chambers are radially somewhat compressed, resembling *A. pseudotopilensis*.

A. cf. densa (6 specimens). These differ from *A. collactea* in being more compressed, with more angled periphery; the 5 chambers in last whorl are more appressed, the sutures on spiral side more recurved.

Pseudohastigerina wilcoxensis (20 specimens).

Remarks on *Acarinina collactea*

After examining the type specimens of *A. collactea*, Jenkins (1965) noted that there is considerable variation in test morphology. The spiral side is convex to flattened, and chambers are globular to subangular with rounded to angular peripheral margins. Although the majority of specimens have straight radial sutures on the spiral side, a few have recurved sutures. Most tests are about 0.25 mm in diameter.

The type sample is from the Heretaungan Stage in New Zealand, near the Lower/Middle Eocene boundary. Jenkins (1965) noted that a similar range of morphological variation is seen in younger Bortonian samples, but the forms with angled periphery are less common. Later these forms disappear, whereas specimens with more rounded margin range up through the Bortonian into the Kaiatan Stage (late Middle Eocene).

A. rotundimarginata is generally regarded as a junior synonym of *A. collactea* (Jenkins, 1971; Berggren, 1977; Blow, 1979; Toumarkine Luterbacher, 1985). A fair range of variation was described and illustrated by Subbotina (1953; English translation 1971), but in comparison with the holotype of *A. collactea*, the specimens generally appear to have a flatter spiral side, more angular peripheral margin with more rounded outline, and somewhat recurved rather than radial sutures on the spiral side. Thus they seem more similar to the 'forms with the angled periphery' (Jenkins, 1965) than to the holotype.

A. spinuloinflata also resembles the 'forms with the angled periphery' more closely than it does the holotype of *A. collactea*. Ludbrook & Lindsay (1969) and Ludbrook (1971) recorded both *A. collactea* and *A. spinuloinflata* from the Burrungule Member, apparently to indicate the range of morphological variation.

In discussing *A. collactea* assemblages from near the top of their range (uppermost Middle Eocene), McGowran (1973, 1978) distinguished groups A and B from above and below the disappearance of *A. primitiva* respectively. He characterised group B as morphologically more varied than group A; it includes specimens recalling *A. pseudotopilensis*, and truncate forms resembling *spinuloinflata* and *rotundimarginata*. Group A may be regarded as *A. collactea* in a strict sense, with specimens generally resembling the holotype.

A comparison of Victorian *A. collactea* assemblages from the Burrungule and Sturgess Point members, and from the basal part of the Browns Creek section in the Aire district (Abele, 1994) appears to support the observations of Jenkins (1965) and McGowran (1973, 1978). The Browns Creek specimens come from just below the top of the range of *A. collactea* (uppermost Middle Eocene, above the disappearance of *A. primitiva*; they represent the Tortachilla rather than the Wilson Bluff transgression). Morphologically they resemble the holotype of *A. collactea* more closely than do the earlier assemblages. This does not apply to size, however; maximum diameter of tests from the Burrungule Member is 0.24 mm, from Sturgess Point Member 0.28 mm, and from Browns Creek 0.38 mm.

STURGESS POINT MEMBER

Port Campbell Embayment

Glenie (1971) recognised a thin mudstone unit just below the Mepunga Formation in many bore sections in the Port Campbell Embayment. The mudstone was distinguished from the rest of the Mepunga Formation but not explicitly excluded from it.

In 1977 I examined samples from the mudstone and overlying beds at the request of R. Blake. The foraminiferal assemblages contain *Acarinina primitiva* and *A. collactea* (Blake, 1980, p.30), indicating late Middle Eocene age.

Blake (1980) characterised the unit as dark brown to black carbonaceous sandy and clayey siltstone. He regarded it as similar in age, stratigraphic position, lithology and depositional environment to the Burrungule Member of the Knight Formation in South Australia, and called it Burrungule Formation.

In support of his opinion, Blake quoted Harris' (1971) correlation of the Knight Formation with the Mepunga Formation. Although Harris referred to the Burrungule Member as early Middle Eocene, Blake (1980, Fig.4) showed the Burrungule Formation as late Middle Eocene, conformably overlain by Late Eocene sediments of the Nirranda Group but separated by a significant break from Early Eocene Dilwyn Formation.

As discussed earlier, in the late 1970s and subsequently it became increasingly clear that the major break is above, not below, the Burrungule Member, which is part of the Wangerrip, not Nirranda, Group. Hence Tickell, Edwards & Abele (1992) rejected Blake's nomenclature, stating that the basal mudstone of the Nirranda Group differs significantly in age and stratigraphic relationships from the Burrungule Member, and regarding it as an informal unit in lowermost Mepunga Formation.

In an unpublished report on eastern Otway Basin stratigraphy, written largely by S.J. Tickell with assistance by myself in 1992, the basal mudstone unit was named the Sturgess Point Member after Sturgess Point at Port Campbell. The type section was designated between 484 and 494 m in Paaratte 2 bore at Port Campbell. The unit is generally less than 15 m thick but locally attains a little more than 20 m.

Tickell recognised the Sturgess Point Member in 60 bores in the eastern Otway Basin, mostly in the Port Campbell Embayment. The unit has been cored in a dozen of these - Cooriejong 1, Coradjil 2, Koroit 10, Narrawaturk 6, Paaratte 2, Panmure 2, Port Campbell 1, Sherbrook 1, Timboon 5, Wangoom 2, Wiridjil 2 and Yangery 1 (Fig.1).

Coeval strata outside Victoria

Ludbrook (1963,1967) recorded *Globigerinatheka index*, *Subbotina linaperta*, *Acarinina primitiva* and *A. collactea* (the 'Mayurra microfaunule') from subsurface in the Gambier Embayment in South Australia. Ludbrook & Lindsay (1969) and Ludbrook (1971) recognised the Middle Eocene *A. primitiva* Zone in the lowermost part of the Lacepede Formation on the basis of this assemblage. McGowran (1978) also recorded *Subbotina* cf. *frontosa*, '*Globorotaloides*' *turgida*, *Pseudohastigerina* aff. *micra* and very rare *Hantkenina* aff. *australis* from these sediments which he referred to as Kongorong Sand.

The beds represent the *Acarinina primitiva* ingressions, correlated with the Wilson Bluff transgression in the more open marine Eucla Basin to the west (McGowran, 1989). Earlier Shafik (1983) recognised two Middle Eocene marine ingressions in the Gambier Embayment on the basis of calcareous nannofossil evidence.

The strata containing *A. primitiva* in the Gambier Embayment were correlated with Zones P 10 and P 11, that is early Middle Eocene, by McGowran, Lindsay & Harris (1971), but were placed against late Middle Eocene Zone P 14 by McGowran (1978). More recently McGowran (1989) equated them with upper Zone P 12 and P 13.

Palynology

Core samples of the Sturgess Point Member from the Timboon 5 and Wangoom 2 bores have been assigned to the Lower *Nothofagidites asperus* Zone (Harris, 1993), as well as samples of Sturgess Point Member and/or Mepunga Formation lower sand from Narrawaturk 6 (Morgan, 1994; these also belong to the *Deflandrea heterophlycta* dinoflagellate zone).

The same spore - pollen zone is represented by Mepunga Formation lower sand at 467 m depth in Paaratte 2 (V.Archer, unpublished), 17 m above the top of the Sturgess Point Member. Mepunga Formation beds a little above the Sturgess Point Member in Brucknell 2, Laang 1, Mepunga 7 and 9, Nirranda 3 and 6, Paaratte 1 and Wangoom 6 bores have also been assigned to the Lower *N. asperus* Zone (Harris, 1993).

Planktonic foraminifers

Middle Eocene foraminiferal assemblages with sparse planktonics have been obtained from Paaratte 2, Narrawaturk 6 and Port Campbell 1 core samples.

Fourteen samples from between 457 and 491 m in Paaratte 2 were processed in 1977 and 1994. Most of these came from strata above 484 m depth, assigned to Mepunga Formation lower sand by S.J Tickell. Lithologically, however, the cores from above 484 m differ little from the core representing the underlying Sturgess Point Member.

A fairly good assemblage was obtained from an unspecified depth in a core cut between 630 and 639.7 m in Narrawaturk 6; the sample was processed in 1989 at the request of C. Menhennitt. According to S.J. Tickell, the boundary between Mepunga Formation lower sand and Sturgess Point Member lies at 638 m, so the sample may represent either unit. Another sample from the upper part of the core (labelled 633.9 m) yielded a poorer assemblage.

A core cut between 1475 and 1493 feet (449.6 and 455.1 m) in Port Campbell 1 has also yielded useful foraminiferal assemblages. Only 6 feet were recovered and it is uncertain which part of the interval they represent. Glenie (1971) placed the top of the basal mudstone unit at 1480 feet. According to S. J. Tickell, however, the top of the Sturgess Point Member is at 449 m (1473.2 feet), so the whole core comes from this unit.

Fig. 3 shows the distribution and abundance of Middle Eocene planktonic foraminifers in Paaratte 2, Narrawaturk 6 and Port Campbell 1 bore sections. Samples with very poor assemblages are not listed.

Fig. 3 DISTRIBUTION CHART OF MIDDLE EOCENE PLANKTONIC FORAMINIFERS IN PORT CAMP-

BELL EMBAYMENT BORE SECTIONS

C common (> 20 specimens)
 S sparse (< 20 specimens)
 R rare (< 10 specimens)
 V very rare (< 5 specimens)

	<i>Acarina primitiva</i>	<i>Acarina collectea</i>	<i>Globigerinatheka index</i>	<i>Subbotina linaperta/angiporoides</i>	<i>Tenuitella aculeata</i>	<i>Pseudohastigerina micra</i>	<i>Chiloquembelina cubensis</i>	<i>Cassigerinella winniana</i>
PAARATTE 2: 457.3-460m	V	R	S		V	V	V	
463.5m	C	C	C	V		V	V	
464.9-465.9m	V	V	S			V	V	
" 15cm from top	S	S	C	V				
" from middle	V	S	C				V	
465.9-466.9m	V	V	R				V	
" 20cm from base	V	V	S			V		
466.9-467.9m		R				V	V	
" 25cm from top	V	R	S		V			V
488.9-490m	V	V	V	V			V	
NARRAWATURK 6: 630-639.7m	R	R	S	V		R	V	V
PORT CAMPBELL 1: 450.5m (1478 feet)	V	V	S	R				

CONCLUSIONS

The main differences between the planktonic foraminiferal assemblages from the Burrungule and Sturgess Point members are:

Planorotalites australiformis is present only in the Burrungule Member;

Acarinina primitiva (except for one specimen ?) and *Globigerinatheka index* are present only in the Sturgess Point Member;

Pseudohastigerina wilcoxensis is present in the Burrungule Member, *P. micra* in the Sturgess Point Member.

These differences, as well as palynological evidence, indicate that the Burrungule Member is distinctly older than the Sturgess Point Member.

The Early Eocene Burrungule Member (uppermost Dilwyn Formation, Wangerrip Group) is confined to the Gambier Embayment, the late Middle Eocene Sturgess Point Member (lowermost Mepunga Formation, Nirranda Group) to the Port Campbell Embayment of the Otway Basin.

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