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MICROPALAEONTOLOGICAL REPORT ON THE
PETROFINA EXPLORATION AUSTRALIA S.A.
AYU-1 WELL
GIPPSLAND BASIN, AUSTRALIA

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1. INTRODUCTION.

A total of 32 samples comprising 19 ditch cuttings and 13 sidewall cores from the Ayu-1 well were submitted for micropalaeontological examination by Petrofina Exploration Australia S.A.

Most of the carbonate sequence comprises Miocene deep water sediments. Down to 1400m the sequence appears to have been a normal, outer shelf to uppermost slope depositional regime. From 1450 to 1730m impoverished faunas in a hard calcisiltite, with some evidence of size sorting, suggest the possibility of a canyon fill or slump deposit of Late Miocene age. Beneath this, a normal marine Middle Miocene sequence was deposited in upper bathyal water depths. Similar water depths are inferred for the Early Miocene section between approximately 2000m and 2394m. An interval of deep water sediments of Late Oligocene age makes up the base of the carbonate section. The thickness of Late Oligocene present is somewhere between 9 and 95 metres. Unfortunately a critical sidewall core at 2451.5m is either mislabelled, or else sampled a lump of younger sediment in the borehole wall, because this sample is clearly out of sequence. Given the absence of other sidewall cores at around this depth, the top of the Oligocene cannot be placed more closely.

The zonation used, that of D.J.Taylor for the Gippsland Basin (see, for example, Taylor: 1966, 1983), is the same as that used in previous well reports on Angler-1 and Anemone-1.

2. LIST OF SAMPLES EXAMINED.

DC = ditch cutting; SWC = sidewall core. All depths in metres below rotary table.

DC 1250
DC 1300
DC 1350
DC 1400
DC 1450
DC 1500
DC 1550
DC 1650
DC 1700
SWC 1730
SWC 1740
DC 1800
DC 1850
DC 1900
DC 1950
DC 2000
DC 2050
DC 2100
SWC 2146
SWC 2165
DC 2200
DC 2250
DC 2300
SWC 2345
SWC 2394
SWC 2451.5 out of sequence
SWC 2482
SWC 2485
SWC 2490

SWC 2491

SWC 2527

SWC 2552

3. NATURE AND AGE SIGNIFICANCE OF THE FORAMINIFERAL ASSEMBLAGES.

1250 - 1350 metres : probably Zone B-2 : Late Miocene.

The moderately hard calcisiltite present in ditch cuttings in this interval has released some fauna, but most specimens are of benthonic habitat, and are not age indicators. Evidence of the age is derived from the presence of Globorotalia conoidea, the age of which is dominantly Late Miocene (although occasionally reported from the Early Pliocene, according to Jenkins, 1986). Globorotalia conomiozea and Globorotalia miotumida are both found in the ditch cutting at 1250m. In Taylor's letter zonation for Gippsland, these species do not overlap, but their presence together here is probably due to caving. The presence of G. miotumida indicates an age at least as old as Zone B-2. Turborotalia acostaensis acostaensis, although very rare, suggests that the age is no older than B-2. The presence of Globorotalia linguaensis in the ditch cutting at 1300m tends to confirm a B-2 determination.

The varied benthos is dominated by Uvigerina peregrina and U. bassensis, particularly in the highest sample. Other genera common in the interval are Lenticulina, Cibicides, Florilus subturgidus and Sphaeroidina bulloides. The depositional environment suggested is outer shelf to shelf/slope break.

1400 - 1700 metres : undifferentiated Zone B-2 / Zone C
: Late to topmost Middle Miocene.

This interval contains impoverished planktonic faunas with almost no index species. The presence of Globorotalia miotumida and G. linguaensis in the top 50m suggests a Zone B-2 age, but Turborotalia acostaensis was not found, and the zone could be as old as C. Below 1500m planktonic specimens are extremely rare (and in one sample absent) and between 1550 and 1650m the age is indeterminable. At 1700m a small amount of planktonic fauna is present in a predominantly benthonic assemblage. The presence of Globorotalia miotumida and G. scitula, in the absence of older species, suggests an age of undifferentiated Zone B-2 to C down to this depth.

At 1730 metres : probably Zone B-2 : probably Late
Miocene.

The highest sidewall core in the well is a hard calcisiltite with a substantial number of minute-sized foraminifera released from the matrix, but with most of the adult-sized specimens embedded in the rock matrix, or damaged when broken out. As a result, there are few specimens available on which to base an age determination. The age rests on the presence of Globorotalia miotumida and a single specimen of Turborotalia cf. acostaensis, providing slender evidence for a B-2 determination. As the sample lies at the base of a major, fairly uniform section of calcisiltites, the age is obviously critical for much of the interval above.

The suggestion of size sorting seen in this sample, plus the impoverished character of the faunas seen

above, despite occasional indications of deep water, suggests that the whole sequence between 1450 and 1730m may be a canyon fill deposit, or at least composed of slumped and rapidly re-deposited shelf sediment.

At 1740 metres : low in Zone C : Middle Miocene.

Electric log evidence suggests that this sample is part of a different sequence from the sidewall core ten metres above. This is confirmed by the differences in lithology and the much richer fauna seen in this sample. The genus Globorotalia is abundant. G. miotumida and G. scitula are both common, suggesting an age no older than the base of Zone C. G. conica is moderately abundant. Taylor defines the top of Zone D-1 on the highest appearance of this species, and overlaps the ranges of G. conica and G. miotumida only at the boundary of the zones; but Jenkins (1986) reports that in New Zealand the ranges of the two species overlap within the G. mayeri zone (roughly the equivalent of Gippsland Zone C). G. peripheroronda and Praeorbulina glomerosa circularis both range up into the basal part of Zone C. Consequently an age very low in Zone C is suggested.

The depositional environment is interpreted as normal marine, upper bathyal depths, based on the presence of Vulvulina pennatula, Karreriella bradyi and very rare Planulina wuellerstorfi in a diverse assemblage.

1800 - 1850 metres : Zone D-1 : Middle Miocene.

These ditch cuttings contain an abundant fauna in a grey calcisiltite which has been partially metamorphosed by drill-bit friction. The abundance of Globorotalia scitula and G. miotumida superficially

suggests Zone C. However the presence of Globorotalia miozea plus a moderate number of G. peripheroacuta indicate Zone D-1. The presence of G. miotumida is presumed to be the result of caving. Globoquadrina larmeui and Globorotalia panda make their highest appearance in the sample at 1800m.

The benthonic assemblages of both samples are very diverse. Significant for environmental interpretation is the presence at 1850m of Planulina wuellerstorfi, Osangularia bengalensis, Sigmoilopsis schlumbergeri and Karrerriella bradyi. The latter sample is clearly of upper bathyal (=upper slope) facies.

1900 - 1950 metres : Zone D or E-1 : Middle Miocene.

The differentiation of Zones D and E, by means of ditch cuttings in which caving is suspected, is difficult if not impossible. The boundary between D-2 and E-1 is defined on the evolutionary appearance of Orbulina universa, an event which is readily obscured by the caving of the species from strata higher in the borehole. Nonetheless, the decline in numbers of the species around this level does suggest that the boundary lies somewhere in this interval. The ditch cutting at 1900m contains, among other species, Globorotalia peripheroacuta and G. praefohsi, indicative of a Zone D determination. Suggestive of a older, Zone E-1 determination is the absence of Orbulina universa and the presence of Praeorbulina glomerosa glomerosa. The sample at 1950m contains an abundant planktonic fauna, including many minute specimens, but a lack of diversity is evident. Globorotalia praefohsi and G. peripheroacuta are absent. However, the sample contains four specimens of Orbulina universa, so that the sample could be either

of basal Zone D age, or could contain minor caving from higher in the sequence (not necessarily from Zone D). Orbulina suturalis is moderately common, and Praeorbulina spp. rare, suggesting again the possibility of a Zone E-1 age.

Benthonic specimens are very rare in both samples. The presence of Vulvulina pennatula in one and Osangularia cf. bengalensis in the other suggests at least outer shelf or upper slope depths.

At 2000 metres : Zone E : astride Middle / Early Miocene boundary.

This ditch cutting contains abundant planktonic specimens, particularly small specimens of Globigerina spp. Also present are large Globorotalia spp. caved from Zones B and C. The presence of rare Praeorbulina glomerosa curva, P. glomerosa glomerosa and P. glomerosa circularis, absence of Orbulina universa, and presence of only two specimens of O. suturalis may suggest an E-2 age determination. (Zone E-2 occupies the topmost 0.5 million years of the Early Miocene; Zone E-1 occupies the basal 0.5 million years of the Middle Miocene). The absence of sidewall core control means that the presence or absence of in situ Orbulina suturalis cannot be verified to differentiate E-1 from E-2. As for the interval discussed above, the benthonic part of the assemblage is very rare. However, a few specimens of Karreriella bradyi and Martinotiella communis suggest that the environment was upper bathyal.

2050 - 2146 metres : probably Zone F : Early Miocene.

The ditch cutting at 2050m contains a moderate amount of planktonic fauna, including fairly common

Globigerinoides trilobus, in a moderately hard calcisiltite. The sample lacks Praeorbulina spp., and contains almost no Orbulina suturalis (which may well be caved). The presence of very rare Globigerinoides cf. sicanus suggests a Zone F determination, particularly in view of the abundance of other Globigerinoides spp. Downhole caving from at least Zones B and C is evident. The depositional environment appears to be essentially the same as for the sample above. The ditch cutting at 2100m contains common Globigerinoides trilobus and an absence of Globigerinoides sicanus, suggesting a Zone G rather than F determination. (Zone G is characterised by the earliest appearances of long-ranging "background" species in the planktonic fauna, including Globigerinoides trilobus and Globorotalia miozea miozea. Consequently caving from younger zones tends to obscure the character of the in situ fauna, which lacks distinctive species of its own). Caving of Globorotalia spp. from higher zones continues to be conspicuous. The depositional environment is as for the sample above.

The sidewall core at 2146m contains very rare specimens critical for age determination at this level. While Globigerina spp. are abundant, Globigerinoides trilobus and G. sicanus were found as only one specimen of each, a situation highly atypical of Zone F. Globorotalia miozea is common, indicating an age of Zone G or younger. The sidewall core may be at the base of Zone F, but the presence of Globorotalia cf. praefohsi and the rarity of the Globigerinoides trilobus group are anomalous. The presence of Planulina wuellerstorfi indicates bathyal depths.

2165 - approximately 2200 metres : Zone G : Early Miocene.

The sidewall core at 2165 contains a planktonic assemblage dominated by small forms, mostly Globigerina angustum, G. ciperensis and G. juvenilis. Globigerinoides quadrilobatus is common and G. trilobus present in some numbers. A moderate number of Globorotalia miozea, G. praemenardii and Turborotalia siakensis are also present, and the assemblage appears to be a normal Zone G one. Benthos are rare. Species such as Osangularia cf. bengalensis, Sigmoilopsis schlumbergeri, Glomospira charoides and cassidulinids suggest shelf edge to upper bathyal water depths.

The ditch cutting at 2200m is totally planktonic dominated, but the effect of caving makes the presence of Globigerinoides trilobus, G. quadrilobatus and Globorotalia miozea not definitive for a Zone G determination, although suggestive of such. The presence of one specimen of Globorotalia kugleri provides slender evidence for the top of the next zone, H-1. The sample may be at, or just below the boundary, of Zones G and H-1. The very rare benthos again contains Planulina cf. wuellerstorfi and Karreriella bradyi, suggesting depths of at least upper bathyal.

Approximately 2200 - 2394 metres : Zone H : Early Miocene.

The ditch cutting at 2200m has been discussed above. The cutting at 2250m contains an abundance of planktonic specimens, many very small in size. The presence of extremely rare Globorotalia kugleri leads to the Zone H-1 determination. Globorotalia zealandica is also present, a distribution consistent with the lowest occurrence of the species in Selene-1. Caving

is a conspicuous feature of the planktonic assemblage in this sample. The cutting at 2300m is less caved. It lacks G. kugleri, but the presence of Globoquadrina dehiscens s.s. in some numbers indicates that the age is still within Zone H-1. The rare benthonic specimens continue to suggest upper bathyal water depths.

Sidewall core samples at 2345m and 2394m indicate a Zone H-2 age, based on the presence of Globigerina woodi and Globoquadrina cf. dehiscens, in a fauna lacking Globigerinoides (except G. cf. primordius). The assemblage is dominated by small Globigerina spp. Catapsydrax dissimilis is conspicuous among the larger species. Very rare specimens of Globorotalia cf. mendacis occur at 2394m. The benthonic assemblage in both samples contains a number of arenaceous species and fragments. The presence of Bathysiphon sp., Cyclamina sp., Haplophragmoides sp., Karreriella bradyi, Amodiscus sp., and cassidulinids may well indicate slope water depths, with some shelf species moved downslope.

At 2451.5 metres : Zone F : Early Miocene : sidewall core OUT OF SEQUENCE.

The presence of a sidewall core containing common Globorotalia miozea, Globigerinoides trilobus and excellent specimens of Globigerinoides sicanus indicates (in the absence of Praeorbulina and Orbulina spp.) a Zone F determination. This is clearly younger than the four sidewall cores between 2146 and 2394m. The only reasonable explanation is either that the core was mislabelled when unloaded, or that the sidewall core gun sampled a fragment of Zone F sediment wedged in the borehole wall.

2482 - 2490 metres : Zone I-1 : Late Oligocene.

Faunas in these sidewall cores contain an abundance of planktonic specimens, mostly small. The presence of specimens of Globoquadrina cf. dehiscens (in the absence of younger species) is indicative of a late Zone I-1 age. Good specimens of Globigerina euapertura are also suggestive of a Zone I determination. Globigerina cf. woodi is represented by only one specimen. Other species of Globigerina are numerous, but all are long-ranging. Nonetheless, the assemblages are typical of the Late Oligocene in Gippsland. The sidewall core sample at 2485m is a limestone with abundant broken specimens, and is contaminated with a trace of younger fauna. The presence of one specimen of Pseudohastigerina micra is anomalous. The species has a range of Eocene to Early Oligocene; but no other evidence for an Early Oligocene age was found, either in this sample or the one below. Furthermore, P. micra appears to have seldom, if ever, been recorded from Gippsland wells, so the presence of a single specimen here remains unexplained.

The sample at 2490m, which is the deepest sample to contain foraminifera in any numbers, is assigned to Zone I-1 on the basis of Globoquadrina cf. dehiscens, and on the absence of Early Oligocene indicators such as Globigerina angiporoides. The presence of Karreriella bradyi, Cyclamina sp., Osangularia bengalensis, Recurvoides sp. and Vulvulina pennatula in a fairly diverse benthos is interpreted to indicate upper bathyal water depths. The contrast with the facies interpreted for the sample one metre below, strongly suggests a disconformity between the two sidewall cores.

At 2491 metres : age indeterminable.

This glauconitic quartz sand was found to contain very rare specimens of Cyclammia sp. This may well be the same form recorded by Taylor as Haplophragmoides cf. incisa from the Gurnard Fm. in Selene-1 (Taylor, 1983). The correct generic placement of arenaceous specimens with cancellate wall structure has been a matter of controversy (see Taylor, 1965; Ludbrook, 1977). All authors who have examined the Early Tertiary "Cyclammia faunas" of southern Australia appear to be in agreement with their shallow-water depositional environment, as suggested by other arenaceous and calcareous species which are sporadically present in some sequences, and by the lithofacies. Taylor (1983a,b) has suggested estuarine and marsh environments for samples comparable to the sidewall core at 2491m. Although the name Cyclammia sp. is retained here on the basis of the wall-structure (which is indistinguishable from that of bathyal specimens higher in the Ayu-1 sequence), the interpretation of a marginal marine facies, as suggested by Taylor, seems a valid one.

2527 - 2552 metres : age indeterminable : barren.

Two sandy sidewall cores were barren of foraminifera or other obvious marine indicators.

4. REFERENCES.

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TABLE 1 : TIME STRATIGRAPHIC SUBDIVISION OF THE INTERVAL 1250-2490M, AYU-1.

DEPTH (M)	ZONE	AGE	ENVIRONMENT
1250-1350	probably B-2	Late Miocene	Outer shelf to shelf/slope break
1400-1700	Undiff.B-2/C	Late Mioc. to topmost Middle Mioc.	?Canyon fill or slump?
At 1730	Probably B-2	Probably Late Miocene	" " " "
At 1740	Low Zone C	Middle Miocene	Upper bathyal
1800-1850	D-1	Middle Miocene	Upper bathyal
1900-1950	D or E-1	Middle Miocene	Outer shelf or upper slope
At 2000	E	Middle/Early Miocene boundary	Upper bathyal
2050-?2146	Probably F	Early Miocene	Upper bathyal
2165-approx.2200	G	Early Miocene	Upper bathyal
approx.2200-2394	H	Early Miocene	Upper bathyal
At 2451.5	(F)	(Early Miocene - OUT OF SEQUENCE)	(Upper bathyal)
2482-2490	I-1	Late Oligocene	Upper bathyal
2491	-	age indeterminable-almost barren	?
2527-2552	-	" " -barren	?