APPENDIX V

PALAEONTOLOGICAL REPORT,

VOLUTA-1 WELL,

by

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CONTENTS

ENCLOSURE (No, 6 of Voluta-1 well completion report)

Distribution of selected Foraminifera and depositional environment.

INTRODUCTION

Voluta-1 was drilled five miles offshore from Cape Bridgewater, in the western part of the Otway Basin.

SAMPLE DETAIL

Ditch cutting samples were received from first returns at 966' to T.D. at 13037', with some gaps due to lost circulation. Conventional cores were taken at approximately 500' intervals down to 11996' and sidewall cores down to 8901' were available. Cutting samples were examined at 100' intervals, which were reduced to 50' or 20' where necessary. Several samples from each core, and all sidewall cores of suitable lithology, were examined. Depths given are from B.D.F. (below derrick floor), and are as marked on samples.

As most of the investigation entailed a detailed examination of the Upper Cretaceous sequence, the following comments are relevant.

Upper Cretaceous faunas have a sparse distribution per unit volume of sediment analysed. Large core samples frequently provided only a small yield of foraminifera. Adjacent cuttings usually provided a much richer fauna, particularly below 9000'. This was largely due to taking a part of each ditch cutting sample from the mud flow at the de-sander mechanism, which produced a concentration of sand-size foraminifera. The remainder of the sample was taken from the shale shaker in the usual way, and the two samples combined in one bag.

Caving from fossiliferous horizons has evidently masked many barren intervals in the Upper Cretaceous. Thus only large-scale facies changes are evident in the cuttings. In some cases cores and sidewall samples have clarified depositional environments, but below 9000' sidewall cores were not taken, and interpretation was difficult.

ZONATION

The biostratigraphic zonation used is that of Taylor for the Gippsland, Bass and Otway Basins. (Ref. 1 and 2). Taylor's zonation of the Upper Cretaceous has been extended and subdivided.

BIOSTRATIGRAPHIC SEQUENCE

The sequence in Voluta-1 extends from Miocene to Cenomanian. Much of the Tertiary section is unsuitable for analysis (dolomitic) or unfossiliferous.

The greater part of the well is composed of 8500' of Upper Cretaceous sediments, largely fossiliferous, and extending in age from Cenomanian to Campanian (and probably to Uppermost Cretaceous). The great interest of the section lies in its thickness, its relatively continuous history of deposition, and the discovery of new faunas at the base, and probably also at the top of the sequence. The well contains the oldest Upper Cretaceous foraminiferal faunas yet found in the basin.

The sequence is detailed below.

Miocene to Oligocene - Zonules G to J - (1030' - 2660')

At 1030' a sidewall core contains a Zonule G (Lower Miocene) fauna including :

Globigerinoides triloba, Globigerina woodi, Globorotalia scitula and G. siakensis.

A cutting sample at 1120'-30' contains a Zonula H (Lowest Miocene) fauna, which includes Globigerina apertura, G. woodi and Globigerinoides triloba immatura.

The Oligocene- Miocene boundary occurs at approximately 1220-30', where Globigerina euapertura, the Oligocene Zonule I index species, occurs with Miocene forms G. woodi, G. apertura, Globigerinoides triloba and Globorotalia siakensis. The presence of the latter species is probably due to contamination rather than to a position on the boundary between Zonules H and I-1.

At 1320-30' the fauna is a sparse Upper Oligocene (Zonule I-1) one, with :

Globigerina euapertura .

Recrystallization and dolomitization of faunas obscure much of the Heytesbury section below this depth.

A sidewall core at 2618' contains Bolivina pontis, Angulogerina otatara and Chiloguembelina cubensis. These species, in the absence of Upper Eocene Globigerina linaperta, indicate a Lower Oligocene (Zonule J) age. Core 1 (2660'-2671') contains a very poorly preserved fauna of the same age.

Eocene - Zonule K - (2684')

Glauconitic ferruginous sandstone was recovered in a sidewall core at 2684', 13 feet below the clayey limestone of core 1. The sand contains abundant glauconitic internal molds of foraminifera, about 85% of them planktonic species. Globigerina linaperta and Globigerina ampliapertura indicate a Zonule K (Uppermost Eocene) age. No calcareous test material remains.

Sidewall cores at 2710' and 2721', still within the ferruginous sand, were barren of foraminifera. For reasons discussed later, the sand is believed to be the Nelson formation, the initial detrital deposit of the Heytesbury group.

Paleocene (?2754' - 4385')

Over an interval of 1500' (2710' - 4207') sidewall cores are barren of foraminifera, and only obvious downhole contaminants are present in ditch cutting samples. As there is only poor palynological data on the upper part of this interval, its age is problematical. A short communication from B.I.P.M. laboratories in The Hague suggested a Paleocene age.

A cutting sample at 4150-60' contains a solitary specimen of Haplophragmoides complanata. At 4207' a sidewall core contains H. complanata, many poorly preserved specimens of Haplophragmoides spp., and one Hyperammina sp. The poor fauna of this glauconitic core is supplemented by a moderately abundant H. complanata fauna from a cutting at 4210-20'. A Paleocene age can be assigned confidently.

This is the sum total of fauna found in the Wangerrip group. The assignment of this thin interval of paralic foraminifera to the Rivernook member is based partly on Dr. Dettmann's palynological examination. (see Appendix VI).

Lowermost Tertiary to Upper Cretaceous - Zonule ?Y - (4631' to 5086')

Poor arenaceous faunas occur in core 5 at 4631', and at 4878' and 5086' in sidewall cores. They are of transitional character between Paleocene and Upper Cretaceous, but have stronger affinities with the former, falling within the Haplophragmoides complanata and H. rotundata lineages of Taylor (Ref. No.3). The thinner, more lobate forms of the genus with acute compressed periphery, such as H. sp. A and H. paupera, do not occur.

Zonule Y, predicted by Taylor but not yet recognized in the Otway Basin, may be represented by these faunas. On palynological evidence these beds are Uppermost Cretaceous in age.

Upper Cretaceous - ?Campanian to Santonian - Zonule Z - (5214' - 7099')

Haplophragmoides sp. A is first seen in a sidewall core at 5214'; this is taken as the top of Zonule Z. Other components of the fauna are H. sp. B and H. sp. C, both common throughout the Upper Cretaceous sequence. Between 5400' and 5700' rare specimens of Trochammina sp., Textularia cf. semicomplanata, Ammobaculites subcretacea, A. goodlandensis and Trochammina cf. subinflata make their first appearance.

The faunas in sidewall cores, on which this Zonule is mainly based, become poorer in individuals and species, and all but Haplophragmoides spp. again disappear at 5773'. Sidewall and core samples at 5880', 5899', 5971' and 6054' are barren.

By 6210' a poor arenaceous fauna containing the same species as those listed above is again present. Dominated by Haplophragmoides sp. A, with some H. sp. B and very rare appearances of other species, this Zonule Z fauna continues down to 7099' with virtually no change. The lower boundary of this sparsely fossiliferous zonule, which is in part a facies variant rather than a sharply defined time zone, occurs at the fault which forms the boundary between the Paaratte formation and the underlying Belfast Mudstone.

Upper Cretaceous - Santonian - Zonule XA-1 - (7100'-8950')

The fauna which occurs below the fault in core 11, at 7104', is not greatly different from Zonule Z, still being dominated by H. sp. A, with H. sp. B and H. sp. C. But numbers of specimens show a tenfold increase; and several arenaceous species, including Textularia semicomplanata and Hyperammina elongata reappear. This paralic fauna marks the final regressive phase of the Belfast Mudstone. Because the facies changes seen here between final Belfast and initial Paaratte deposition are relatively slight, it is believed that relatively little section has been faulted out.

At 7200' the changes just perceptible with the crossing of the fault boundary are clearly marked. Calcareous and planktonic species make their appearance for the first time in the Upper Cretaceous, although in very small numbers. Except for the uppermost part, described above, it is a fairly homogeneous fauna, with a gradual increase in the abundance and diversity of species, down to about 8600'. At 7200' the fauna includes Haplophragmoides sp. A, H. sp. B, H. sp. C, Dorothia filiformis, Trochammina minuta, T. subinflata, Lenticulina sp. -4, Allomorphina pyriformis, Alabamina australis and Globigerina sp. At 7400' Textularia semicomplanata, T. anceps, Ammobaculites cf. subcretacea and Pallaimorphina heliciformis appear, and at 7500' Gyrodinoides nitida. The planktonic species group Hedbergella trochoidea occurs as rare specimens, but never exceeds three in any sample.

Typical Zonule XA faunas of Taylor's assemblage 2 from the Port Campbell Embayment, occur between 7760' and 8200'. They are also present in miniature forms, and much smaller numbers, between 8600' and 8800' (see section on interpretation). Calcareous forms include Cibicides excavatus, Gyrodinoides nitida, Valvulineria erugata, Lenticulina (Marginulinopsis) curvisepta, L. (Robulus) navarroensis group, L. (Marginulinopsis) jarvisi, Quinqueloculina sp., Alabamina australis, Pallaimorphina heliciformis, Marginulina inaequalis, Buliminella cf. parvula and Hedbergella trochoidea group. Conspicuous by their absence are Ceratobulimina spp. and Hoeglundina supracretacea, both found in the Port Campbell Embayment. Hanzawaia californica appears just above the base of the zonule, at 8850'.

Arenaceous forms include Haplophragmoides sp. A, H. sp. B, H. sp. C., Dorothia filiformis, Marssonella oxycona, Textularia semicomplanata, T. anceps, Trochammina minuta, T. sp., Ammobaculites subcretacea, A. goodlandensis, A. cf. fragmentaria, Hyperammina elongata, and Dorothia conulus. The arenaceous species generally exceed 70% of the total fauna. The only significant difference from the composition of Taylor's faunas is the increased importance of Trochammina spp., reflecting the difference in facies.

Upper Cretaceous - ? Coniacian - Zonule XA-2 - (8950'-9180')

In this interval the same faunas are present, with the addition of Gavelinopsis cenomenica. This is one of the index fossils of Taylor's Upper Turonian Zonule XB, together with Colomia austrotrochus and Textularia trilobita. However, the highest appearance of G. cenomenica was never delineated by Taylor, because a facies change to paralic conditions near the base of his Zonule XA eliminated all calcareous species for some hundreds of feet. When they next appeared down section, a fully developed Turonian XB fauna was present. In Voluta-1, little regression occurs at the XA - XB boundary, and hence calcareous species remain in the fauna. The appearance of G. cenomenica 230' above Textularia trilobita (which marks true Zonule XB) necessitates splitting Zonule XA into two subzonules. The lower subzonule XA-2, is defined as extending from the highest appearance of Gavelinopsis cenomenica to the appearance of Textularia trilobita or other species indicative of XB, and is probably synchronous with Taylor's Assemblage 3 in the Port Campbell Embayment.

By inference, Zonule XA-2 is Coniacian in age, occurring above Upper Turonian and below Santonian zonules. Colomia austrotrochus, also an XB index fossil, appears within the zonule at 9010'.

Because of downhole contamination and lack of sidewall cores, it is not certain how many species of Zonule XA-1 actually extend down into XA-2.

Upper Cretaceous - Upper Turonian - Zonule XB - (9180'-11700')

The entry of Textularia trilobita at 9180' indicates the top of this zonule, which can be recognized in the absence of calcareous faunas.

Foraminifera from Zonule XA-2 are found for the first 500' of Zonule XB; they are then replaced by a slightly different fauna. This persistence of the younger fauna is probably partly due to caving.

Haplophragmoides sp. B becomes the most abundant arenaceous form, with some H. sp. C and H. sp. A. Marssonella oxycona, Dorothia filiformis, Trochammina spp., Ammobaculites goodlandensis, A. cf. subcretacea and A. cf. fragmentaria continue downwards. Textularia trilobita, the index species, is common to abundant in nearly all samples in the zone. Dorothia glabrella is rather sparsely, but persistently, distributed between 9630' and 11521' (core 20). Stensoina spp. occur throughout the zonule.

Faunas from cores are very sparse, due to the low frequency of specimens per ounce of core prepared, and the difficulty of extracting them intact from hard siltstone. Sampling of Zonule XB faunas from the mud flow at the de-sander mechanism, although somewhat misleading due to sample mixing and blurring, and some caving, produced a much richer fauna than from cores because of the natural grinding action of the drilling bit. Although foraminifera are abundant, many specimens at these depths are deformed and altered beyond recognition

Zonule XB faunas established from cores 16, 17, 18 and 20 include the following species: arenaceous Haplophragmoides sp. B, H. cf. sp. B, and H. sp. C (dominant), Dorothia filiformis, D. glabrella, Ammobaculites goodlandensis, Textularia trilobita, Marssonella oxycona and Hyperammina sp. Among the sparse calcareous forms are Gavelinopsis cenomenica, Hanzawaia californica, Nodosaria sp., several species of Lenticulina (Robulus), and Saracenaria cf. triangularis. Some other species can be added - Gyrodinoides nitida (abundant in cuttings, and present in core 21), and Pleurostomella spp., Stensoina cf. truncata, Stensoina sp., Lagena cf. apiculata and Colomia austrotochus - from new appearances in cutting samples. From their abundance in cuttings it is believed that Alabamina australis and Hedbergella trochoidea also continue into XB. Whether species such as Allomorphina pyriformis, Guembelina reussi, and certain Marginulina spp. also occur in situ in XB is uncertain.

At 9630' a large robust Textularia (designated sp.-6) is first found, and below 9880' a smaller T. sp.-7 is present, Both continue down into Zonule XC to at least core 21 (11988').

Upper Cretaceous - Cenomanian - Zonule XC - (11700' - ?12300')

A new zonule, designated XC, is marked by the entry of Textularia washitensis and T. "prototrilobita" (informal name only) at 11700'. The morphology of this species suggests that it is the ancestor of Textularia trilobita. The latter occurs in cuttings with decreasing frequency down to 12500', but its presence is probably due to caving. In core 21 at 11988' T. trilobita is absent and T. "prototrilobita" is the dominant textularid. As T. trilobita was a new species described by Taylor, it is believed that T. "prototrilobita" is also an undescribed form.

Due to caving in cuttings, a Zonule XB fauna masks the XC fauna for most of the zonule. However, core 21 at 11988' contains the following fauna:
Textularia washitensis, T. "prototrilobita", T. sp.-6, Haplophragmoides sp. C, Dorothia filiformis, Trochammina cf. umiatensis, Gyrodinoides nitida, Pyrulina cf. cylindroides, ?Hyperammina sp. and Dentalina spp., and shell fragments of Inoceramus sp. Thus the zonule can be fairly safely assigned to the Cenomanian.

Due to poor samples it is not possible to say whether the sequence between Zonules XB and XC as represented in Voluta-1 is continuous, or whether a faunal break is present.

? Upper Cretaceous - ?? Zonule XD - (?12300' - ?13037')

Between 12300' and 12950' the fauna decreases greatly in numbers and preservation becomes very poor. Cuttings down to 12950' contain sparse calcareous faunas from Zonule XC, which are probably due to caving. Indeterminable arenaceous genera make up over half the faunas. A distinctive species, Spiroplectammina goodlandana, which is possibly the ancestor of Textularia washitensis, is first found at 12940'-50'. It is possible that another zonule, "XD", is present below 12300', but the uselessness of most of the fauna prevents any conclusions being drawn at this stage.

DEPOSITIONAL ENVIRONMENT AND GENERAL DISCUSSION

Following deposition of the Otway group and downfaulting of the Voluta area, Upper Cretaceous deposition commenced in a paralic or brackish lagoonal environment. The oldest known foraminiferal strata in the basin contain very poor faunas below 12300', and are possibly of early Cenomanian age.

In the interval 12300' - 11700' Cenomanian faunas became established in a restricted marine environment. The evidence strongly suggests Voluta-1 to have been within a long narrow embayment, aligned NW - SE, with a silled entrance to the SE, producing ponded conditions even in the times of maximum marine transgression.

Arenaceous species tolerant of unfavourable conditions are dominant: mainly Haplophragmoides spp. and Textularia spp. Due to the lack of other diagnostic species, zonation in the Upper Cretaceous of the Otway Basin has been based mainly on species of Textularia.

Whether the sequence between Cenomanian Zonule XC and Upper Turonian Zonule XB remains marine, becomes regressive, or is broken by an unconformity, is uncertain. At the top of XC an unusual element of the fauna is the quantity of sea urchin fragments at 11700'. Faunas at 11620'-30' are poor but not markedly "regressive" in aspect. Core 20 at 11521' has a fauna dominated by Haplophragmoides spp., without Textularia spp., tending to suggest shallow water conditions. However, insufficient evidence is available for anything more than conjecture.

Essentially uniform restricted marine conditions seem to have prevailed throughout Upper Turonian (Zonule XB) times. (It is possible that the lower part of this zonule extends into the Middle Turonian.) Marine influence seems to have reached a maximum at this time, with ocean currents carrying a few planktonic specimens across the postulated circulation barrier at the entrance to the embayment.

Upper Turonian faunas apparently pass into Coniacian (XA-2) faunas at 9180' without a perceptible change in environment. Similarly, no change in facies is apparent between XA-2 and XA-1 (Santonian) at 8950'. In contrast to the Port Campbell Embayment, this part of the sequence appears to be without faunal breaks.

The interval assigned to the Coniacian may be too brief, and might eventually be extended.

Restricted marine conditions initiate Santonian Zonule XA-1 at 8950', but at 8800' the environment appears to change. Between this depth and 8600' the calcareous specimens become few in number and of miniature size. They are well sorted to a fine silt size. It is possible that the Voluta area was partially emergent at this time, and that small calcareous specimens were transported by wind, possibly over a beach barrier, to a lagoonal environment. A restricted arenaceous fauna of the normal size dominates this interval, and suggests regressive or lagoonal conditions.

A return to restricted marine conditions is evident at about 8600', and this environment persists almost to the top of Zonule XA-1.

Core 11 at 7104' has an abundant but almost entirely arenaceous fauna indicating shallowing and an approach to paralic conditions. Immediately above this is the bounding fault between Belfast Mudstone and Paaratte formation, and between Zonules XA-1 and Z. From the facies change to paralic at the top of the Belfast Mudstone, it would seem that relatively little of the section is missing through faulting.

The Zonule XA-1 - Zonule Z boundary is generally a reflection of facies changes rather than a time plane. The zonule is characterized by the continuation of paralic arenaceous species from Zonule XA-1, and the absence of calcareous species. However the zonule also has time significance, in that part of it extends into the Campanian. It is much more readily zoned by palynology (see Appendix VI).

The impossibility of defining Zonule Z as a time zone in Voluta-1 illustrates the severe difficulties imposed on time stratigraphy by the numerous facies variations in the Otway Basin. Only a well section in an open marine facies, possibly beyond the confines of the basin and situated on the upper continental slope, could resolve all these problems.

Zonule Z extends from 7100' to 5214' and comprises the Paaratte formation and part of the Curdies formation. It is a paralic sequence with a sparse and erratic distribution of microfauna. A minor regression is indicated between about 6100' and 5800', where cores are barren of fauna and dolomite and carbonaceous material appear in samples.

In the upper part of the Curdies formation, marine influence becomes still more remote. The environment varies from paralic to non-marine in Zonule ?Y. The existence of this zonule is suggested, not proven, by a series of poor faunas transitional in character between Upper Cretaceous and Paleocene.

The position of the Tertiary - Cretaceous boundary is impossible to determine in Voluta-1 in the present state of our knowledge. Its precise position does not seem to be of much practical importance, as deposition appears to have been continuous from Upper Cretaceous to Tertiary. The uppermost parts of the Curdies formation appear to extend into the basal Tertiary. (see Dettmann, Appendix VI). Paralic foraminifera with transitional characteristics, but generally with Paleocene affinities, occur between Core 5 (4631') and 5086'. The highest recognizable Cretaceous fauna occurs at 5214' (top of Zonule Z). However the top of the Cretaceous is placed at the top of the Nothofagidites spore-pollen zone.

No fauna was found in the basal sand of the Wangerrip group, the Pebble Point formation, and it is believed to be non-marine. The Rivernook member, directly above, contained an abundant arenaceous fauna at 4210', indicating a definite if brief return to paralic conditions. This contrasts with the open marine character of the Rivernook member further east in the Port Campbell Embayment. In keeping with this observation, the remainder of the Wangerrip group in Voluta-1 is entirely barren of microfauna, and appears to be non-marine.

The Nirranda group appears to be absent in Voluta-1. Ferruginous sands at 2754' mark the beginning of the Heytesbury group transgression, with the deposition of the Nelson formation. A sand at 2684' contains the glauconitic molds of an abundant planktonic fauna of Uppermost Eocene age (Zonule K). It indicates a rapid deepening and influx of ocean currents, which is quickly followed by carbonate sedimentation. At 2618' a sidewall core in the overlying marl contains a diagnostic Zonule J (Lower Oligocene) fauna. No perceptible faunal break is present. It is characteristic of the Nirranda group that where found it is separated from the overlying Heytesbury group by an unconformity that is recognizable as a faunal break. No such break is evident here, and the change from glauconitic sands to clays, marls and limestones seems to reflect a normal transgressive sequence. The Uppermost Eocene age of the Nelson formation confirms indications that the Heytesbury transgression moved from westward to eastward across the Otway Basin.

Post-Eocene Heytesbury sedimentation followed its customary pattern of moderately deep water shelf carbonates, with much secondary dolomitization obscuring the age of the limestone sequence. Open marine Lower Miocene limestone occurs in a sidewall core at 1030'.

The highest occurrence of the Heytesbury group is at the sea floor, where ?Miocene limestones are overlain in places by Pleistocene dune limestone. Upper Miocene clays of problematical relationship to the Heytesbury group also outcrop on the sea floor.

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