



PE990014

FORAMINIFERAL SEQUENCE - NAUTILUS A-1 WELL

OTWAY BASIN

VICTORIA.

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Nautilus A-1 was drilled in the central portion of the Otway Basin, 40 miles in a southerly direction offshore from Warrnambool.

Samples were examined from 999' to total depth at 6597'; ie. rotary cutting samples at 50' or less interval: 29 side wall cores and 8 conventional cores. Contamination in rotary cuttings was sporadic and varied in intensity. All depths quoted were those on submitted samples and were related to datum; Kelly Bushing at +95' M.S.L. Water depth at the site was 327' M.S.L.

An upper Tertiary calcareous sequence recorded from first returns down to 5650' where lower Oligocene planktonic faunas were reported. Between 5650' and 5720' sandy glauconitic siltstones were present with rare Oligocene planktonic foraminifera. At 5720', dark mudstones were penetrated, which contained Upper Cretaceous faunas and the drilling terminated at 6597', still in Upper Cretaceous dark mudstones. The faunas suggest that the uppermost Cretaceous was not represented. For a summary of the sequence see fig. 1.

The drilled sequence was almost completely marine. Apart from the interval between 5650' and 5720' (see fig. 2), abundant foraminiferal faunas afforded adequate biostratigraphic and environmental control. To this extent the Nautilus sequence is atypical for the Otway Basin where the thicker sections contain at least 3000' of Eocene to uppermost Cretaceous sands and silts (see figs 3 and 5), with faunas occupying less than 10% of the total thickness. The summary of biostratigraphy on fig. 1 and facies diagram on fig. 4 shows clearly that the normal lower Tertiary to uppermost Cretaceous interval is absent in the Nautilus section.

THE UPPER TERTIARY SEQUENCE

At 1500' the well penetrated the *Orbulina* surface (see Glaessner 1967, P.3) passing from middle Miocene (= upper Miocene of Glaessner) into the lower Miocene with a planktonic fauna of *Globigerinoides bisphericus*, *G. trilobus* and *G. glomerosus curvus* in cuttings and sidewall core at 1570'. This fauna is the immediate precursor to the development of *Orbulina suturalis*, marking the top of Taylor's (1966) Zonule F and the *Praeorbulina glomerosa curva* Zone of Jenkins (1967). The sequence of planktonic events throughout the lower Miocene is normal with that in sequences in the Otway, Bass and Gippsland Basins and is expressed in terms of Taylor's (1966) down sequence zonal scheme (see fig. 1). The sequence also agrees with the zonation of the New Zealand lower Miocene by Jenkins (1967) although Taylor differs in detail due to the necessity of using rotary cutting samples. The significant point in the Nautilus sequence is that there is no biostratigraphic break at the *Orbulina* surface, when comparing with the Barracouta (Taylor, 1966) and other Gippsland sequences where Zonules F and G are absent.

The Miocene/Oligocene boundary has been placed at 4500' on the initial appearance of *Globigerina euapertura* which indicates the top of Zonule I. Jenkins' (1965) work suggests that this event is still in the lower Miocene. But here the complete reliance on rotary cuttings makes this determination a matter of convenience for consistency in local correlation. A conventional core sample at 4640' contains a poor fauna with *G. euapertura* without *G. woodi* or other lower Miocene planktonics, thus corresponding with Jenkins' *Globigerina euapertura* Zone which he places at the top of the Oligocene.

The highest appearance of *Globorotalia testarugosa* equates the top of Taylor's (1966) Zonule J with the 5170' level in Nautilus. The highest appearance of *Globigerina angioporoides* is in cutting samples at 5250' thus correlating with the top of Jenkins' (1965) *Globigerina angioporoides angioporoides* Zone. Once again there is a discrepancy between the observed southern Australian and

New Zealand sequences in that Globorotalia testarugosa persists throughout Jenkins Globigerina euapertura Zone and not just for a few feet above the extinction of Globigerina angioporoides as is illustrated here, also in the Gippsland and by Lindsay (1967) in South Australia zoned sequence. Zonule J = the Chiloguembelina cubensis Zone of Lindsay (i.e. fig. 2), although Lindsay's Zonal indicator Chiloguembelina cubensis is only present in one sample well below the top of Zonule J in Nautilus. C. cubensis is also uncommon in the Gippsland sequences. On the other hand Globigerina angioporoides is much more common in the Nautilus sequence than in Lindsay's sequence (compare fig. 2 this report with fig. 2 of Lindsay). In the New Zealand sequence (Jenkins, 1965, fig. 2) Chiloguembelina cubensis is shown as an important form in this part of the sequence.

In correlating from Nautilus to a land section in the proximity, one finds that C. cubensis becomes more frequent whilst Globigerina angioporoides is less abundant and taxonomically more nondescript. For instance in the Narrawaturk-2 section (Vict. Mines Dept. water bore at Peterborough; see fig. 5) the interval between 1804' and 1847' was constantly cored (37 feet recovered), with a coring gap 1847-1894', thence another core. The sequence is as follows:-

	-1804		
		<u>Globigerina euapertura</u> common	I-1
Clifton Fm.			
	-1821--	Extinction of <u>Guembelitra stavensis</u> -----	
			I-2
1830-----	-1829--	Extinction of <u>Chiloguembelina cubensis</u> +-----	
		<u>Globigerina testarugosa</u>	
	-1835--	Extinction of <u>Globigerina angioporoides</u> ,----J-1	
		<u>Guembelitra</u> , <u>Chiloguembelina</u> & <u>Globigerina</u>	
	-1847--	<u>euapertura</u> common.-----	
Narrawaturk Marls		no core - cuttings inadequate.	?
	-1894--	-----	
		Highest record of <u>Globigerina linaperta</u> ,	
		<u>G. ampliapertura</u> , <u>G. pseudoampliapertura</u> .	K
		<u>Chiloguembelina</u> common.	

This agrees with Lindsay's sequence and Zonule I-2 is an obvious correlate of his *Guembelitra stavensis* Zone. The question of why *Chiloquembelina* sp. is very rare and *Guembelitra* sp. absent in *Nautilus* is possibly a function of depositional depth. It is either ecological, related to water mass movement and preferred depth habitat, or to selective solution of calcium carbonate at depth. The tests of both species are extremely delicate in the Narrawaturk and other faunas whilst the *Nautilus* planktonic faunas below 5000' are thick and robust. This suggests that selective solution may be the answer upon considering the evidence put forward by Berger (1968). This question of depth will be discussed later.

Cutting samples below 5400' contain *Globigerina brevis* and *Globorotalia gemma*. The former species has not been recognised before in Southern Australia by either Lindsay (1967) or myself. The short and restricted range of *Globigerina brevis* allowed Jenkins (1965) to establish the *G. brevis* Zone for the entire biostratigraphic range of the species. *Globorotalia gemma* has an identical range in New Zealand. Jenkins shows that *Globigerina ampliapertura* ranges through the *G. brevis* Zone into the overlying *G. angioporoides* *angioporoides* Zone. Lindsay (1967, fig. 2) does not extend *G. ampliapertura* above the range of *G. linaperta* and a similar situation occurs in Narrawaturk-2 (see above). In *Nautilus* a form associated with *G. brevis* is regarded as the transitional morphotype *G. ampliapertura-euapertura*.

The interval from 5400' to at least 5650' in *Nautilus*, is equates with Jenkins' *Globigerina brevis* Zone of the New Zealand sequence. This is obviously the lower part of Taylor's (1966) Zonule J as it is above the highest appearance of *G. linaperta* (= Zonule K). Therefore Zonule J can be split into the upper biostratigraphical interval -

J-1 = *G. angioporoides* *angoiporoides* Zone of Jenkins and the lower J-2 = *G. brevis* Zone of Jenkins.
The faunal constituents of these intervals in *Nautilus* are shown on Fig. 2.

Zonule J-2 was first recognised in Esso's Prawn A-1 well (Otway Basin - offshore Tasmania) by Taylor (appendix in Esso's completion report), though Globigerina brevis cannot be recognised probably due to facies. It may be present in Narrawaturk-2 (see above), but unfortunately samples are inadequate between 1847'; i.e. between J-1 and K.

Below 5650' the calcareous sequence changes suddenly to sandy glauconitic siltstones. No faunas were isolated from sidewall cores at 5657', 5662', 5673' and 5705' but one sample from core 8 (5674-91') contained very small specimens of Globigerina ampliapertura - euapertura. The interval between 5650' and 5720' is believed to be lowermost Oligocene as the single morphotype would suggest a lineage fragmentation interval equating with Zonule J-2. This statement requires further verification.

Because of evidence discussed both above and below the base of the upper Tertiary sequence is placed at 5720' on the faunas contained in submitted samples. The base of the upper Tertiary sequence is regarded as lowermost Oligocene, although from Jenkins' (1965) discussion it could be placed in the uppermost Eocene.

THE LOWER TERTIARY SEQUENCE

No lower Tertiary foraminiferal species (either planktonic or benthonic) were identified in the Nautilus sequence, nor were such forms present as mud-contaminants in rotary cuttings lower in the sequence. Apart from the fact that Zonule J-2 (equated with Jenkins G. brevis Zone) may straddle the Oligocene/Eocene boundary, Eocene and Paleocene sediments are not apparent in the Nautilus section.

THE UPPER CRETACEOUS SEQUENCE

Distribution of all upper Cretaceous species is shown on Fig.2. The discussion is on the species isolated in Nautilus but not recorded by Taylor (1964).

The fauna in cutting samples below 5650-5720' changes dramatically from a dominance of thick tested, robust planktonic forms to a sudden appearance of fine grained arenaceous species. This is demonstrated on both fig. 2 and fig. 4. The arenaceous species (listed on fig. 2) are those of Taylor's (1964) upper Cretaceous fauna and are not of the lower Tertiary arenaceous assemblages (Taylor 1965 and manuscript). At 5800' the cutting samples contain benthonic calcareous species referable to Taylor's (1964) Victorian upper Cretaceous sequence and not to the Victorian Paleocene species monographed by McGowran (1965).

The benthonic species Stensioeina exsculpta is recorded at 5950'. Morphologically the 2 specimens are probably assignable to S. exsculpta granulata. Cita (1966, pp. 249-250) would limit the genus to the Upper Cretaceous (Turonian-Maastrichtian), showing (l.c., tab.-1) a range of Coniacian to Campanian for S. exsculpta (sensu lato) and limiting S. exsculpta granulata to the Santonian. The associated benthonic forms at 5950' are amongst those recorded by Taylor (1964) in his Victorian upper Cretaceous Zonule A.

The highest appearance of upper Cretaceous planktonic species is in the core between 6102-17'; Hedbergella trocoidea being present. At 6200' Globigerinelloides asperus is associated with Taylor's Zonule A benthonic species. Pessagno's (1967) recent study of Upper Cretaceous planktonics from the Gulf Coast plain and Caribbean Areas, shows that G. asperus ranges from the Coniacian, through the Santonian into the early Campanian (l.c., text fig. 4 and p. 275). In Western Australia Belford (1960) found the species in both Santonian and Campanian sediments. Belford does not record Coniacian or upper Turonian faunas, as discussed by Burckle et al (1967).

In Nautilus the side wall core at 6377' contains a planktonic range overlap with the lowest appearance of Globigerinelloides asperus and the highest appearance of Hedbergella brittonensis. On referring to Pessagno (1967, text. fig. 4), a

time correlation is suggested, close to the Coniacian/Turonian boundary. This suggestion is supported by the highest appearance of Stensioeina praeexsculpta, which is the oldest representative of the genus and is regarded by Cita (1966, tab.-1) as signifying a Turonian age. The presence of endemic arenaceous benthonic species Textularia trilobita shows that the sidewall core at 6377' marks the top of Taylor's upper Cretaceous Zonule B.

The new evidence presented here supports Taylor's (1964, pp. 547-549) original contention that Zonule A has strong Santonian affinities and that Zonule B was Turonian. It is shown here and on fig. 2 that :-

- (i) the interval between 5800-6117' contains Santonian faunas which are assignable to Zonule A;
- (ii) the fauna at 6200' could be either Santonian or Coniacian but yet represents Zonule A;
- (iii) the sparse arenaceous faunas between 6200' to 6377' are of Zonule A and are probably Coniacian on superposition. A similar sparse fauna exists in the same stratigraphic position on shore (refer Taylor, l.c., fig. 3 and 5);
- (iv) the top of Zonule B (at 6377') corresponds with the Coniacian/Turonian boundary;
- (v) Zonule B continued to total depth (at 6597') so that the Nautilus section was terminated whilst still in Turonian (probably upper Turonian) sediment.

Local biostratigraphic correlation has been achieved for the Nautilus Upper Cretaceous sequence between 5800' and total depth (6597'). This correlation can be extended to the terms of the standard Cretaceous stage classification with an increased degree of accuracy. However, the highest horizon of the upper Cretaceous in Nautilus (5800-5720') presents a problem in that the fauna is purely arenaceous, although it would be assigned to Taylor's Zonule A. In other Otway Basin wells (see Taylor,

l.c. and Shell Development's Pecten and Voluta well completion reports) there are mainly arenaceous faunas above the faunas equivalent to those at 5800-6117' in Nautilus. In Flaxmans-1 this upper interval reaches a thickness of 1800' and is considered to extend above the Santonian to at least Campanian (see fig. 3). The interval above 5800' in Flaxmans-1 is informally referred to as Zonule Z. The Upper Cretaceous Zonule A of Taylor (1964) (*sensu stricto*) is below 5800' in Flaxmans-1 and is referred to as Zonule XA in the extension of Taylor's (1966) down sequence classification from Upper Tertiary to Upper Cretaceous. Thus the interval 5800-5720' in Nautilus could be referred to as the base of Z or top of XA.

THE CORRELATION OF THE NAUTILUS SEQUENCE

Correlation between Nautilus A-1, Shell's Pecten 1A and Frome-Broken Hill's Flaxmans-1 are demonstrated on fig. 3, from the comparison of the foraminiferal sequence. It is noted that the Pecten 1A sequence has been reinterpreted slightly from that given in the completion report.

From all five figures presented in this report it is obvious that there is a dramatic change in sedimentation at 5720' in Nautilus. The facies analysis diagram on fig. 4 shows that the Upper Cretaceous sequence of alternating anaerobic and aerobic dark mudstones (= Belfast mudstones) is identical to the diagram given for Port Campbell-2 by Taylor (1964, fig. 5), apart from the silty sandstone interval which contains the highest arenaceous fauna in Port Campbell (= Paaratte Formation). But this highest arenaceous fauna is only 80' thick in Nautilus and as it is contained in dark mudstone this may support Taylor's contention that the detrital inundation (= base of Paaratte Formation) of the Upper Cretaceous marine embayment was diachronous.

At 5720' the sediment is a detrital sandy siltstone to silty sandstone containing rare Oligocene planktonic foraminifera. 70' higher (at 5650' - see fig. 4) skeletal micrites contain an abundance of Lower Oligocene planktonic foraminifera

and the original sediment would best be described as a globigerinid ooze.

The section on fig. 3-A is drawn to demonstrate the relationship between time and thickness of sedimentation, taking into account that the Lower Oligocene Zonule J is absent in both Pecten-1A and Flaxmans-1. All three sections are drawn from a datum taken as the base of Oligocene (base J) or top of Eocene (top K), irrespective of drilled depths relative to sea level. Biostratigraphic correlation points are joined where possible. It can then be read off the diagram that a maximum thickness of 3600' Eocene to uppermost Cretaceous sediment is absent in Nautilus when compared with Pecten and Flaxmans.

The normal section on fig. 3-B shows that the missing 3600' maximum time/thickness gap was rapidly filled during Oligocene and Lower Miocene times by marine calcareous sediment. The Oligocene to Lower Miocene sediment in Nautilus is considerably thicker than that in Pecten and Flaxmans (see fig. 3-B), Narrawaturk-2 (see fig. 5) or any other section drilled in the Otway Basin, partially due to an Oligocene hiatus in many sections.

The correlations demonstrate that the Nautilus sequence is anomalous when compared with any other known sections in the Otway Basin. The apparent unconformity in Nautilus (fig. 3-A and B) requires more consideration as to its significance. On evidence so far presented it could be either a subaqueous erosional unconformity, a structural or even faulted unconformity, or a hiatus due to sediment starvation.

FACIES OF OLIGOCENE/MIOCENE FILL

Section fig. 3-B and section fig. 5 shows that rapid Oligocene/Lower Miocene sediment filled the time thickness gap when comparing Nautilus with other sections. In the section of fig. 5 Narrawaturk-2 has been used instead of Flaxmans-5[?] due to the more detailed information regarding the Upper Tertiary (see earlier discussion). Fig. 5 was compiled by quantitatively

selecting the dominant lithological and faunal constituents of samples and assessing the significance of the benthonic foraminifera.

The following facies sequence in Nautilus can be demonstrated in fig. 5 together with the detail in fig. 4 over a more limited interval:

- (i) 5720-5650' - Initial sediment of glauconitic silty sands and sandy silts, which may be reworked older material, although no recycled fauna was present.
- (ii) 5650-5400' - The analysis on fig. 4 (based on 10 gms of sediment) support the contention that this was a globigerinid ooze. As already mentioned, the planktonic specimens are all large, (>.3 mm) robust and thick tested without the delicate species of equivalent horizons on-shore. Berger (1968) ranks calcium carbonate solution susceptibility with specific character, habitat depth and total water depth. An empirical depth figure cannot be given, even for recent oceans, because of the coincidence between increased solution and top of Antarctic Bottom waters. The associated benthonic species (fig. 2) would indicate a depth of at least 3000'.
- (iii) 5400-4900' - A pelagic limestone rather than a globigerinid ooze with more calcareous (inorganic mud) than above, (fig. 4).
- (iv) 4900-4500' - is dominantly a pelagic limestone but containing up to 10% of detrital elements. These elements are fragments of carbonate cemented quartz and glauconite grains, together with "battered Robulus". The worn Robulus spp. are from .3 - .6 mm diameter lens and are nondescript because of lack of ornament. Both detrital elements are common constituents of the Clifton Formation (seen in Pecten - 22 miles away). The Clifton Formation and the Nautilus interval between 4900 - 4500' are synchronous as both contain Zonule I planktonics. This

interval is considered relatively shallower than that of 5650-5400' because of the presence of detrital material and an autochthonous benthonic foraminifera fauna rich in fine grained arenaceous species including Gaudyrina heywoodensis, Vulvulineria granulose and Textularia spp; the oldest recording of arenaceous Tertiary species in the section.

- (v) 4500 - 4209' - a palagic limestone with additional elements of quartz and glauconite of size range $<.15\text{mm}$, thus differing from the coarser detritus between 4900 - 4500'. Benthonic and planktonic foraminifera are rare and all specimens $<.3\text{ mm}$; in many samples the foraminifera are only in the $<.15\text{ mm}$ fraction. This suggests size sorting and differential size settling and that the benthonic fauna is completely allochthonous. The difference between interval (iv) and this interval may be more a function of current velocity and angle of sediment repose rather than of depth. But if it is a function of the repose angle, then interval (v) must be further upslope than interval (iv).
- (vi) 4029-2800' - The sediment contains a high proportion of sponge spicules (up to 20% of total sediment). These rod-shaped hollow spicules would tend to be held in suspension longer than the material in intervals (iv) and (v). Thus differential size sorting and settling are once again evoked with a suspicion of grading from the coarser (iv) to the slow settling (vi), when compared with Connolly and Von der Borch's (1967) examples from recent sediments on the southern Australian sea-floor. But Connolly and Von der Borch's graded beds are measured in less than 10 cm. units, whilst those of Nautilus are measured in hundreds of feet. The fine sedimentation of this interval was interrupted at least once (3825') by the introduction of coarser detritus, including bryozoal fragments and "battered" Robulus spp.

- (vii) A bryozoal rich marly limestone and marls containing planktonic foraminiferal faunas, which correlate with the bryozoal Gellibrand Marl of the Port Campbell Embayment, e.g. Pecten, Flaxmans, Narrawaturk, etc.). In Nautilus the benthonic foraminiferal fauna is rich in Cibicides refulgens, C. mediocris, Diocidicidites biserialis and Karrereria maoria which were probably adherent on seaweed, as were the bryozoa. The site of the seaweed growth would be on the continental shelf and the Gellibrand Marls (e.g. in Narrawaturk or in outcrop) are inner continental shelf deposits. Reed (1965, p.55) reaches this conclusion in respect to the Heywood Marl (= the Gellibrand Marl in the western part of the Basin). The 2800-1800' interval in Nautilus may represent inner continental shelf deposits, but the entire fauna could be allochthonous, having been rafted on seaweed onto the outer shelf or slope.
- (viii) 1800 - ?' A white rubbly limestone with occasional bryozoal marls. The benthonic fauna includes the species from 2800-1800' with Cassidulina subglobosa, Rosalina australia and Patellina corrugata. This fauna is similar to that of the present day continental shelf, where there is considerable current and wave base action.

Much of the faunal constituent of these calcareous sediments is either pelagic, or apparently allochthonous material which can be traced to synchronous sediments which were deposited in shallow water. The record of this sequence cannot be considered complete, because of inadequate samples, so that the account given above is very simplified. Yet there is a definite up-sequence trend from deep water sediments to shallow water. The sedimentation can be described as fill, in that the continental shelf has been built out from a position near Pecten in Oligocene to the position of Nautilus by mid Miocene times (see fig. 5). The amount of allochthonous material suggests that it was

carried over the edge of the shelf by slumping or current action (in the case of seaweed rafting). Inorganic material (including calcareous clays) would have been accumulated by the same mechanisms. The nature of the sediment particles in recent deep sea sediments off southern Australia support this view (Connolly and Von der Borch, 1967).

Difficulty exists in explaining the thickness of pelagic limestones in the sequence (5650-5170') with 480' of lower Oligocene sediment. In Narraturk-2 the same interval occupies 65' of shallow water sediment. A possible explanation is that with the Oligocene transgression nutrient rich cold waters upwelled onto the edge of the continental shelf stimulating the growth of a large plankton stock. Any large scale slumping would have muddied the water and killed vast quantities of plankton.

THE NAUTILUS UNCONFORMITY

The outstanding feature of the Nautilus section is the total absence of uppermost Cretaceous to Eocene sediment (approximating 3500' in sediment thickness in other sections) and the presence of a thick Oligocene to Miocene sediment fill which is approximately 3500' thicker than in other sections. The situation is compensatory and the coincidence of relative thicknesses is too close to imply structural movement and then readjustment. The apparent upper Cretaceous to Oligocene unconformity is not considered to be the result of exposure then sinking.

The Lower Oligocene sediment in Nautilus is approximately 3500' lower than any other known section in the Otway Basin. In three other sections the Lower Oligocene is represented by shallow water deposits or are absent. The Nautilus Lower Oligocene is globigerinid ooze with associated benthonic species indicating a water depth of greater than 3000'. Thus there is a coincidence between assumed water depth and present elevation differences. This is shown on the scale in fig. 5.

The immediate conclusion is that an approximate 3500' thickness of sediment was moved by slumping into deeper water, exposing Santonian sediment at the Nautilus site. This slumping must have occurred in later Eocene or early Oligocene times. Sedimentation would therefore have resumed at a depth of 3500', which is consistent with all data presented here. Under these circumstances an unconformity due to sub-aqueous erosion is postulated at 5720' in Nautilus.

Coring projects reveal that unconformities in deep-sea sediments are the rule rather than the exception especially on the continental slope and marginal plateaux. Unconformities and missing Tertiary time units are shown by JOIDES, (1965, figs. 3 and 4) on the Florida-Hatteras slope and the Blake plateau. An interesting local example is a core taken in 3000 metres of water in the Naturaliste plateau off south western Australia. In this core Burckle et al (1967) reports:-

- 9 - 119 cm Pleistocene planktonic foraminifera deposited in >1000m of water;
- 119 - 222 cm Upper Cretaceous (Mid-Turonian) planktonic foraminifera deposited in >1000m of water.

The core exhibits a clear cut time break, though angularity of the unconformity could not be clearly demonstrated on the seismic profiles (Burckle et al, l.c., fig. 4). The time break may have been due to sediment and plankton starvation at the site.

Sediment starvation may be the explanation for the Nautilus unconformity although Esso's seismic profiles do exhibit angularity. In the Naturaliste model, deep-sea sediment rests on deep-sea sediment after a time break. In Nautilus, deep-water pelagic Oligocene sediments rests on fairly shallow water Upper Cretaceous deposits which have an extremely low planktonic count (<1%). The benthonic constituents of the Nautilus Upper Cretaceous faunas are those of the Otway Basin dark mudstones which Taylor (1964, p.552) regarded as indicating a maximum

depth of 200m. Thus there is marked change in sedimentary environment on either side of the unconformity (refer fig. 4), which can only be accounted for in terms of structural or sediment movement.

Abbreviation of sedimentation cannot be completely dismissed in considering the Nautilus section as coring was not constant over the interval between definite Upper Cretaceous and definite lowermost Oligocene (i.e. between 5720' and 5650'). Coring was carried out between 5674' and 5691' and 4 sidewall cores were taken. It has been emphasised that 3500' of uppermost Cretaceous to Upper Eocene sediment is absent in Nautilus. Abbreviation into 70' of sparsely fossiliferous silts and sands (between 5720' and 5650') is difficult to comprehend especially as the only foraminifera present suggest a lower Oligocene age. The lack of any recycled material suggests that exposure of older (pre-Oligocene) material was sudden and the exposures were quickly sealed by slumped or suspended clays or silts. The 70' of sands and silts in Nautilus are probable remnants of the slumped material captured in a subaqueous erosional hollow. The Oligocene planktonic fauna was added ("salt and pepper" addition) at the time of slumping.

The preferred explanation of the Nautilus unconformity is that sudden slumping removed 3500' of loosely consolidated sands and silts. The base of the slumping was the lithologically homogeneous dark mudstone (= Belfast Mudstone - drilled thickness of 880') which is now indurated. Surely with 3500' of overburden, induration would have taken place by Oligocene times. This lithological unit would have been more resistant to slumping and scouring than the units above.

The data produced validates the argument that the Nautilus unconformity was in fact the continental slope in Oligocene times. The Oligocene sequence is complete in the Nautilus section but this is not so in many other Otway Basins sections as shown on fig. 3, and in the data compiled by Taylor (in press). A lower Oligocene hiatus was suggested originally by Carter's

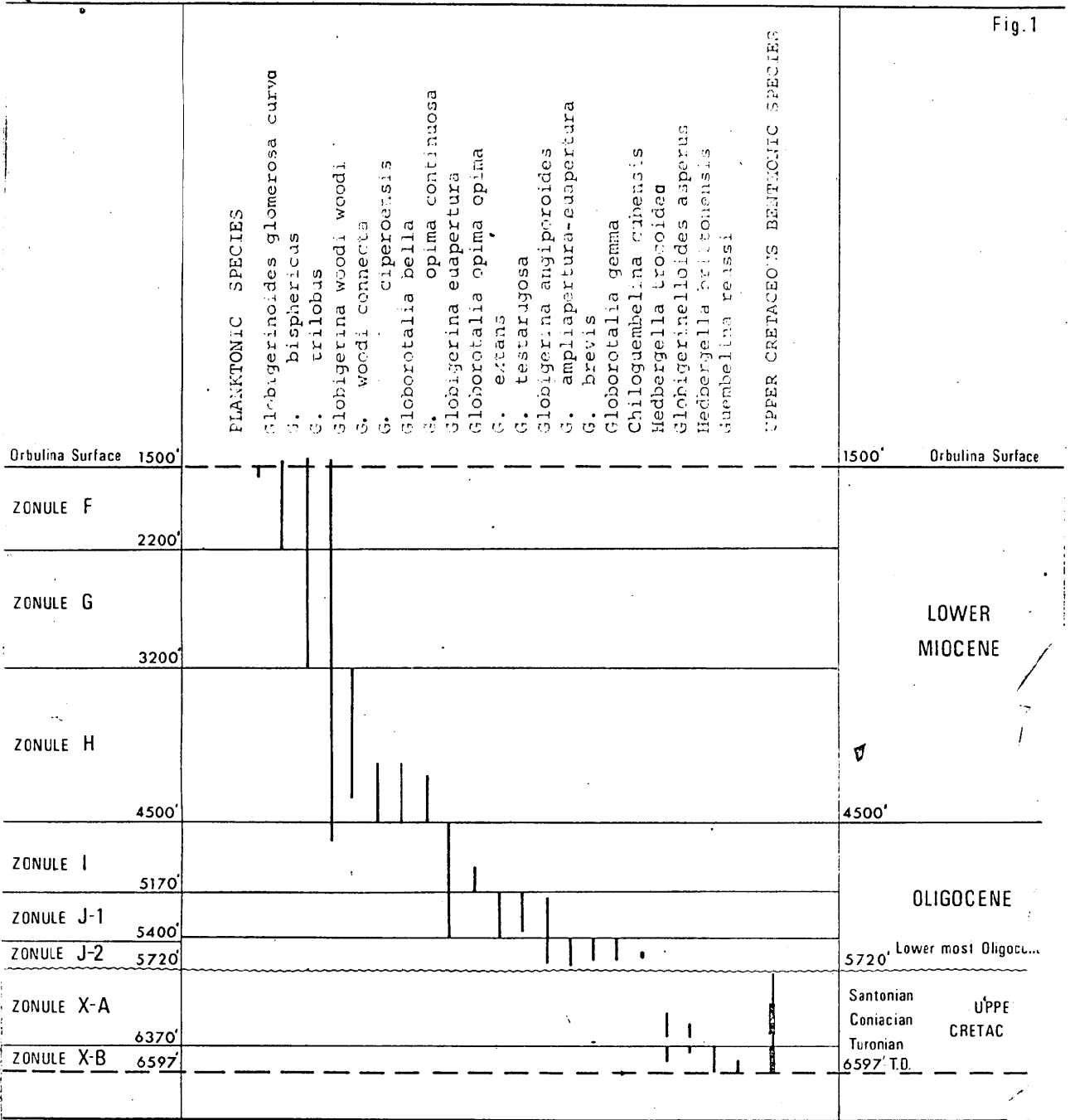
(1958) Aire Coast (eastern Otway Basin) foraminiferal sequence. Following the subaerial exposure, a shallow water sandy calcarenite was deposited. This Upper Oligocene unit, the Clifton Formation, is rich in bryozoal fragments, is cemented by iron carbonates and hydrates and contains phosphatic nodules. Baker's (1962) description of the sediment and mineral content shows clearly that it was the result of an unconformity in an area of low relief. Thus there was slumping and deep water deposition in one part of the basin corresponding with subaerial exposure in the marginal areas. Even in marginal areas where Oligocene sedimentation was continuous in some sections (e.g. Narrawaturk - fig. 5) the Lower Oligocene marls were shallow water deposits and the Upper Oligocene is represented by the typical Clifton Formation lithology. From fig. 5 it appears that Narrawaturk was in a lower structural position than Pecten where the Lower Oligocene is absent.

A Lower Oligocene structural adjustment is obvious with two apparently simultaneous events; uplift in the northern part of the basin; down-warp on the southern extension of the continental shelf resulting in slumping and formation of a new continental slope. The Nautilus section shows that sediment built up during Oligocene to Miocene times so that the continental shelf was extending southward to establish its present position.

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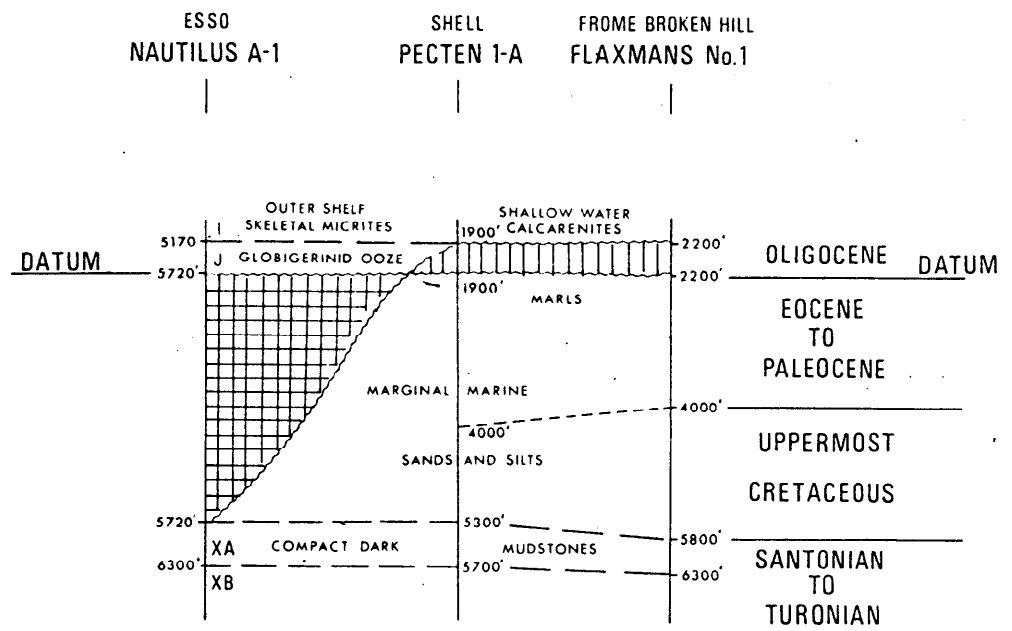
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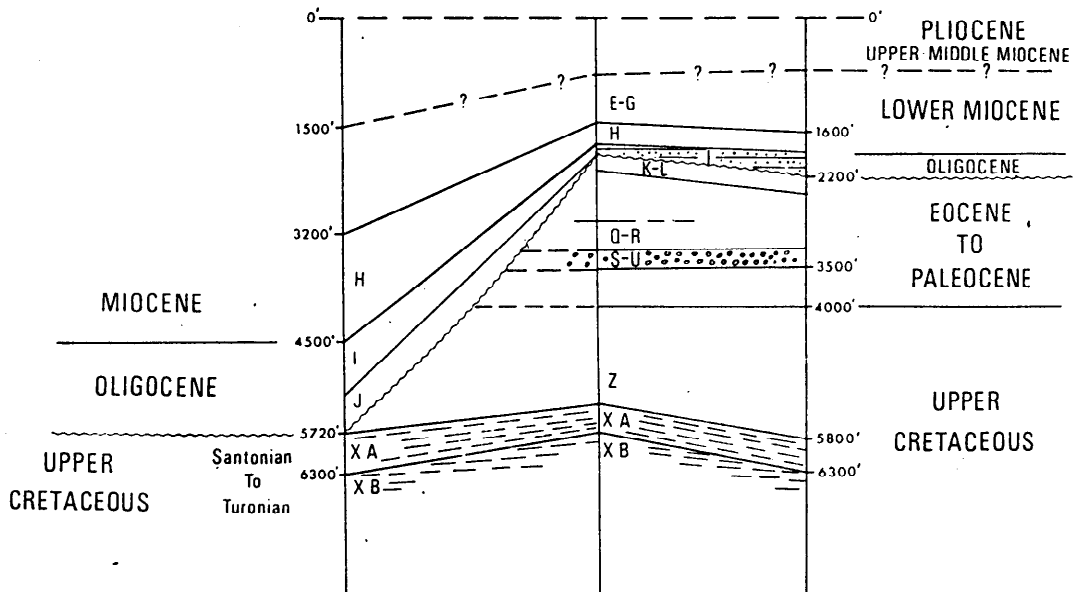
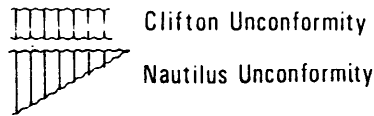


NAUTILUS A-1
Summary Biostratigraphy
 DATUM 95' M.S.L.

REFER FIGURE 2 FOR DET.
DISTRIBUTION 5000-659



A—Time-Relative to Thickness Datum-Base of Oligocene

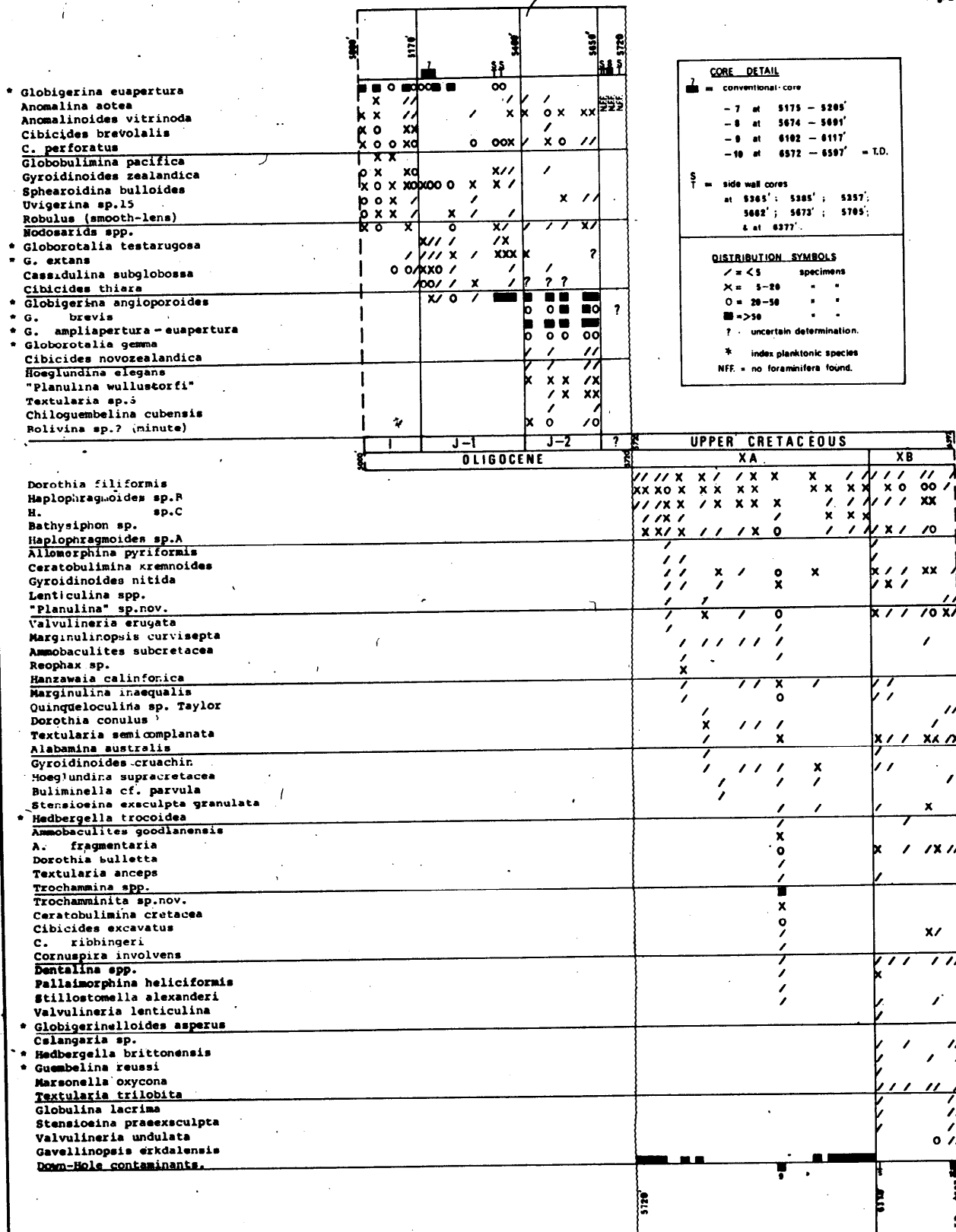


B—Biostratigraphical Cross Section

MARKER UNITS

- Clifton Formation
- Pebble Point Formation
- Belfast Mudstone

Cross Sections Flaxmans to Pecten to Nautilus



CORE DETAIL

7 = conventional core

- 7 at 5175 - 5205'

- 8 at 5674 - 5691'

- 9 at 6102 - 6117'

- 10 at 6572 - 6597' - T.D.

S = side wall cores

T at 5365'; 5385'; 5397'; 5662'; 5673'; 5705'; & at 6377'.

DISTRIBUTION SYMBOLS

/ = < 5 specimens

x = 5-20 "

o = 20-50 "

■ = > 50 "

? = uncertain determination.

* = index planktonic species

NFF = no foraminifera found.

Foraminiferal distribution chart - Nautilus-A-1
from 5000' to 6500'.

