THE FORAMINIFERAL SEQUENCE, PECTEN 1A WELL

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CONTENTS

1. Note on the zonation scheme

The biostratigraphic scheme of Taylor (1966) (Ref.1) for the Gippsland, Bass and Otway basins, was used in this investigation. The scheme contains a series of 30 alphabetical zonules spanning the Upper Cretaceous and Tertiary, and is based on the extinction, rather than the initial appearance, of index species. This enables a well to be zoned entirely on cuttings, despite downhole contamination, providing the in situ faunas are moderately abundant. The local subdivision is necessarily less detailed than the Shell zonation schemes based on tropical faunas, because the local temperate and cold water faunas are impoverished in both species and individuals.

2. Sample Detail

Faunal determination of three conventional cores, sidewall cores and cuttings was carried out from the first returns at 600' (in the initial hole, Pecten-1) down to the top of the Otway group at 5892' in Pecten-1A. Cutting samples were checked at approximately fifty foot intervals, and more closely where good faunas were found. Distribution of faunas was recorded quantitatively in the Upper Cretaceous, and qualitatively in the Tertiary intervals. No detailed examination was made of the interval 600 - 1700 feet.

3. Faunal Sequence

Pecten - 1A penetrated a superficial layer of Pleistocene beach rock, and drilled through an unknown thickness of Middle and Upper Miocene limestone, before the first casing was set at 850 feet. (Information from Pecten-1, suggested that the Middle/Lower Miocene boundary was somewhat above 550 feet.)

From the first returns of Pecten-1A at 864 feet down to 1300 feet, Lower Miocene limestones were penetrated. Precise zonule boundaries were not defined. (see Text Fig.1).

Between 1300 feet and 1870 feet the planktonic fauna was dominated by Globigerina ampliapertura, G. euapertura, Globorotalia opima and G. obesa, indicating an Oligocene (Zonule I) age. Miocene contamination over this interval was heavy. No detailed analysis of the cuttings above 1700' was made, but the fauna suggested that both Zonules I_1 and I_2 were present.

No indications of the Lower Oligocene Zonule J were found, and a minor timebreak, corresponding to Hiatus III in the rest of the basin, is indicated at or above about 1880 feet. (Ref.No.2.)

At 1880 feet the end-members of the Eocene Globigerina linaperta lineage first appear in the cuttings, and by core No.1 (1892-1915 feet) the fauna of the uppermost Eocene Zonule K is well developed. Core No.1 is a bedded marly clay with an abundant shallow water benthonic fauna, and moderately abundant planktonics, indicating shallow open marine conditions. The fauna includes: Globigerina linaperta, Globigerina ampliapertura, G. euapertura, Globorotalia opima, G. obesa, Globoquadrina larmeui, Bolivina pontis, B. anastomosa, Cibicides perforatus, and Cerobertina kakahoica.

A rich Zonule K planktonic and benthonic fauna continues down to 2150 feet. Here the lithological change from a marly clay to a sand is not immediately apparent, due to caving. This uppermost Eocene fauna between about 1900 feet and 2150 feet includes Globigerina linaperta (the index fossil of the zonule), Globigerina ampliapertura, Globorotalia opima, and Chiloguembelina cubensis.

Between about 2300 feet and 2630 feet the sandy sequence contains very few in situ foraminifera. Rare Eocene benthonic species similar to those in the overlying clay occur at 2470-80 feet. Diagnostic in situ planktonics are absent, and hence no definite age can be ascribed to this interval, but it is probably Upper Eocene.

The first appearance of Paleocene faunas is at 2700 feet. A very sparse calcareous fauna contains Globorotalia chapmani which indicates Zonule R, the middle zone of the Upper Paleocene. Faunas in sidewall cores between 2800 feet and 3200 feet are confined almost entirely to the arenaceous genus Haplophragmoides. At 3200 feet a rich calcareous fauna diagnostic of Zonules S and T appears; it is correlated with the Middle - Upper Paleocene Rivernook member. The fauna is dominated by Vaginulina longiforma, Praebulimina quadrata, Kolesnikovella angusta, and Anomalinoides praespissiformis. In the absence of diagnostic planktonics, Zonules S and T cannot be separated. The horizon is at least 80' thick (proved from 3200' to a sidewall core at 3280'). At 3338' a sidewall core contains a paralic Haplophragmoides paupera fauna, which continues, with very rare calcareous specimens, down to about 3456'. There is no evidence of the presence of the Middle Paleocene Zonule U (the fauna usually associated with the Pebble Point formation).

From 3456' to the topmost Cretaceous fauna at 4022', sidewall samples are barren of foraminifera, although heavy Zonule S contamination occurs down into the Cretaceous. The distribution of Upper Cretaceous faunas is controlled by facies. However, within this framework two faunal zones are distinguishable; these correspond to Taylor's zonules XA and XB. (Ref. No.3.) The boundaries of these zonules in Pecten-1A are determined solely by facies changes; the boundary between XA and XB is therefore not a time plane. The nearest approximation to time planes that can be established are the correlations of two marine ingressions in Zonule A with two similar ingressions in Zonule A of Flaxmans-1.

The Upper Cretaceous sequence commences at or slightly above 4022 feet, where an arenaceous fauna of Haplophragmoides sp. A, H. sp. B, and H. sp. C of Taylor, with Haplophragmoides spp. and Dorothia filiformis, is definitive. Other species, including Ammobaculites subcretacea, A. goodlandensis, Bathysiphon sp., Hyperammina elongata, and Textularia spp. are less frequent components of this fauna, which occurs sporadically from 4022 feet to 5300 feet. This interval corresponds to the maximum limits of Zonule XA.

Two shaley horizons containing calcareous faunas occur in this interval. The upper horizon, sampled by a sidewall core at 4022 feet in the Curdies formation, includes Hoeglundina supracretacea, Alabamina australis, Gyrodinoides nitida, Valvulineria lenticula, Stilostomella alexanderi, Lenticula sp. and Nodosaria sp. Although several of the species are long ranging, the total fauna (including arenaceous species) is indicative of XA. These two shale stringers correlate with similar shales of XA age in Flaxmans 1.

At 5300 feet, coincident with the top of the dark shales of the Belfast Mudstone, the first appearance of new arenaceous species was recorded. As this is associated with a wave of calcareous species, it would appear that the distribution of this fauna is facies controlled, and that the upper boundary of the zonule in a time sense is not represented in this well. The fauna of the interval 5300-5800 feet is moderately diverse in species (by the standards of the local Upper Cretaceous) in contrast to the small number of species found in the dominantly paralic interval 4022-5300 feet. Fairly common in this "Belfast Mudstone" interval are the following species: Valvulineria erugata, Stensoina praeexsculpta, Gavelinopsis cenomenica, Cibicides ribbingi, Pallaimorphina heliciformis, and the planktonic Hedbergella trochoidea; while species also present in higher intervals such as Hoeglundina supracretacea, Valvulineria lenticula, Alabamina australis, Gyrodinoides nitida and Ceratobulimina kremnoides increase markedly in abundance below 5300 feet.

Species such as Textularia cf. trilobita, Gavelinopsis cenomenica and Colomia austrotrochus would appear to indicate a Zonule XB age (=Turonian) for this interval. However, true T. trilobita, one of the index fossils for the zone, was found only in the deepest sample (5760 feet). Above this, an evolutionary series of slight variants changes perceptibly towards a different species by the time the form T. cf. trilobita disappears at 5300 feet due to a facies change.

For this reason, and because the palynological data indicated correlation with the base of Taylor's Zonule XA rather than with XB, it is proposed to regard the time interval represented by the deposition of the Belfast Mudstone, as a transition zone between XA and XB. Its age would be approximately Coniacian.

Between 5600 feet and 5760 feet (basal "Belfast Mudstone" - top of Flaxmans formation) the fauna again becomes very sparse with mainly arenaceous species. An isolated interval between 5760 feet and 5800 feet again contains calcareous foraminifera. A true XB fauna, represented by rare Textularia trilobita, with other species as above, was found in this interval. Palynological data confirmed the Turonian age of this sample. Below 5800 feet (the base of the Flaxmans formation) no faunas were found.

4. Biostratigraphic Interpretation

The Upper Cretaceous foraminiferal sequence commences in Pecten -1A at approximately 5800 feet within the interval correlated with the Flaxmans formation. Foraminifera have not been previously reported from this interval. Taylor (Ref.No.3) suggested that Upper Cretaceous marine sedimentation began in a coastal trough between Port Campbell-2 and Flaxmans-1 in Turonian times with the deposition of the basal Belfast Mudstone. Marine sedimentation probably commenced slightly later in Pecten-1A with the deposition of the Flaxmans formation but still within the Turonian.

The Belfast Mudstone in Pecten-1A evidently represents an interval of time between the Turonian (XB Zonule) and the Santonian (XA Zonule). This gap, corresponding approximately to the Coniacian, or part thereof, has not been recognized previously in any well with the possible exception of Sherbrook-1. The interval is designated "XA - XB transition" on a combination of containing persistent, if sparse, planktonic foraminifera, throughout most of the interval. It suggests a restriction of part of the Port Campbell Embayment to open marine conditions during the deposition of the Belfast Mudstone.

In Flaxmans-1 and Port Campbell-2 Belfast Mudstone deposition continued into Zonule XA (Senonian; probably Santonian) times; but in Pecten-1A shale/silt deposition ended earlier, still within XB - XA transition zone. The lower parts of the Paaratte formation in Pecten-1A are time equivalents (and therefore lateral facies variations) of the upper part of the Belfast Mudstone in Port Campbell-1 and 2. This facies variation from "barred basin" (restricted marine) and open marine in the centre of the Port Campbell embayment, to "marginal marine" (=paralic) conditions on the edges of the embayment was described by Taylor (Ref.No.3) and is supported by the results from Pecten-1A.

In summary, Pecten-1A location is interpreted as becoming part of a marine Cretaceous depositional trough in very late Turonian times (with the deposition of the Flaxmans formation). Deposition of the Belfast Mudstone apparently occurred between XA and XB times, that is, during the Coniacian, in a fairly open marine environment. Deposition of the Paaratte must have commenced near the end of Coniacian times, and paralic sedimentation been initiated earlier in Pecten than elsewhere. Deposition of the Paaratte continued on the (now) high Pecten structure in Santonian times, while the deposition of the Belfast Mudstone continued in the deepest part of the trough.

Two marine ingressions represented by shales containing Zonule XA calcareous faunas were recognized in Pecten-1A at 5150 feet interbedded in the Paaratte formation and at 4044 feet interbedded in the Curdies formation. These are correlated with tongues of the Belfast Mudstone.

The top of the Cretaceous foraminiferal sequence in Pecten-1A is at about 4022 feet within marine and paralic equivalents of the Curdies formation. Since the Cretaceous extends at least as high as 3908' (on palynological data; see Appendix No.X) with rare microplankton still present, the top of the foraminiferal sequence may not represent the top of the marine sequence. Sedimentation may have continued without a marked break from Cretaceous to Tertiary times.

Earliest (?)Tertiary deposits are in moderately glauconitic but non-foraminiferal silts and sands. A marginal marine environment is suggested for the interval 4000-3450 feet, but the reasons for the absence of foraminifera over this interval are unknown.

Poor Haplophragmoides faunas between 3450 feet and 3300 feet suggests the development of paralic conditions with limited access to the sea in Middle Paleocene times. Between 3300 feet and 3200 feet a major marine transgression of Upper Paleocene age occurs. It is represented by dark shales correlated with the Rivernook member of the Dilwyn formation. The fauna suggests a slightly shallower facies than for the outcropping Rivernook memberin the Princetown area.

Following this a return to paralic conditions over the interval 3200 - 2750 feet is again evident. Sporadic Haplophragmoides spp., indicative of marsh to lagoonal conditions, are the only faunas found.

At 2700 feet a brief marine ingression is represented by a dark shale with a sparse planktonic and benthonic fauna. It is correlated with the Trochocyathus member of the Dilwyn formation. No diagnostic Paleocene foraminiferal faunas were found above this interval.

In outcrops in the Princetown area five Paleocene marine ingressions (or minor transgressive/regressive cycles) have been recognized; (i.e. Pebble Point shell bed, Rivernook member, Turritella "Bed", Trochocyathus "Bed", and Princetown member ingressions.) In Pecten-1A only two (Rivernook member and Trochocyathus member) have been recognized on faunal evidence. This suggests that the Pecten structure was elevated above the level of all but the most severe Paleocene marine ingressions.

A change from carbonaceous silts to clean sands at 2630 feet marks a basin-wide disconformity covering the Lower and Middle Eocene. In Pecten-1A the sands between 2630 feet and 2150 feet appear to be largely non-marine. Foraminiferal faunas are absent for most of the interval, and the sands are strongly limonitic and have a dolomitic cement in the upper parts. Correlates of these (Mepunga) sands in Flaxmans-1 and in outcrop at Brown's Creek are marine, and contain glauconite and a rich Upper Eocene foraminiferal fauna. Marine sedimentation in Pecten-1A was not initiated until the uppermost zone of the Eocene. Thus Pecten-1A had been above sea level earlier (in the uppermost Paleocene = "Princetown fauna" times) and had been re-covered by the sea much later (in Zonule K times), than onshore areas of the Port Campbell embayment. The time gap in this regional regressive/transgressive cycle is increased by the high structural position of Pecten.

The resumption of marine sedimentation occurs fairly abruptly with the deposition of a marly clay, correlated with the Narrawaturk Marl, in uppermost Eocene (Zonule K) times. The rich and diverse benthonic fauna of core No.1 suggests a moderately shallow environment; the lithology (bedded clayey marl), a fairly quiet depositional site disturbed only occasionally by turbulence.

At approximately 1880' a paleontological hiatus (the absence of Lower Oligocene Zonule J) was detected. This minor hiatus is the regressive/initial transgressive phase separating Nirranda group sediments from the Heytesbury group, and is developed in a number of wells in the Port Campbell embayment. This minor hiatus again reflects the high position of the Pecten structure.

Open marine, moderately deep water marl deposition resumed in Middle Oligocene (Zonule I) times. It gradually altered to limestone formation and continued without apparent break until Middle or Upper Miocene times. The Oligocene - Miocene sequence in the well was not examined in detail.

5. Note on the seafloor cores

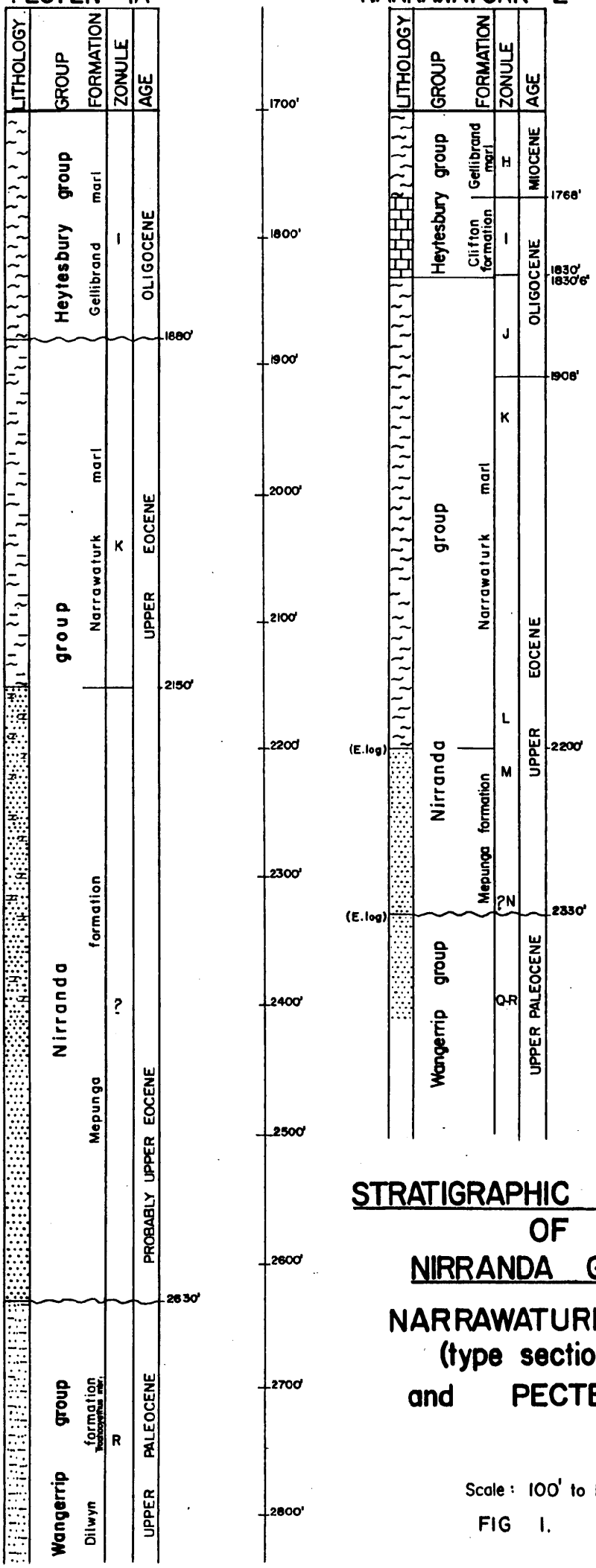
Cores at the site penetrated up to 30' of two types of fine-grained moderately deep water limestones. No age could be confidently assigned to them, other than to say that they are probably Upper Miocene and Pliocene in age. The planktonic faunas of this stratigraphic interval are as yet little known in Victoria. Overlying these limestones was a very thin crust (1' thick) of Pleistocene beach or dune limestone, confirming a fall in Pleistocene sea level of over 200'.

REFERENCES

Ref. No. 1 Taylor, D.J. 1966: Geological Survey of Victoria, unpublished report. (to be published).

Ref. No. 2 Taylor, D.J. 1967: Geological Survey of Victoria, unpublished report. (to be published).

Ref. No. 3 Taylor, D.J. 1964: Foraminifera and the Stratigraphy of the Western Victorian Cretaceous Sediments: Proceedings of the Royal Society of Victoria, Vol.77, part 2, p.535-602.



STRATIGRAPHIC POSITION OF NIRRANDA GROUP

NARRAWATURK - 2 . (type section) and PECTEN – IA

Scale : 100' to 1"

FIG 1.

Drawing No 2050

BIOSTRATIGRAPHIC ZONULES (after Taylor 1964)

DEPTH

4000 4100 4200 4300 4400 4500

FAUNA

Sample No foraminifera

ARENACEOUS
Arenaceous genus and sp indet
Haplophragmoides sp A
Haplophragmoides sp B
Haplophragmoides sp C
Haplophragmoides spp
Haplophragmoides sp 7
Dorothia conulus
Dorothia sp
Dorothia filiformis
Ammobaculites subcretacea
Ammobaculites goodlandensis
Ammobaculites cf fragmentaria
Hyperammina elongata
Bathysiphon sp
Ammobaculites sp
Textularia semicomplanata
Textularia sp
Textularia sp 2
Marsonella oxycona
Textularia anceps
Textularia trilobita
Reophax sp
Miliammina sp
Trochammina sp

CALCAREOUS
Stilostomella alexanderi
Lenticulina sp
Nodosari sp
Hoeglundina supracretacea
Valvulineria lenticula
Alabamina australis
Gyroidinoides nitida
Bulimina sp
Dentalina sp
Ceratobulimina kremnoides
Lenticulina navarroensis
Gyroidinoides sp 1
Lenticulina curvisepta
Anomalinoides sp 2 (cf. nobilis)
Marginulina sp
Marginulinopsis sp
Marginulina inaequalis
Alabamina sp
Allomorphina pyriformis
Gyrodinoides sp
Frondicularia aff. micronata
Vulvulineria erugata
Pullaimorphina heliciformis
Cibicides ribbingi
Cibicides excavatus
Nodosaria alternistriata
Globulina sp
Ceratobulimina cretacea
Vulvulineria spp
Colomia austrochus
Globulina lacrima
Hedbergella trochoidea
Hoeglundina sp
Gavelinopsis cenomenica
Stensoina praeexsculpta
Quinqueloculina sp
Bolivina sp 3
Pullenia sp
Lagena sp
Guembelina sp
Praebulimina ovulum
Gyrodinoides cruachin
Massilina sp
Nodosaria obscura
Hanzawaia sp 1
Spiroculina sp
Sigmoilina sp
Cornuspira subprimitiva
Marginulina jarvisi

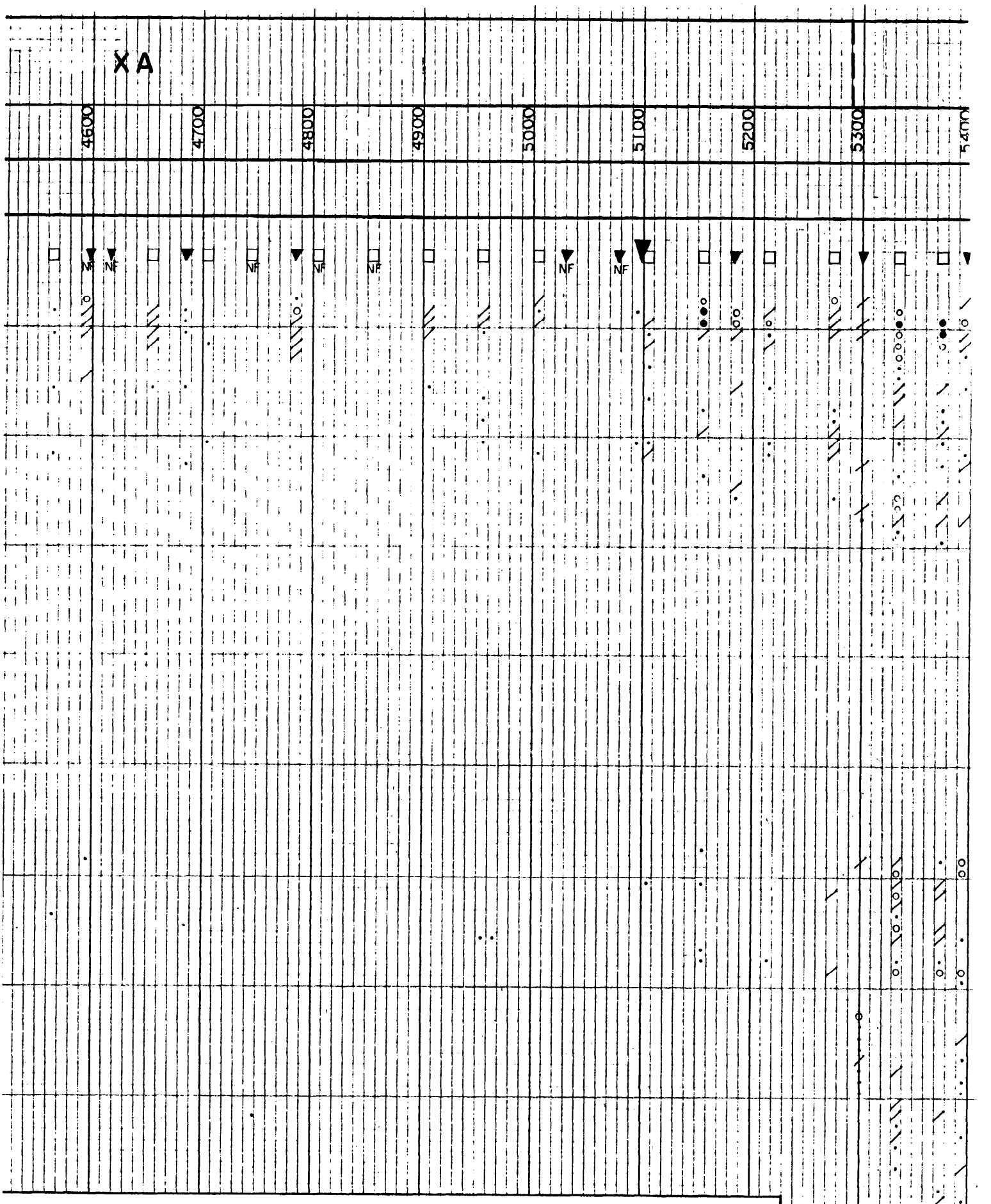
NR NF GI NF GI NF

LEGEND

Samples —
- Core
- Sidewall core
- Cutting sample

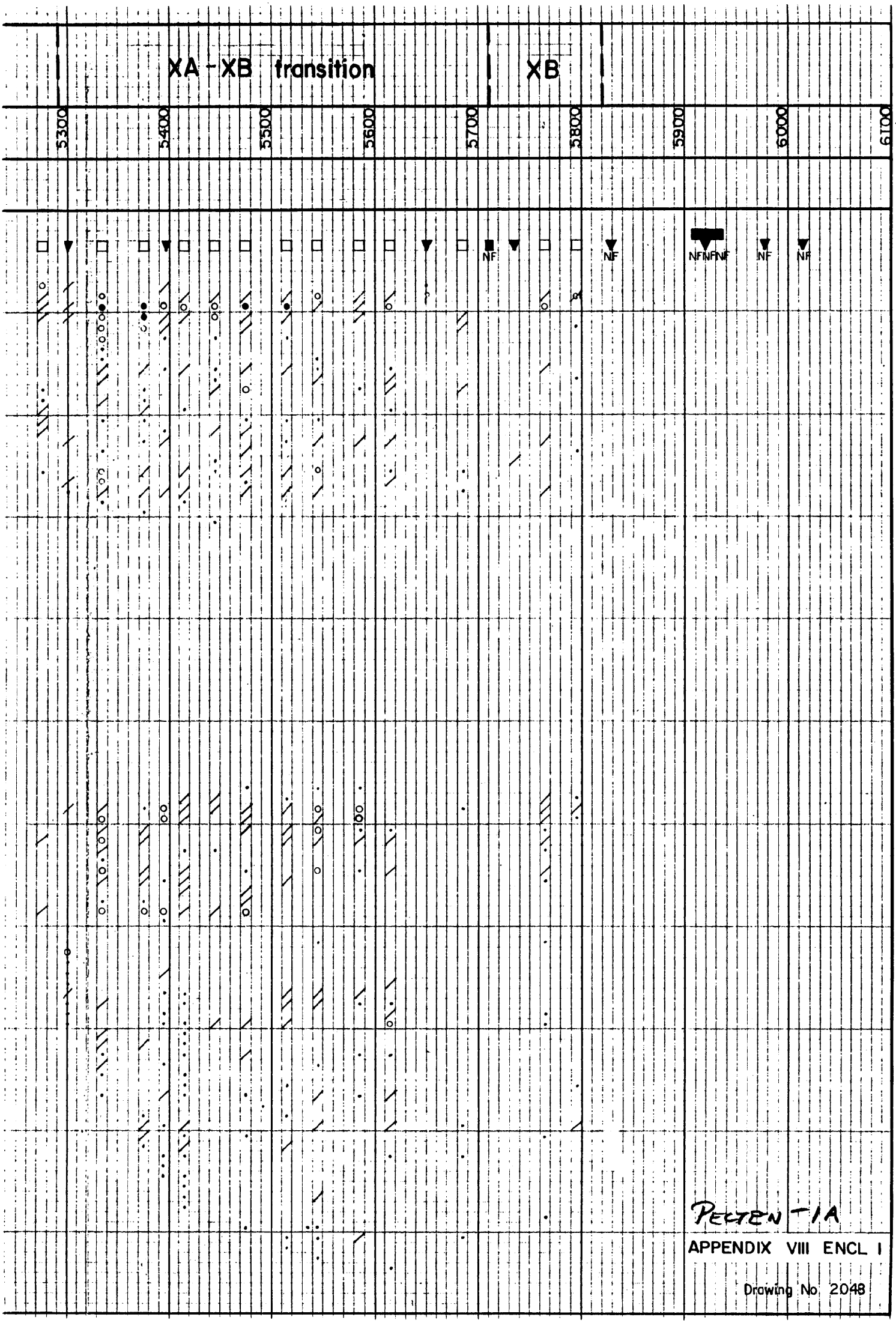
Frequency —
- 1 Specimen
- 2-5 Specimens
- 6-20 Specimens
- 21-100 Specimens

DISTR



ISTRIBUTION OF UPPER CRETACEOUS FORAMINIFERA

PECTEN IA



PECTEN - 1A

APPENDIX VIII ENCL I

Drawing No 2048