FILE

INTERNAL DOCUMENT 153.

I.O.S.

STRATIGRAPHY AND PALAEOENVIRONMENTAL ANALYSES OF CORES TAKEN DURING DISCOVERY CRUISE 118, N.E. ATLANTIC

P.P.E. Weaver

Internal Document No. 153

February 1982

NATURAL ENVIRONMENT RESEARCH COUNCIL
INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey GU8 5UB
(042-879-4141)

(Director: Dr. A. S. Laughton, FRS)

Bidston Observatory,
Birkenhead,
Merseyside L43 7RA
(051-653-8633)
(Assistant Director: Dr. D. E. Cartwright)

Crossway,
Taunton,
Somerset TA1 2DW
(0823-86211)
(Assistant Director: M. J. Tucker)

STRATIGRAPHY AND PALAEOENVIRONMENTAL ANALYSES OF CORES TAKEN DURING DISCOVERY CRUISE 118, N.E. ATLANTIC

P.P.E. Weaver

Internal Document No. 153

February 1982

Work carried out under contract to the Department of the Environment

Institute of Oceanographic Sciences
Brook Road
Wormley
GODALMING
Surrey GU8 5UB

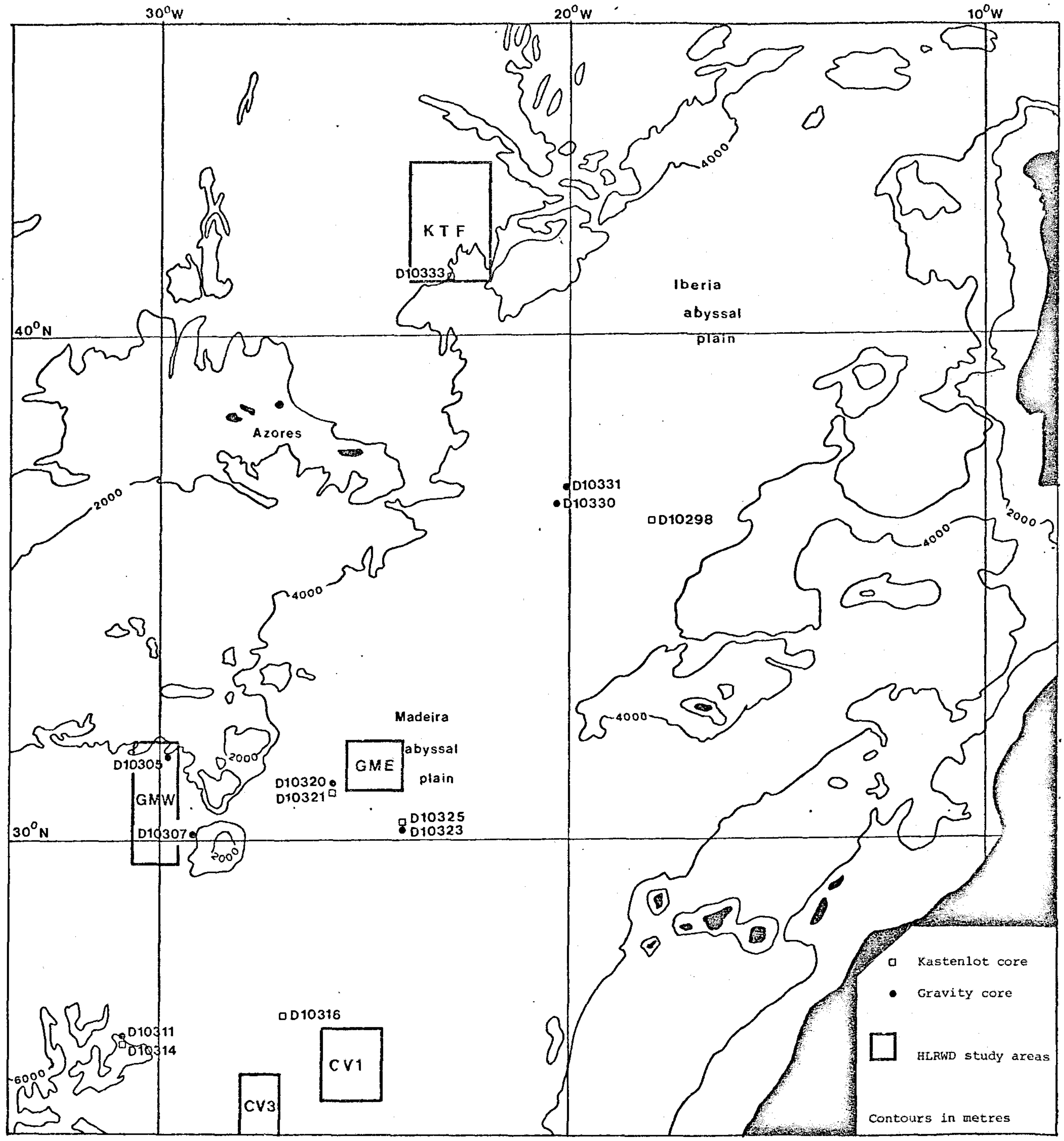
INTRODUCTION

Discovery Cruise 118 visited several sites in the eastern North Atlantic during early 1981 (Text-figure 1). The objective of the cruise was to conduct geophysical experiments and to take core and dredge samples in various deep-sea environments as part of the feasibility studies into ocean disposal of High Level Radioactive Waste (Francis, 1981). Cores were taken in environments ranging from brown clay sediments below 6000 m to pure carbonate oozes from less than 3000 m. Some of the coring sites were located in or adjacent to HLRW study areas with a view to establishing geological histories of sediment input and erosion. Cores were taken over a wide geographic area from as far south as 25°39'N to as far north as 41°07'N. In total 14 successful cores were taken (Table 1) using two different corers. Most were taken using a modified Barry gravity corer, which was used without the trigger mechanism, but with a Calvert corer head and a 12 ft x 3 inch barrel. The rest of the cores were taken with the Kastenlot box corer using a 2 m x 15 cm square barrel.

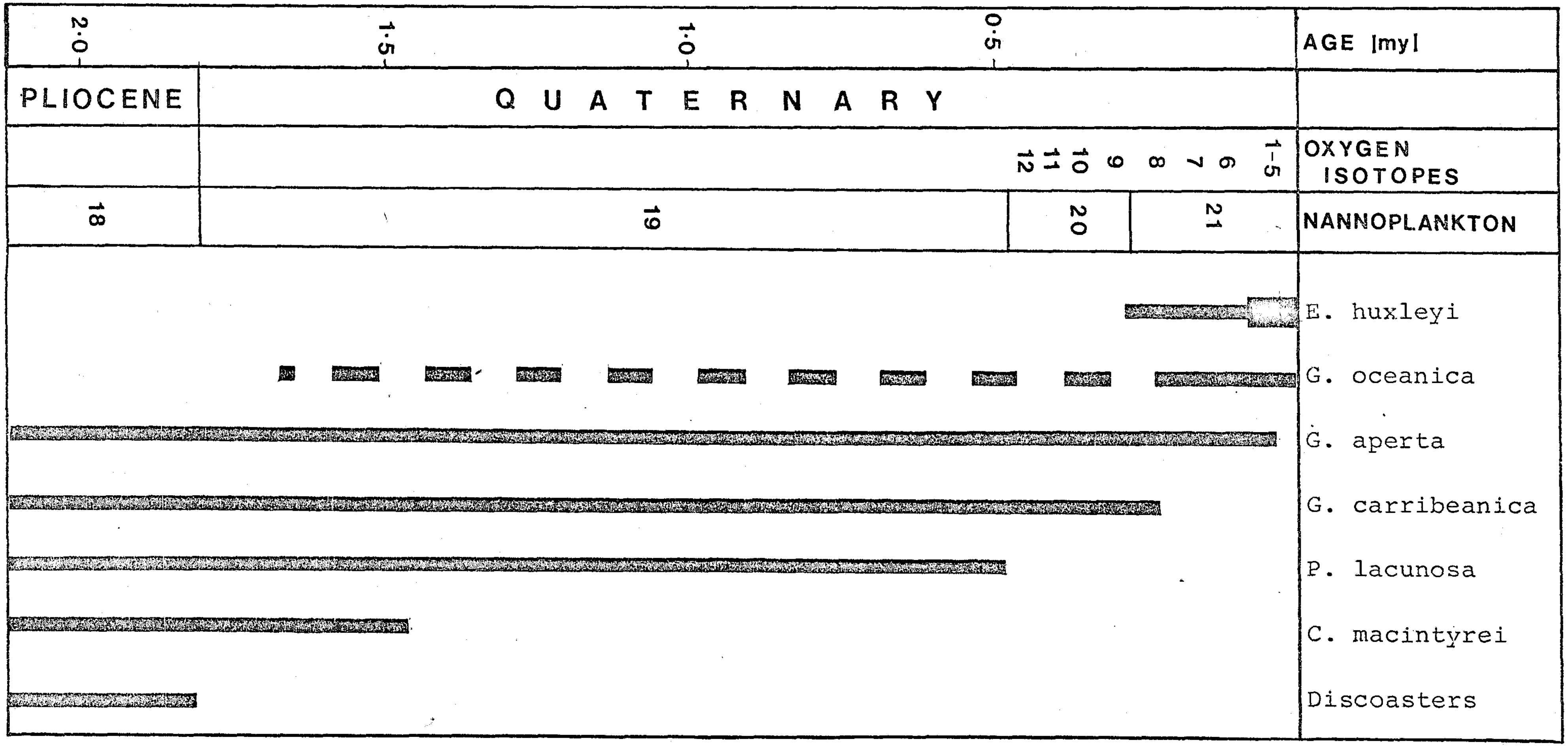
STRATIGRAPHIC TECHNIQUES

The techniques used for stratigraphic analysis of these cores have involved the use of planktonic foraminifera and nannoplankton. Planktonic foraminifera proved very useful in the King's Trough Flank HLRWD study area, for correlation over relatively short distances (Weaver, 1980). However, in the present cores their value has been limited and nannoplankton have proved more useful. Facilities for the study of nannoplankton and expertise in this field have therefore been gained during 1981. The chief advantage of nannofossils is their ability to define stratigraphic zones accurately, on evolutionary appearances and extinctions. Pleistocene stratigraphy based on planktonic foraminifera is achieved by plotting relative abundances of species and interpreting the results in terms of glacial and non-glacial cycles. Whilst this method is very useful over short distances in areas of relatively stable deposition, it cannot be used for the varied environments sampled on Cruise D 118 since different species are found in the more southerly areas and the foraminifera are easily destroyed by dissolution.

Text-figure 2 shows the stratigraphic relationships of the most useful nannoplankton species. Using these species the Quaternary can be divided into 3 main zones (NN19-21). Full descriptions for the recognition of these zones



Text fig. 1. Bathymetry of part of the north-eastern Atlantic showing location of coring sites and current *HLRWD* study areas.



Text fig. 2. Nannoplankton stratigraphy of the Quaternary.

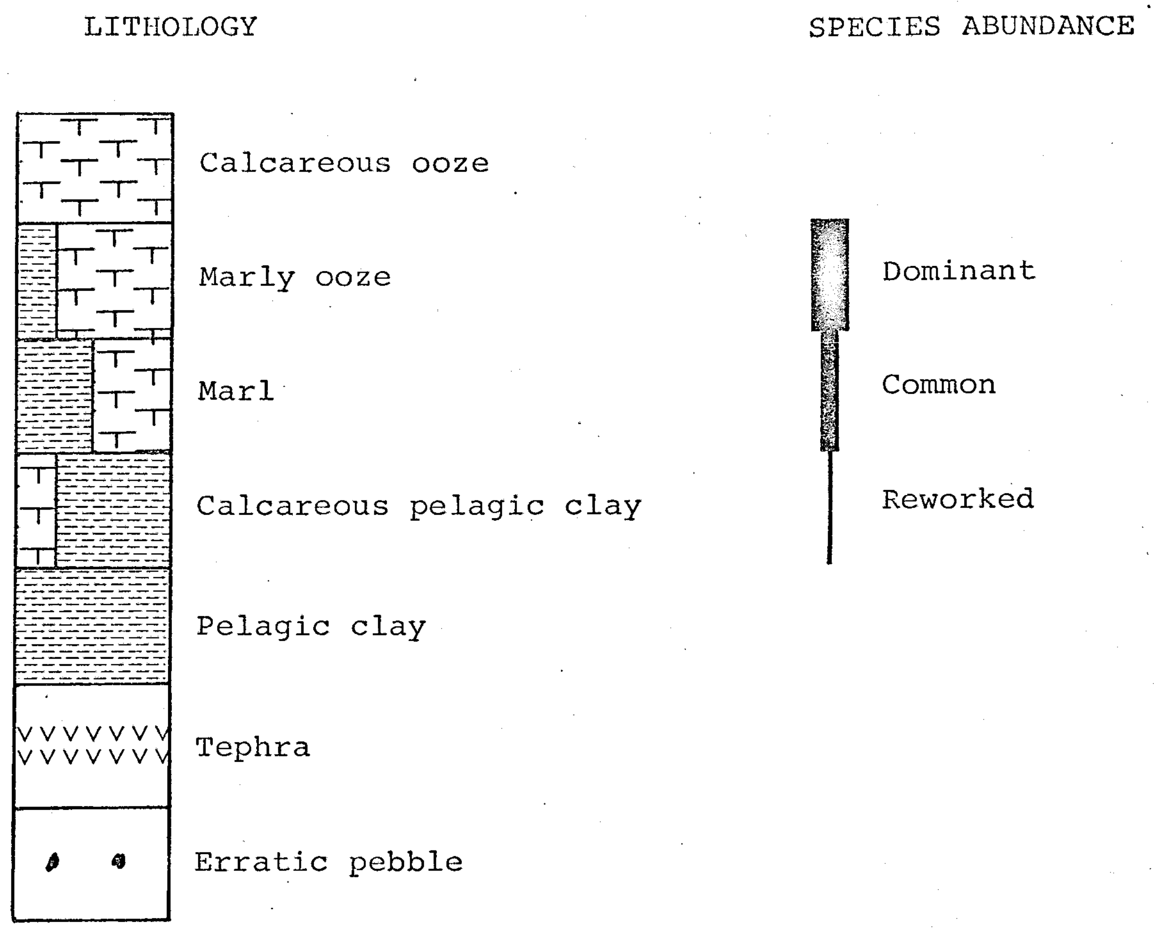
can be found in Martini (1971) and Hay (1977). The zone of E. huxleyi, (NN21), can be further subdivided since this species reaches an acme at the very top of the Quaternary where it completely dominates the fauna (Gartner, 1977; figure 3). Further subdivision of the Quaternary can be obtained by examination of various species of Gephyrocapsa. Although 10 species have been recognised with the electron microscope (Samtleben, 1980) only 4 species can be distinguished with the light microscope (Pujos Lamy, 1976). The distribution of these species is shown in Text-figure 2. Essentially G. oceanica dominates the upper part of the Quaternary whilst G. carribeanica dominates the lower part. G. aperta also appears in large numbers at irregular intervals. The techniques used in nannoplankton studies involve the use of a transmitted light microscope capable of magnifications up to x1000. Slides incorporating a thin smear of disaggregated sediment are examined under oil immersion. This technique is, however, not powerful enough to readily identify E. huxleyi which is only about 2μ across and so the samples also need to be examined under the Scanning Electron Microscope.

As with the King's Trough cores, lithological descriptions, calcium carbonate and grain size measurements, together with X-ray diffraction analyses and X-radiographs of the cores have all been taken. Oxygen isotope analyses were carried out under subcontract by N.J. Shackleton at Cambridge and these results are incorporated in this report.

CORE STRATIGRAPHIES

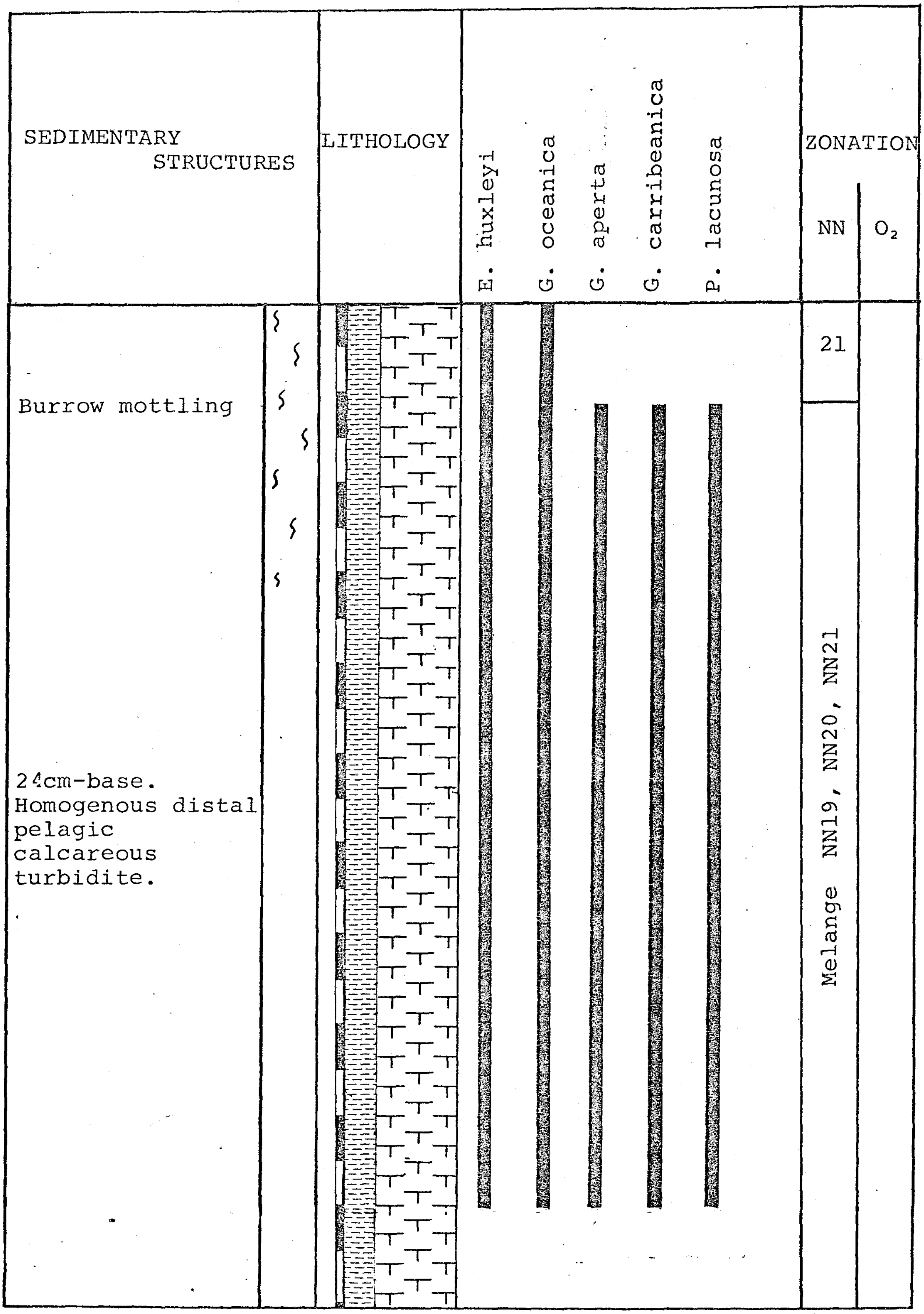
D10298 (Text-figure 4)

This core consists of 24 cm of pale marly ooze which shows numerous burrow mottles overlying 1.96m of soft, pale, fine-grained marly ooze. This lower unit contains no sand size fraction (> 63μ) and, below the upper few centimetres, has no burrow mottles. It is interpreted as representing the distal portion of a pelagic turbidite. Sediment from the upper unit shows signs of strong dissolution with virtually no complete planktonic foraminiferal tests. Coccoliths from this layer are also corroded, and the common occurrence of C. leptoporus (a species resistant to dissolution) suggests a decrease of the less resistant species. E. huxleyi is common in this unit whilst Gephyrocapsas are less common and consist primarily of G. oceanica. This suggests an age in the upper part of zone NN21. The 1.96m of fine-grained turbidite material contains no planktonic foraminifera, but its coccolith



Scale divisions on Text figs. 4-13 = 10 cm

Text fig. 3 Key to Text figs 4-13.



Text - Fig. 4. Lithology and stratigraphy of D10298.

flora consists of dominantly Gephyrocapsa spp. (G. carribeanica and G. aperta) with numerous E. huxleyi and also P. lacunosa present in every sample. This association indicates a mixing of zones NN19, NN20 and NN21 material, but the presence of E. huxleyi suggests that the turbidite flow occurred during zone NN21.

D10305 (Text-figure 5)

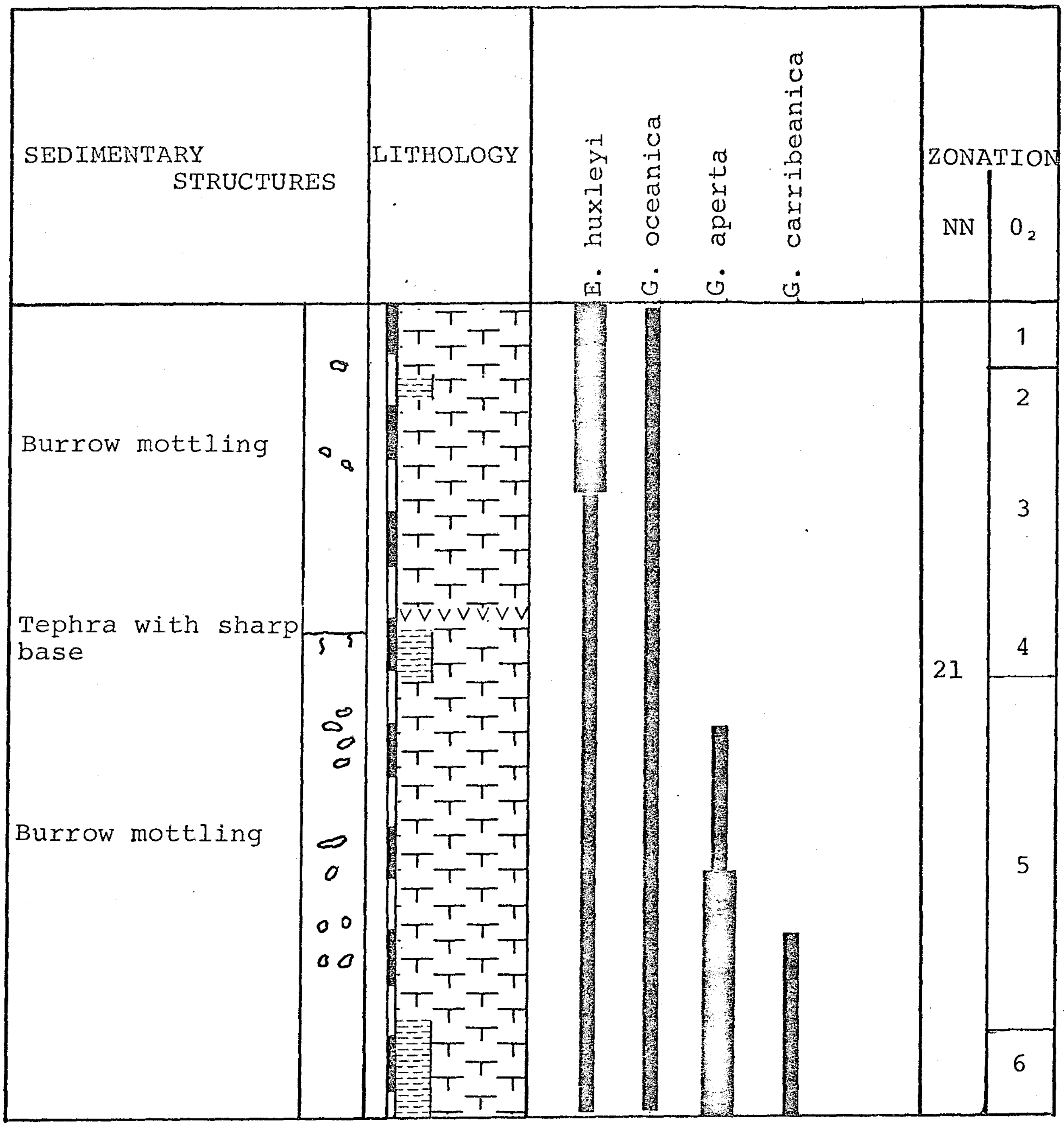
This core was taken on a gentle slope just west of Cruiser Seamount. The site lies at the northern end of the Great Meteor West study area. It consists of 1.57 m of alternating oozes and marly oozes with a tephra layer at 57-62 cm. It was taken well above the CCD (at 4139 m) and contains a well preserved fauna. The coccoliths show that the upper 57 cm lies at the top of zone NN21 with very abundant E. huxleyi. Below this E. huxleyi is still present, becoming rarer at the base of the core, but the flora is dominated by Gephyrocapsa spp. G. oceanica is dominant down to 100 cm and below this G. aperta becomes the dominant species.

The planktonic foraminifera comprise a transitional to subtropical fauna dominated by G. inflata, G. ruber and G. truncatulinoides. Changes in the faunal composition due to glacial cycles are difficult to recognise, but G. sacculifer shows two abundance peaks - at the top of the core and at 120-130 cm. The oxygen isotopes suggest continuous deposition to stage 6, with stage 5e at 120-130 cm which correlates with the peak of G. sacculifer.

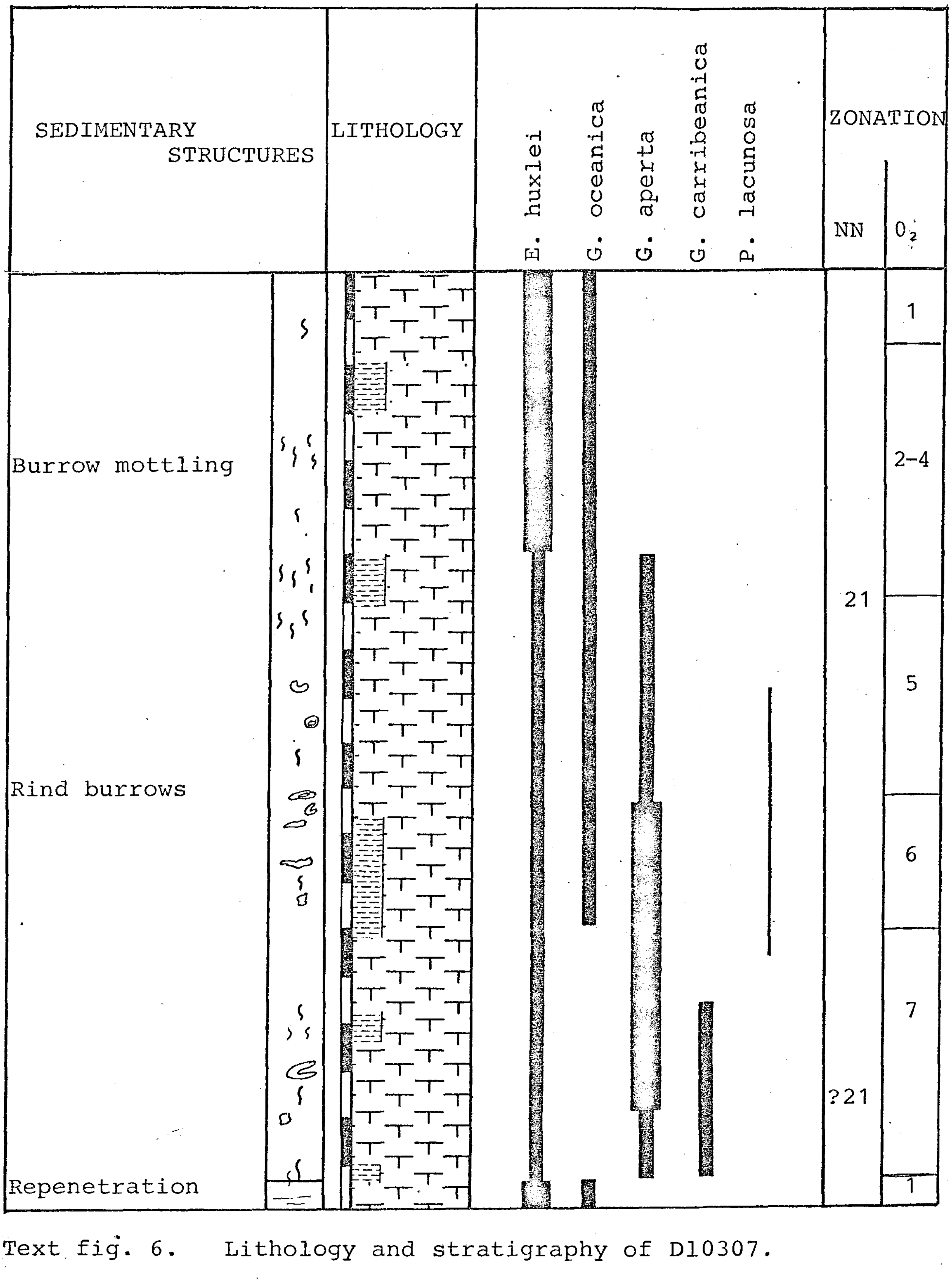
D10307 (Text-figure 6)

This core was taken on the western flank of Great Meteor seamount in 4001 m of water. It consists of alternating oozes and marly oozes with burrow mottling and several rind burrows. E. huxleyi can be found throughout the core and is dominant from 0-60 cm. This indicates zone NN21 throughout, although from 156-190 cm G. carribeanica can be found in association with E. huxleyi. These two species are normally regarded as having a very short overlapping range (Text-figure 2) and so the very common occurrence of G. carribeanica at this level may indicate some reworking of zone NN20 material. Oxygen isotope data on this core is inconclusive - Shackleton suggests a possible stage 5-6 boundary at 114 cm and an indistinct stage 7 centred at 155 cm.

The lowest 8-10 cm of this core gave surprising results. The coccolith flora show a pronounced dominance of E. huxleyi and the oxygen isotopes give a value almost the same as the core top sample. On examination of the X-radiograph a pronounced hiatus can be seen across the core 8-10 cm from the



Text fig. 5. Lithology and stratigraphy of D10305.



Text fig. 6. Lithology and stratigraphy of D10307.

base. After taking this core it seems that the corer has repenetrated the surface sediment and taken a further 8-10 cm of Recent material.

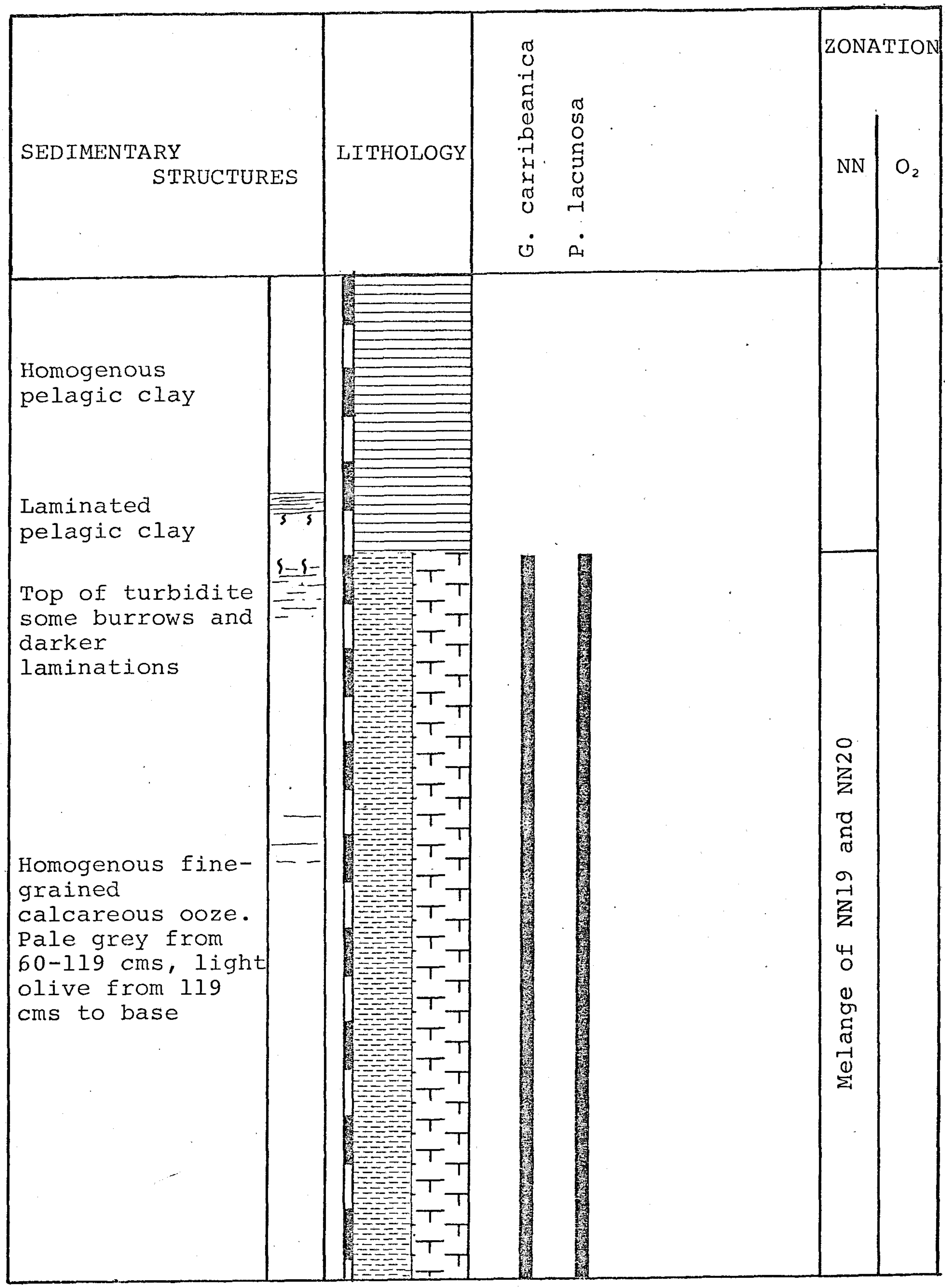
D10311/D10314 (Text-figure 7)

This site was chosen in water over 6000 m deep to sample pelagic clay deposits. Two cores were taken on the same site - D10311 with a gravity corer and D10314 with a Kastenlot corer. As expected, the cores showed similar lithologies with some foreshortening of the softer layers in the gravity core. The stratigraphic investigations were all carried out on D10311 since D10314 was used exclusively for geotechnical purposes.

The upper 60 cm of D10311 (84 cm in D10314) consists of brown pelagic clay with no measurable calcium carbonate. X-ray mineralogy on this unit showed traces of dolomite with a detrital rich layer from 43-47 cm. Due to the absence of carbonate no foraminifera or nannoplankton were recovered from this unit.

From 60-217 cm in D10311 (84-240 cm in D10314) the sediment consists of fine-grained calcareous ooze. This is pale grey from 60-127 cm (84-153 cm in D10314) and pale olive below. This colour change may indicate that the olive sediments are reduced, since no other differences have been detected between the two colour types. The whole of this unit represents the distal part of a turbidite - it contains no sand size fraction. Since it contains about 40% carbonate it presumably originated at, or above, the CCD (carbonate compensation depth) and was transported into this area. It contains a reasonably well preserved coccolith flora which suggests an upper zone NN19 or zone 20 age since it contains P. lacunosa, abundant G. carribeanica, but no C. macintyrei.

The date of the turbidite flow must be considerably younger than 1.46 million years (extinction point of C. macintyrei) since the sediment had first to accumulate before redeposition, but older than 270,000 years, since the sediment contains no E. huxleyi. While the turbidite may represent a mixture of upper zone NN19 and NN20 material, it does not incorporate any material from earlier or later intervals. These dates, therefore, give an estimate of maximum and minimum age for the base of the pelagic clay which, using the less foreshortened depth of 84 cm from D10314, gives average sedimentation rates between 0.31 and 0.057 cm/1000 years. Measurements of excess Th^{230} in D10311 (Thompson, pers. comm.) reveal a date of 300,000 years for the base of the pelagic clay, which shows that the turbidity flow occurred towards the end



Text fig. 7. Lithology and stratigraphy of D10311.

of zone NN20 and that the average sedimentation rate for the pelagic clay was 0.2 cm/1000 years.

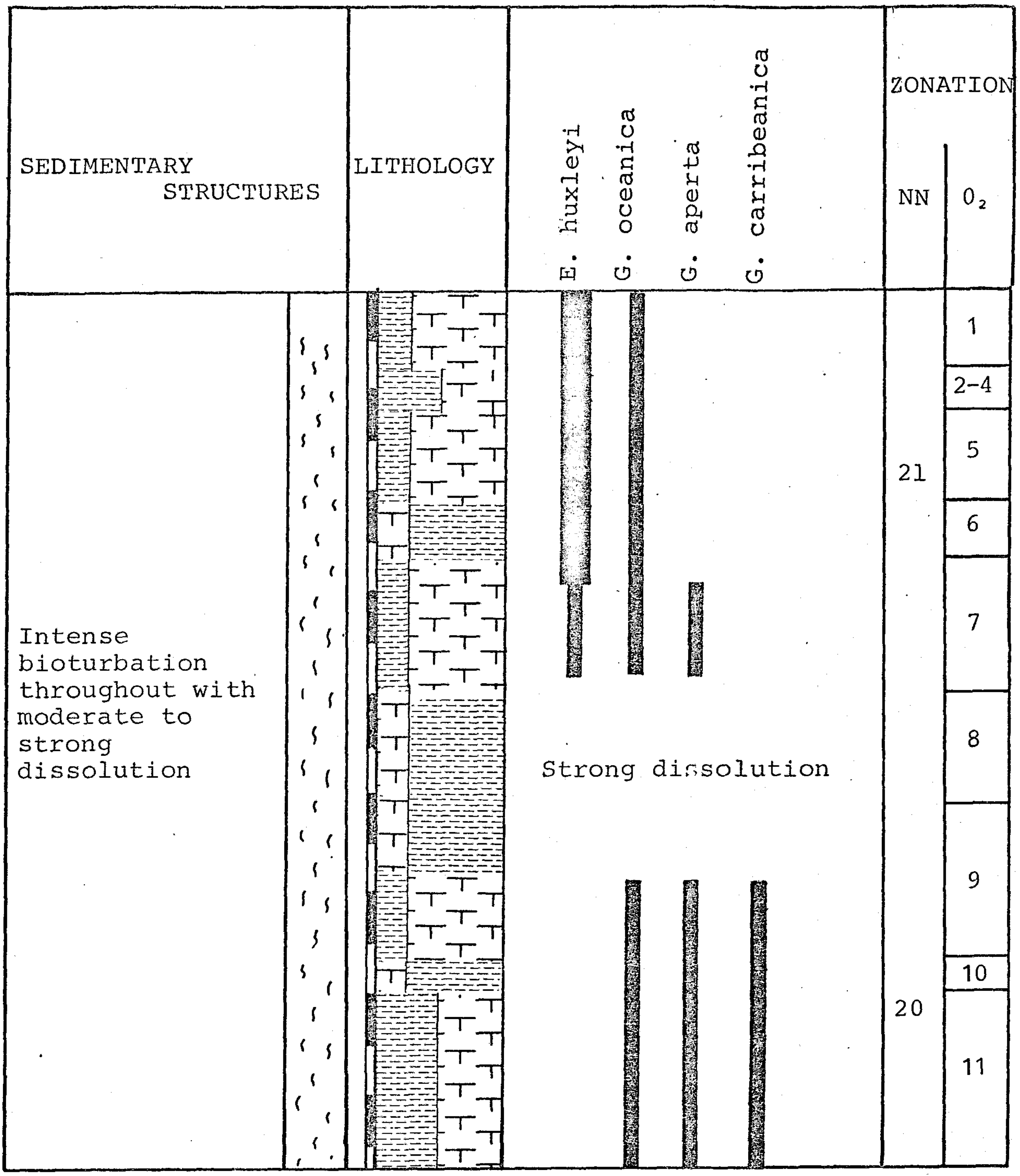
The origin of the turbidite poses an interesting problem. The core was taken in a deep area, almost surrounded by hills, and it was initially thought that the turbidite represented a local event. Its fairly high carbonate content suggests that the material was originally deposited above the CCD, (probably above 5000 m water depth). This is also suggested by the coccoliths which show relatively few signs of dissolution. However, the hills which surround this area all lie well below 5000 m and there are no large areas even above 5400 m which could supply carbonate rich material for such a thick turbidite. A local source therefore seems unlikely. A core (D9128) taken 85 miles SSE of D10311 on a previous cruise revealed a similar succession of 50 cm of brown clay overlying a calcareous turbidite. This core was sited at the edge of the abyssal plain and the turbidite here was thought to have originated somewhere on the abyssal plain. It is possible that the turbidites in D10311 and D9128 represent the same flow, although this would necessitate the flow progressing between a series of hills and possibly over a sill (I.O.S. unpublished bathymetry data). To define the exact origin of this turbidite it would be necessary to take further cores in the area.

D10316 (Text-figure 8)

This core was taken in 4966 m water depth. It shows the effects of varying rates of dissolution since it consists of alternating units of calcerous pelagic clay and marly calcareous oozes. The top 77 cm belongs to zone NN21 with *E. huxleyi* being dominant down to about 50 cm. Shackleton (pers. comm.), however, suggests that there is strong mixing at the top with some glacial material being brought up. He also suggests that the interval 40-65 cm does not produce the expected oxygen isotope results for stage 3, 4 material. This may be due to the strong bioturbation evident in this core combined with a relatively slow deposition rate. Below 77 cm to 117 cm there is relatively strong dissolution. The coccoliths suggest zone NN20 but this may be due to dissolution of *E. huxleyi*. From 117 cm to the base the coccoliths definitely indicate zone NN20.

D10320/D10321 (Text-figure 9)

These two cores were taken at the same location, in an area of hills just west of the Great Meteor East study area about 150n. miles east of the Cruiser and Great Meteor seamounts. The lithologies in both cores were identical and



Text fig. 8. Lithology and stratigraphy of D10316. Oxygen isotope zones are used to represent glacials and interglacials and are not based on direct measurements.

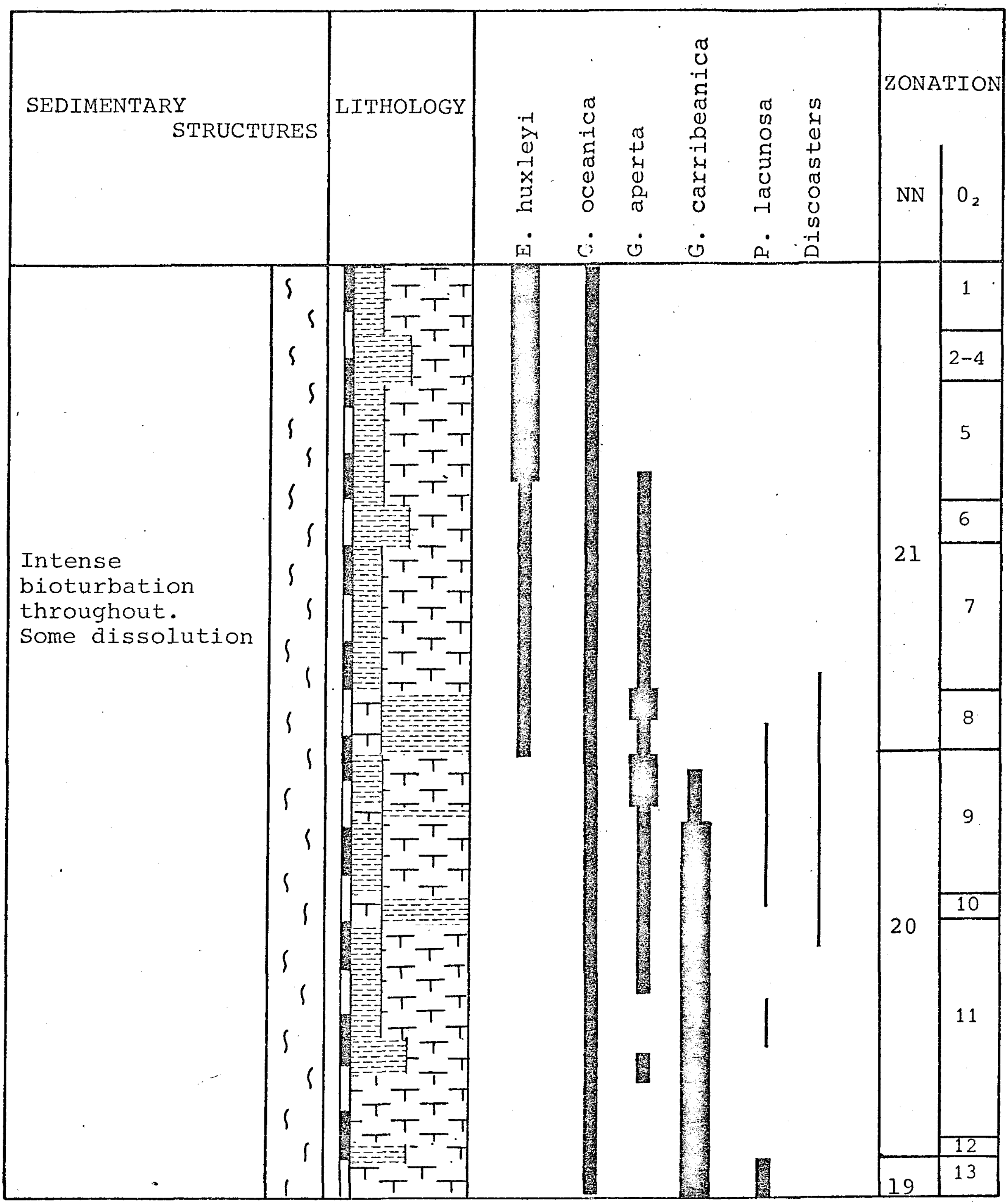
all the information was collected from D10320 which penetrated to 2 m, as opposed to 1.65 m for D10321. The cores consist of alternating marls and marly oozes with $CaCO_3$ contents varying between 44% and 93%. They are intensely bioturbated throughout. In D10320, the upper 105 cm belongs to zone NN21 with E. huxleyi dominant down to 43 cm. From 105-188 cm zone NN20 is represented and, below this, zone NN19. Occasional reworked specimens of P. lacunosa and Discoaster spp. can be found throughout this core but they are particularly common between 83-143 cm. Shackleton (pers. comm.) regarded this core as having a poor resolution oxygen isotope record; as with D10316 the slow deposition rate combined with strong bioturbation has made oxygen isotope stratigraphy difficult.

The two reliable dates given by the nannoplankton zones - 270,000 years at 105 cm and 460,000 years at 188 cm provide a basis for subdivision of the core into glacial and interglacial intervals. Glacial intervals are known to correlate with more clay-rich horizons due to the increased activity of Antarctic Bottom Water (AABW), which causes increased dissolution. The three pelagic clay intervals within the E. huxleyi zone therefore represent glacial intervals correlating with oxygen isotope stages 8, 6 and 2-4. The lithology of zone NN20 can be similarly subdivided (Text-figure 9) although there is an anomalous marl at 166-174 cm.

Using this subdivision into glacial and interglacial intervals and the ages of the boundaries between intervals given in Shackleton and Opdyke (1976), the following sedimentation rates can be determined:

Stage	Depth (cm)	Duration ($x10^3$ years)	Sedimentation Rate (cm/1000 years)
1	1-14	13	1.08
2-4	14-25	62	0.18
5	25-50	53	0.47
6	50-60	67	0.15
7	60-92	56	0.57
8	92-105	46	0.3
9	106-137	50	0.62
10	137-141	20	0.2
11	141-188	73	0.64

Average glacial sedimentation rate: 0.2 cm/1000 years.
Average interglacial sedimentation rate: 0.61 cm/1000 years.



Text fig. 9. Lithology and stratigraphy of D10320. Oxygen isotope zones are used to represent glacials and interglacials and are not based on direct measurements.

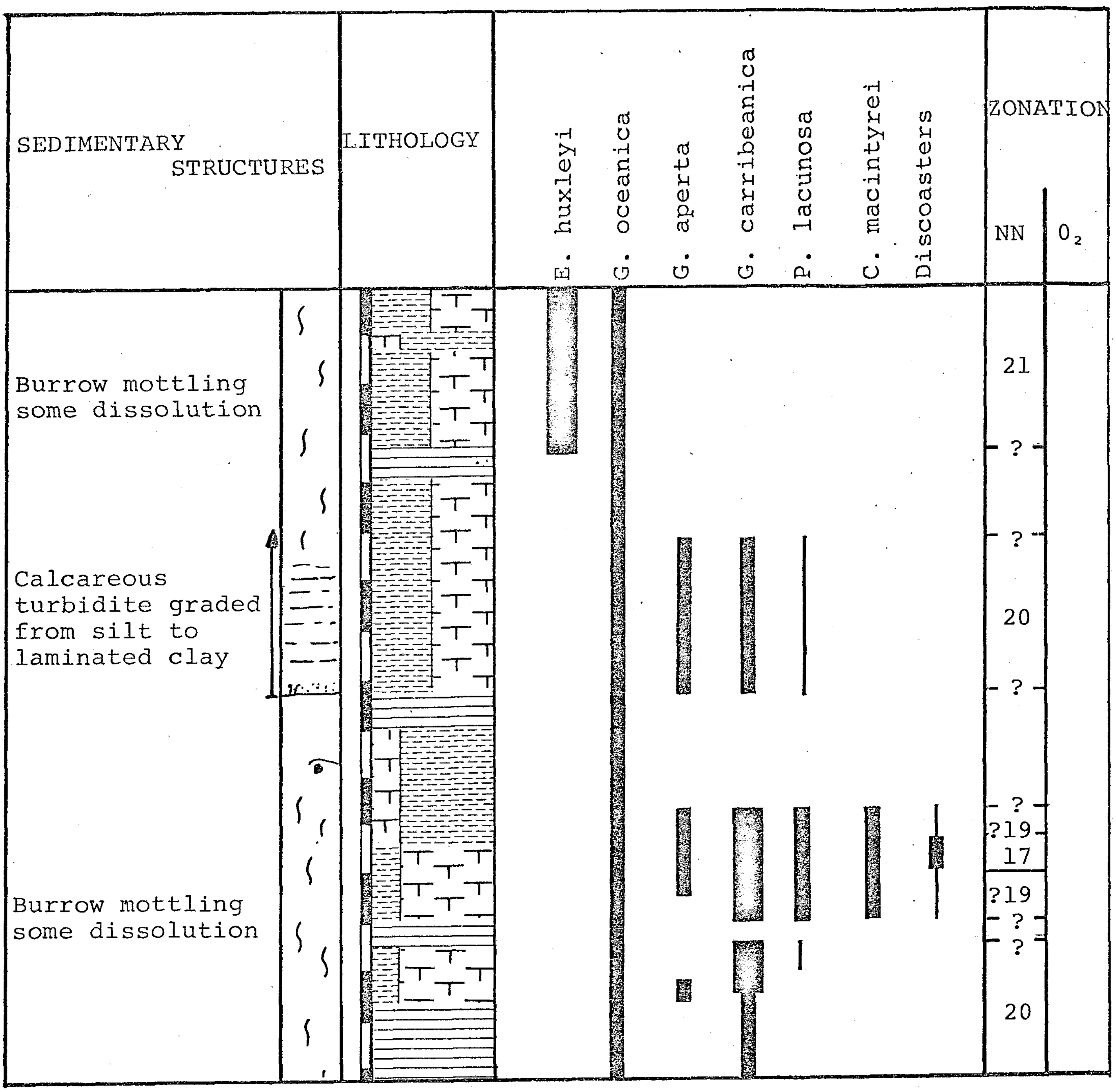
D10323 (Text-figure 10)

This core was taken about 200 n. miles east of Great Meteor seamount near the western boundary of the Madeira abyssal plain. This area lies below the CCD at 5400 m water depth and consequently the sediment has suffered strong dissolution giving rise to pelagic clay intervals where the calcium carbonate content may fall as low as 5%. These are interspersed with more marly intervals representing periods of less intense dissolution. As a consequence of the dissolution the planktonic foraminifera have been largely destroyed and cannot be used. The nannoplankton have also suffered dissolution but definitely show zone NN21 down to at least 32 cm.

The stratigraphy below 54 cm is rather complicated. There is a thin turbidite from 54-81 cm which has a sharp base, a thin basal layer of detrital silt, and then grades up into a fine-grained, laminated unit containing micronodules. The silt contains abundant quartz with dolomite and amphibole grains and presumably represents transport from the continental shelf. The turbidite contains zone NN20 microflora with rare P. lacunosa - possibly reworked. Below the turbidite, down to 104 cm, zone NN20 is again present although this interval does contain occasional contaminants of P. lacunosa and Discoasters. A sample from 115 cm contained numerous Discoasters together with rare P. lacunosa and C. macintyrei and is assumed to be of zone NN17 age. Samples from above and below 115 cm contain lesser amounts of Discoasters and rare P. lacunosa possibly due to bioturbation of the NN17 layer. Below 135 cm, zone NN20 is again represented to the base of the core.

D10325

This Kastenlot core was taken on the same site as D10323 and contains the same sequence of lithological units down to the top of the turbidite. The top of the turbidite is represented in D10325 by 0-8 cm of sediment which shows disturbed laminations. Below this there is no correlation of lithological units between the two cores. It was, however, noticed that the lithological units below the turbidite strongly resembled those above the turbidite in colour, degree of bioturbation and thickness. It was, therefore, suspected that the corer may have repenetrated the sediment. This was confirmed by the coccoliths which showed zone NN21 extending from 0-33 cm and from 60-94 cm, and zone NN20 extending from 33-60 cm and 94 cm to the base of the core. There was no obvious reduction of thickness in lithological units in the repeated section and this may indicate that the Kastenlot corer does not progressively foreshorten the sedimentary sequence. Such a phenomenon has been recorded with the Barry corer (Weaver and Schultheiss in prep.)



Text fig. 10. Lithology and stratigraphy of D10323.

D10330 (Text-figure 11)

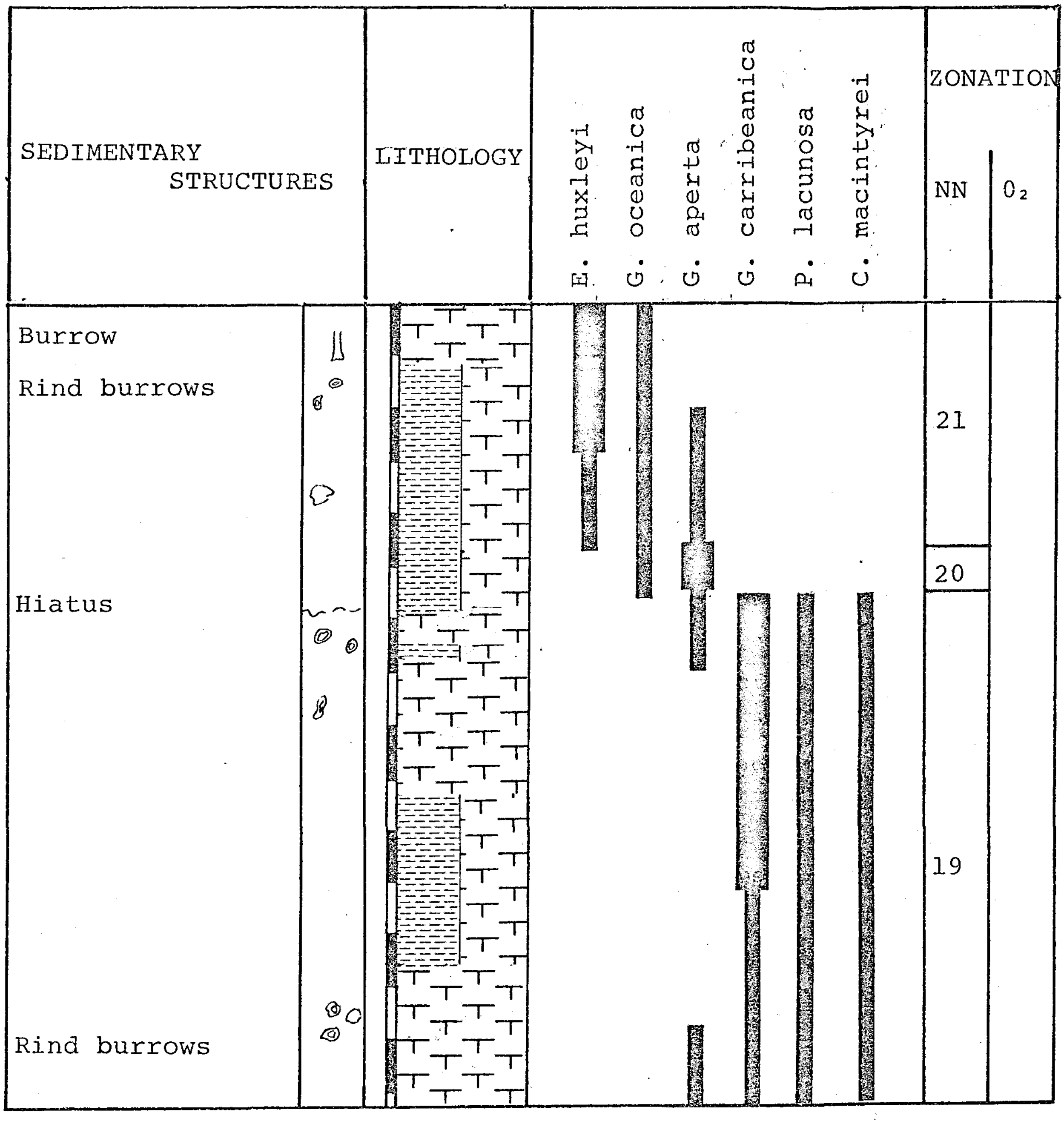
This core was taken on the lower slope on the southern flank of the Azores fracture zone. It consists of 1.52 m of marly oozes and chalks, the lower 95 cm being somewhat indurated and separated from the upper 57 cm of softer oozes by a reasonably sharp boundary. The coccoliths show that the upper 42 cm belongs to zone NN21 with E. huxleyi present throughout and dominant from 0.30 cm. From 45-57 cm, the coccoliths indicate zone NN20 with dominant G. aperta. Below 57 cm to the base of the core zone NN19 is indicated by the common occurrence of P. lacunosa. Relatively small specimens of C. macintyrei (about 10μ across) are also present throughout this unit and suggest the lower part of zone NN19. (C. macintyrei became extinct 1.46 million years ago). It therefore seems that there is a major haitus in this core representing at least 1 million years. It is uncertain whether sediment was not deposited during this interval or whether it was deposited and later removed. The absence of a distinct hardground at the boundary may suggest some erosion immediately prior to deposition of the upper unit, and the indurated nature of the lower unit may indicate the stripping off of an overburden. Such a removal could be due to a slump, erosive turbidite or increased bottom current activity.

The core contains numerous 'rind' burrows, which consist of a white ring of sediment with the sediment inside and outside the ring being identical. These structures are about 2-3 cm across and occur throughout the core.

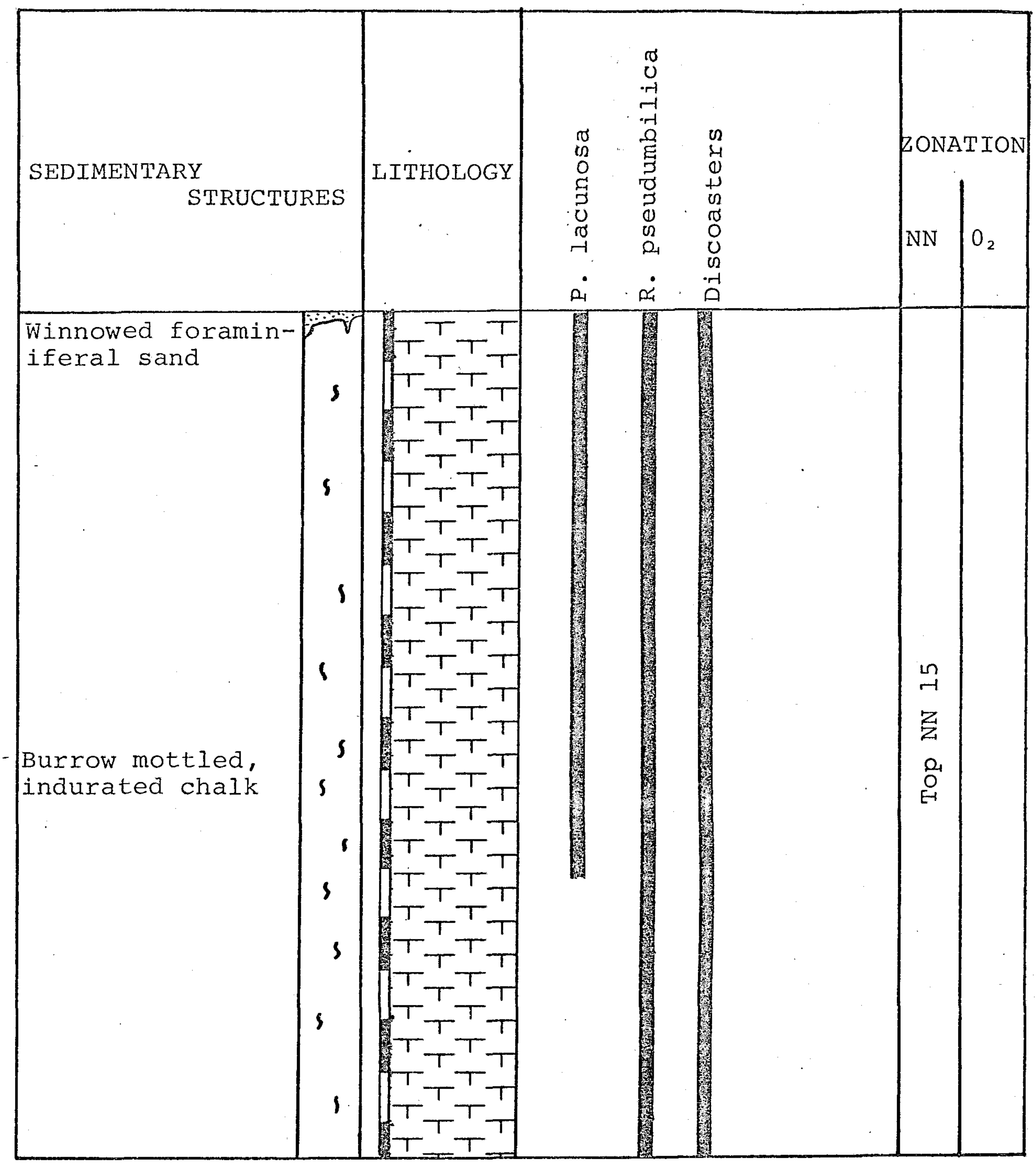
D10331 (Text-figure 12)

This core consists of 5 cm of foraminiferal sand overlying 1.62 m of white chalk. It was taken on top of a ridge to the north of D10330. The sand contains numerous Pteropods and foraminifera which suggests very strong winnowing of Quaternary sediment. The white chalk, however, is of Pliocene age. Its foraminiferal fauna includes G. obliquus, G. altispira, G. crassaformis and G. margaritae, which suggests a Lower Pliocene age (Sphaeroidinella dehiscens zone of Orr and Jenkins, 1977; zone N19-20 of Blow, 1969). The nannoplankton include Reticulofenestra pseudumbilica, P. lacunosa and Sphenoliths, together with several Pliocene species of Discoaster. P. lacunosa and R. pseudumbilica have a very short overlapping range at the top of zone NN15 and this locates this chalk very accurately at the top of the Lower Pliocene.

This area, therefore, received normal pelagic deposition at least until the end of the Lower Pliocene. Further sediments may have been deposited



Text fig. 11. Lithology and stratigraphy of D10330.



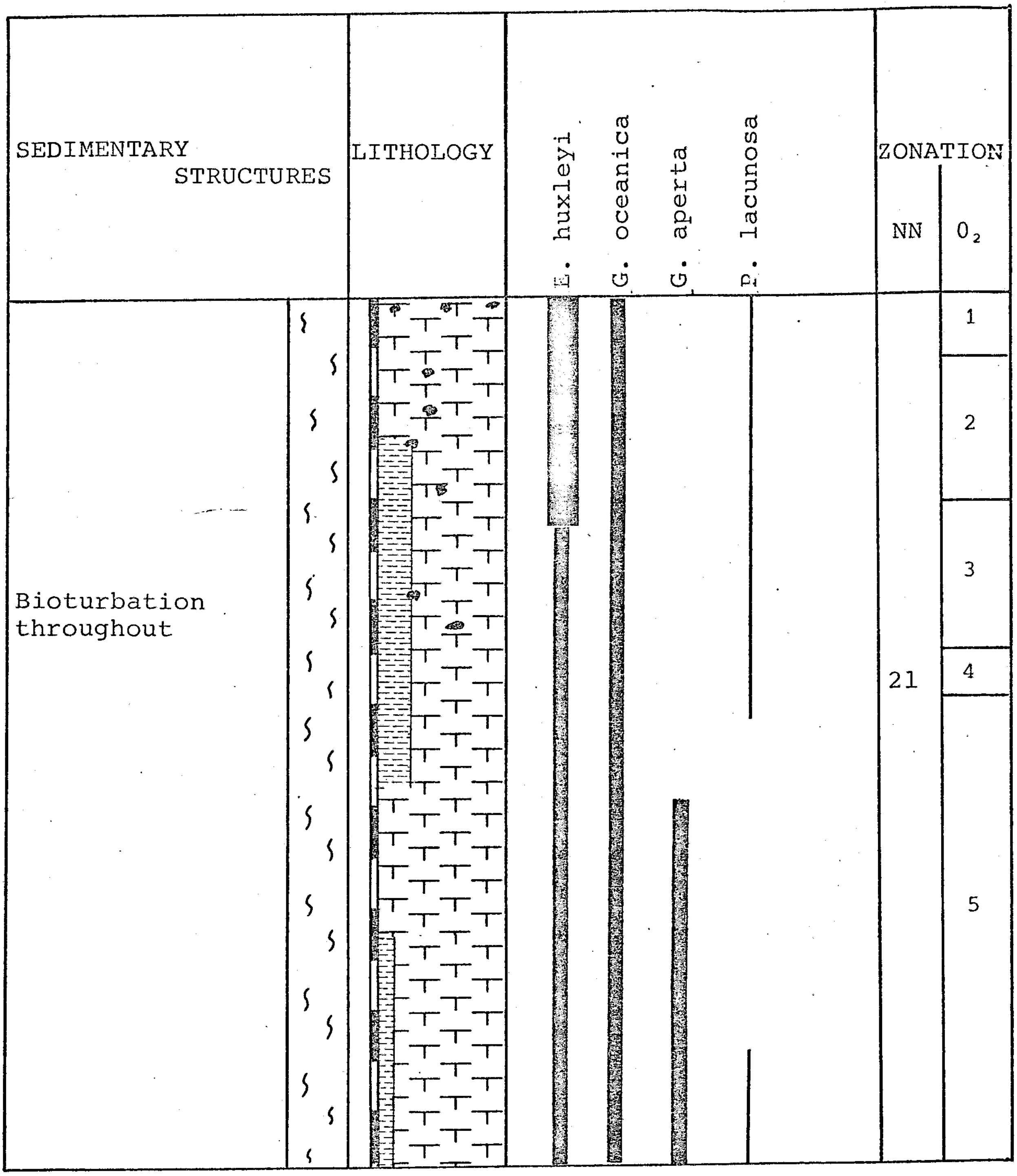
Text fig. 12. Lithology and stratigraphy of D10331.

and later removed after this time, or deposition may have ceased altogether until a thin veneer of strongly winnowed foraminiferal sand was deposited during the Pleistocene.

D10333 (Text-figure 13)

This core consists of 1.74 m of alternating oozes and marly oozes. It was taken in a fairly deep area in the southern part of the King's Trough Flank study area. It is bioturbated throughout and contains numerous erratic pebbles especially in a layer at the surface. Coccoliths from the core show that it all belongs in the NN21 zone. The core comes from the King's Trough area and can be closely compared to the Shackleton (S8-79 cores; Weaver, 1980). The planktonic foraminifera show the same changes as in these cores revealing the presence of the Z, Y and X zones of Ericson et al. (1961). The short lived pulse of sinistrally coiled G. truncatulinoides seen in the S8-79 cores is not seen in D10333, presumably because the core did not penetrate to sufficient depth.

As in the S8-79 cores there is a close comparison between lithological and palaeontological subdivisions. D10333 was taken with the Kastenlot box corer which is thought to give less core shortening than the Barry gravity corer. The Z zone in D10333 is 27 cm long compared to 10-16 cm in the S8-79 cores. The Y zone in D10333 is 70 cm long compared to 40-90 (average 69 cm) in the S8-79 cores. Estimated sedimentation rates for D10333 are, therefore, 2.5 cm/1000 years for the Z zone and 1.1 cm/1000 years for the Y zone. The former figure is slightly higher than the corrected figure for the S8-79 cores, but the figure for the Y zone is somewhat less than the corrected figure for the Y zone in the S8-79 cores. The reasons for this discrepancy between zones are not clear since the Kastenlot corer was expected to give less core shortening throughout. The shortening of the Y zone may be due either to preferential shortening of the softer Y zone or to local conditions which caused less material to be deposited during this interval in this area. The fact that this core was taken in the deepest part of the King's Trough area, however, suggests that local conditions should favour increased deposition rates. This may indicate reduced or interrupted sedimentation in this area, but there is no lithological evidence for this in the core.



Text fig. 13. Lithology and stratigraphy of D10333.

CONCLUSIONS

1. The foraminiferal stratigraphy used in the King's Trough area cannot be used across large areas of the North Atlantic. A coccolith stratigraphy, however, whilst producing considerably longer zones, can be used over wide areas, and can also produce definitive dates for particular horizons. Each coccolith zone can then be subdivided into glacial and interglacial intervals and these can be correlated from core to core.

2. The development of a coccolith stratigraphy enables a rapid interpretation of cores in terms of coring artefacts such as re-entry. Recognition of such artefacts prevents duplication of lengthy experimental analyses such as permeability and porosity measurements. Preliminary stratigraphic analyses should, therefore, be made on all cores.

3. Cores D10305 and D10307 were taken in the Great Meteor West study area. Evidence of slumping had been found in this area by Dutch scientists on HNLMS Tydeman, but our two cores showed complete sedimentary sequences back to oxygen isotope stage 6. Deeper cores at these two sites, or cores at other sites, would presumably reveal the extent of the disturbances found by the Dutch scientists.

4. Cores D10311 and D10314 showed unexpected thick calcareous turbidites in a pelagic clay environment. The only plausible origin for these turbidites seems to be from a flow which originated a considerable distance away on the abyssal plain. To reach the coring sites this flow must have passed between a series of hills and possibly over a sill. It must also have crossed the CV1 and CV3 sites which lie to the east. GLORIA records from a recent IOS cruise on MV Farnella do, in fact, show surface features on the CV3 area which indicates mass movement of sediment.

5. Cores D10316, D10320 and D10321 show dissolution cycles and consequently have very low deposition rates. Such low rates combined with bioturbation make it difficult to obtain an oxygen isotope stratigraphy on these cores. The planktonic foraminifera are largely destroyed by dissolution and so coccoliths provide the best method of stratigraphy. Since intervals of strong dissolution correlate with glacial periods when Antarctic Bottom Water was more widespread and more corrosive, each coccolith zone can be subdivided into glacial and interglacial intervals on lithology. The

fact that the number of glacial and interglacial intervals in each zone corresponds reasonably well with the expected number, suggests that deposition in these areas has been continuous. This combined coccolith/lithologic stratigraphy enables a correlation of cores such as D10316 and D10320 even though they come from areas 700 km apart.

6. Cores D10323 and D10325, taken to the south of the G.M.E. study area, both show a turbidite layer. Such turbidites have been previously recorded in the eastern part of this area by Dutch scientists. Core D10323 also includes some Pliocene material which may represent local slumping.

7. Cores D10330 and D10331 were taken to provide a link between the King's Trough Flank area to the north and the Great Meteor and Cape Verde areas to the south. D10330 was taken on the lower slope of the Azores fracture zone ridge and revealed a large hiatus with early Pleistocene at the base. D10331 was taken on top of a ridge on the southern flank of the Azores fracture zone and revealed Lower Pliocene material with a thin cover of Pleistocene sand. These two cores therefore show examples of sedimentation around upstanding topography. The area on top of the ridge may have received sediment which was later removed, or it may have received no sediment for a long period. Currents in this area today are so strong that only coarse sand can be deposited. At the base of the ridge sediment is again absent either due to non-deposition or later removal. The cause may be due to 'moating', in which the speed of bottom currents is preferentially increased around high areas, thus scouring a moat around their base.

REFERENCES

Blow, W.H., 1969. Late Middle Eocene to Recent Planktonic Foraminiferal Biostratigraphy. In (Bronniman, P. and Renz, H.H. eds) Proc. Int. Plankt. Conf. 199-421 pls. 1-54.

Ericson, D.H., Ewing, M., Wollin, G. and Heezen, B.C., 1961. Atlantic deep-sea sediment cores. Geol. Soc. Amer. Bull. 72, 193-286.

Francis, T.J.G., 1981. Geophysics and sediment sampling in the north east Atlantic. Institute of Oceanographic Sciences cruise report no. 117, pp 1-33.

Gartner, S., 1977. Calcareous nannofossil biostratigraphy and revised zonation of the Pleistocene. Marine Micropalaeontology 2, 1-25.

Hay, W.W., 1977. Calcareous nannofossils. In Oceanic Micropalaeontology (Ramsay A.T.S. ed.) pp 1055-1200 Academic Press, London/New York.

Martini, E., 1971. Standard Tertiary and Quaternary Calcareous Nannoplankton zonation. Proceedings of the II Planktonic Conference, Rome, 1970, 2 pp 739-785.

Orr, W.N. and Jenkins, D.G., 1977. Cainozoic planktonic foraminifera zonation and selective test solution. In Oceanic Micropalaeontology (Ramsay A.T.S. ed.) pp 163-203. Academic Press, London/New York.

Pujos-Lamy, A., 1976. Emiliania et Gephyrocapsa (Nannoplankton Calcaire): Biométrie et intérêt biostratigraphique dans le Pleistocene Supérieur Marin des Azores. Rev. esp. Micropal, 9, 69-84.

Samtleben, C., 1980. Die Evolution der Coccolithophoriden-Gattung Gephyrocapsa nach Befunden im Atlantik. Paläont. Z., 54, 91-127.

Shackleton, N.J. and Opdyke, N.D., 1976. Oxygen-Isotope and Palaeomagnetic Stratigraphy of Pacific core V 28-239 Late Pliocene to Latest Pleistocene. In: Cline R.M. and Hays, J.D., (Eds) Investigation of Late Quaternary Paleoceanography and Paleoclimatology. Geol. Soc. Am. Mem. 145 449-464.

Weaver, P.P.E., 1980. A correlation of late Quaternary cores from south of King's Trough, North Atlantic. Institute of Oceanographic Sciences Internal document no. 119. pp. 1-14.

Weaver, P.P.E. and Schultheiss, P.J. (in preparation). Repenetration of open barrel gravity cores.

CORE	POSITION	AREA	WATER DEPTH (m)	CORE LENGTH (m)	LITHOLOGY	STRATIGRAPHY
D10298 (Kastenlot)	36°24'.7N 18°20'.0W	North eastern part of Madeira abyssal plain	5547	2.20	0-24 cm marly ooze 24-220 cm fine-grained distal calcareous turbidite	0-24 cm NN21 24-220 cm melange NN19, NN20, NN21
D10302 (Kastenlot)	34°19'.9N 21°34'.2W	North eastern part of Madeira abyssal plain	5035	0.51	Marly calcareous ooze. Disturbed during coring. Most of original core lost.	Not studied
D10305 (Barry)	31°45'N 29°49'.1W	Abyssal plain west of Cruiser seamount. At northern end of GMW site	4139	1.57	Calcareous ooze and marly calcareous ooze. 57-62 cms tephra	NN21 throughout. Oxygen isotope stages 1-6 present.
D10307 (Barry)	30°12'.8N 29°11'.5W	Lower rise west of Great Meteor seamount close to eastern side of GMW site.	4001	2.01	Calcareous ooze and marly calcareous ooze	Probably NN21 throughout, but may be mixed NN21/ NN20 towards base.
D10311 (Barry)	25°39'.2N 30°57'.6W	Deep within ridge flank topography.	6129	2.17	0-60 cm pelagic clay 60-217 cm homogeneous fine-grained, calcareous distal turbidite.	0-60 cm no data. The turbidite comprises NN19 and NN20 material and was deposited during zone NN20.
D10314 (Kastenlot)	25°38'.3N 30°57'.3W	Deep within ridge flank topography	6130	2.40	0-84 cm pelagic clay 84-240 cm homogeneous fine-grained, calcareous distal turbidite	As for D10311

TABLE 1

continued............

CORE	POSITION	AREA	WATER DEPTH (m)	CORE LENGTH (m)	LITHOLOGY	STRATIGRAPHY
D10316 (Kastenlot)	26°13'.2N 26°59'.1W	High area just west of abyssal plain	4966	1.75	Marly calcareous ooze and marl	Zones NN21 and NN20 Strong mixing (bioturbation) indicated by oxygen isotopes
D10320 (Barry)	31°05'.2N 25°50'W	East of Great Meteor seamount just off SW corner of GME site	5005	2.00	Marly calcareous ooze and marl. Ooze at base	Coccoliths reveal zones NN21, NN20, NN19. Core can be subdivided into glacial and interglacial intervals on lithological evidence.
D10321 (Kastenlot)	31°04'.8N 25°49'.3W	Same site as D10320	4978	1.65	As for D10320. Litho-logical units can be correlated between the 2 cores.	Not studied. Presumed identical to D10320.
D10323 (Barry)	30°21'.7N 24°06'.8W	East of Great Meteor Seamount to south of GMW site	5406	1.67	Marly calcareous ooze and marl. Some pelagic clay 50-81 cm turbidite graded from sand to clay.	Thin NN21 zone then zone NN20 to base. 110-125 cm possibly NN19 with NN17 present at 115 cm.
D10325 (Kastenlot)	30°22'.9N 24°05'.8W	Same site as D10323	5407	1.06	Same lithology as D10323 down to upper part of turbidite (60 cm) then sequence repeated due to corer re-entry.	0-33 cm NN21 33-60 cm NN20 then repeated
D10330 (Barry)	36°49'N 20°18'.8W	Lower slope on the southern flank of the Azores fracture zone	4460	1.52	Calcareous ooze and marly. Calcareous ooze indurated below 57 cms	0-45 cm NN21 45-57 cm NN20 Hiatus 57-152 cm NN19

TABLE 1

continued.......

CORE	POSITION	AREA	WATER DEPTH (m)	CORE LENGTH (m)	LITHOLOGY	STRATIGRAPHY
D10331 (Barry)	$37^{\circ}08'$N $20^{\circ}05'$W	Top of ridge on southern flank of Azores fracture zone	2730	1.67	0-5 cm foraminiferal sand 5-167 cm chalk	0-5 cm Quaternary 5-167 cm Pliocene NN15
D10333 (Kastenlot)	$41^{\circ}07'.3$N $22^{\circ}57'.1$W	Southern part of King's Trough study area	4133	1.74	Calcareous ooze and marly ooze	NN21 throughout. Oxygen isotope stages 1-5.