BMR Journal of Australian Geology & Geophysics, 3, 1978, 341-345

The near-surface sediments of the Scott plateau and Java Trench: nannofossil assessment and implications

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Quaternary sediments are apparently more widespread and better represented in the northern Scott Plateau and Java Trench than in parts of the central Scott Plateau, where older rocks are exposed on the sea floor. Nevertheless, wherever Quaternary calcareous nannofossils are recovered from these areas, they are associated with reworked Upper Cretaceous and Tertiary forms. This may have been caused by bottom currents actively eroding parts of the central Scott Plateau and redistributing the fine fraction elsewhere on the plateau, Java Trench and nearby areas. These currents may have been active from the middle Miocene.

Late Pleistocene to Holocene calcareous nannofossils occur throughout the near-surface (*ca* 1 m thick) sediments in the northern Scott Plateau, but are absent from such sediments in the Java Trench. However, Pleistocene nannofossil assemblages, older than those from the Scott Plateau, occur intermittently at lower levels in the near-surface (*ca* 1 m thick) sediments in the Java Trench. This difference is explained by suggesting that the present Nanno Solution Depth lies between 3290 m and 4950 m water depth in the Scott Plateau and Java Trench areas, but in earlier Quaternary times it fluctuated between 5090 m and 5424 m in the same areas.

Introduction

Early in 1977, a German-Australian team aboard the R.V. Valdivia, sampled the Scott Plateau and Java Trench areas in the north of Western Australia. The aim of the present paper is to date the near-surface sediment layer (average thickness 1 m) of these areas (Fig. 1) by using calcareous nannofossils, and to attempt to evaluate the distribution of these fossils in the context of carbonate dissolution in the oceanic realm; overall results of the cruise are given by Hinz & others (1978), and further detailed in Stackelberg & others (1978).

Calcareous nannofossils have been widely used for dating oceanic sediments, even though assemblages of these fossils often include reworked elements (see e.g., Andrews, Packham, & others, 1975). However, detection of reworking may allow recognition of possible provenance areas (see e.g., Shafik, 1978b).

Calcareous nannofossil distribution in sediments is principally controlled by depth of deposition. Selective solution of nannofossils in the oceanic realm is well documented (e.g. Bukry, 1971), and marginal-marine nannofossil species—indicative of shallow-water deposition—are being increasingly reported.

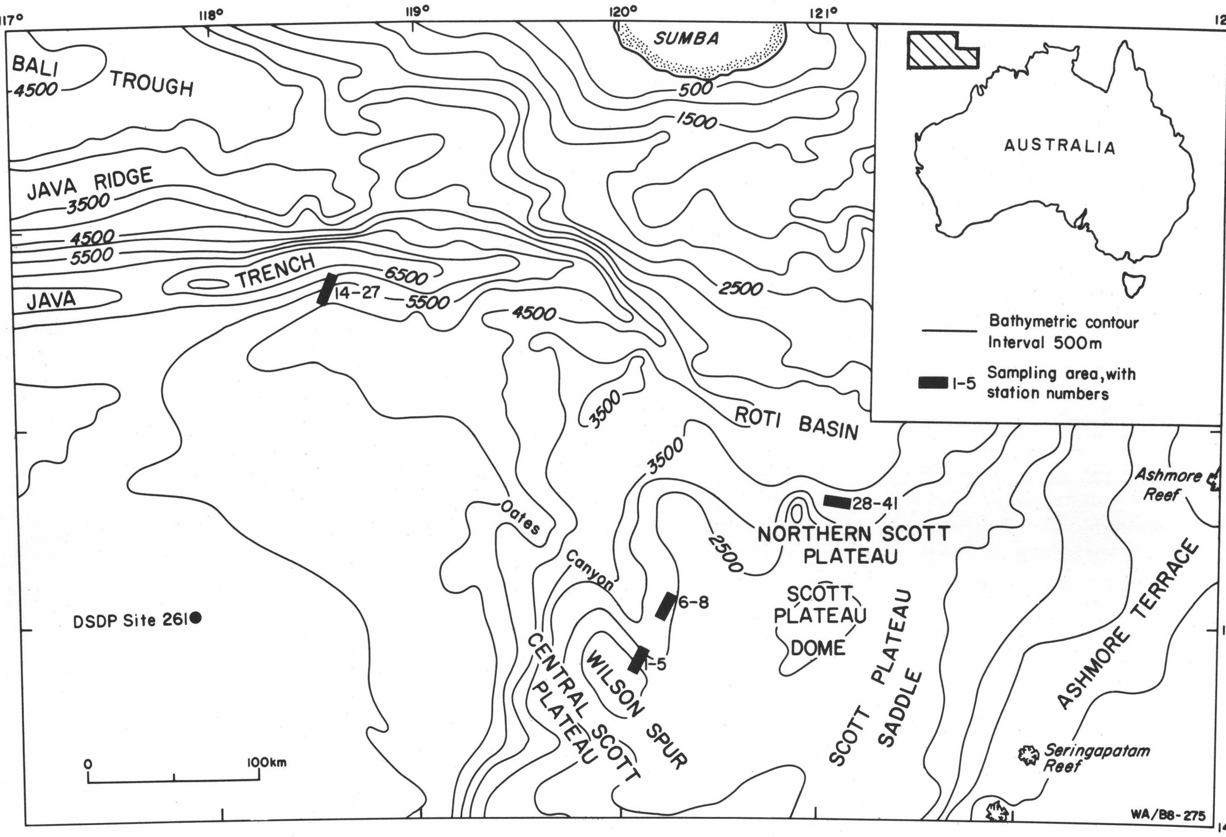

Figure 1. Locality map (modified after Hinz & others, 1978).

Total dissolution of calcareous nannofossils occurs at a greater depth than planktic foraminiferids (see Hay, 1970). Andrews, Packham, & others (1975, p. 17) used the terms Foram Solution Depth and Nanno Solution Depth (NSD) to describe 'depths at which all forams and nannofossils, respectively, are removed from the sediments'—in preference to the terms compensation depth and lysocline, because of ambiguities surrounding the latter terms. The NSD may, however, be considered as an approximation of the carbonate compensation depth.

Samples from twenty-two cores, as well as three dredge samples, representing the near-surface sediments of the Scott Plateau and Java Trench, were analysed by means of light microscopy; critical samples were also studied under the scanning electron microscope. All the cores examined are Boomerang cores (each is about 1 m long) except for one core (KL14) which is a piston core (about 4 m long); their descriptions, and also details of the calcareous nannofossil assemblages, are given in Stackelberg & others (1978).

Nannofossils from the Scott Plateau

Calcareous nannofossils are abundant throughout the Scott Plateau cores, and can be separated into Upper Cretaceous and Quaternary assemblages; the latter, however, include reworked forms as old as the Late Cretaceous. In contrast, most of the dredge samples lack nannofossils. However, relics of sediments (paler in colour) adhering to these samples contain abundant to sparse Quaternary calcareous nannofossils.

Central Scott Plateau

Core KL1 consists of fine chalk, rich in nannofossils. Preservation of these fossils is fair to good. Most species are easily identifiable, even though those from the top of the core show signs of dissolution. Assemblages from the top and bottom of the core are similar, and include abundant *Broinsonia parca* (Stradner) and *Eiffellithus eximius* (Stover); *Tetralithus aculeus* (Stradner) is absent. The co-occurrence of these species—in the absence of *T. aculeus* (Stradner)—signifies an early Campanian age (Shafik, 1978a). Nannofossil diversity is limited in comparison with coeval marginal-marine assemblages: species such as *Kamptnerius magnificus* Deflandre, *Lucianorhabdus cayeuxi* Deflandre, *Tetralithus obscurus* Deflandre, and *T. ovalis* Stradner—common to lower Campanian hemipelagic sediments—are absent. These species are susceptible to solution in deep water, and the overall composition of the nannofossil assemblages of Core KL1 suggests deep-oceanic sedimentation well above the NSD.

Traces of pale, calcareous nannofossil-bearing sediments, adhering to the dredge samples (KD11, KD7, & KD2) contain *Gephyrocapsa oceanica* Kamptner, and questionable *Emiliania huxleyi* (Lohmann), which indicate a Pleistocene-Holocene age. In addition, these adherent sediments contain other Quaternary calcareous nannofossil species associated with reworked Cretaceous and Tertiary taxa. (The older material of both dredge samples KD11 and KD7 consists of dark grey mudstone, barren of nannofossils. The mudstone of sample KD11 contains evidence suggesting a late Jurassic age (see Stackelberg & others, 1978).)

Northern Scott Plateau

The near-surface sediment layer of the northern Scott Plateau consists mainly of grey silty marl, with abundant calcareous nannofossils throughout. The nannofossils include Quaternary taxa as well as older species. The latter represent most of the stages of the Late Cretaceous and Tertiary, and are presumed to be reworked. Reworked taxa are common to all samples examined, and most occur in abundance; individual reworked species are randomly distributed among the samples. Elements indicative of marginal-marine deposition are absent among the reworked taxa, suggesting that the associated sediments are oceanic.

Emiliania huxleyi (Lohmann) is the youngest age-diagnostic species amongst the autochthonous taxa. This species is difficult to identify with light microscopy; its presence—throughout the cores—was confirmed using electron microscopy. The warm, cold, and intermediate morphotypes of *E. huxleyi* (Lohmann) distinguished by McIntyre & Bé (1967) were recognised in the cores (Fig. 2), indicating mixing of water masses; the warm-water morphotype is, however, predominant.

The abundant occurrence of *Emiliania huxleyi* (Lohmann) has been widely used as evidence for the Holocene by several workers (e.g. Gartner, 1977), but the relative abundance of this species in the northern Scott Plateau cores could not be established with certainty; dilution by reworking is difficult to assess. However, the earliest appearance of *E. huxleyi* (Lohmann) has been widely accepted as a reliable datum within the uppermost Pleistocene (at 0.27 m.y.; Gartner, 1977). The presence of *E. huxleyi* (Lohmann) throughout the near-surface sediment layer of the northern Scott Plateau can be taken to indicate that this layer is latest Pleistocene to Holocene in age; the occurrence of species such as *Certolithus cristatus* Kamptner, *Gephyrocapsa oceanica* Kamptner, *Umbilicosphaera mirabilis* Lohmann is consistent with this age assignment.

Nannofossils from the Java Trench

The near-surface sediment layer of the Java Trench consists largely of grey mud. Calcareous nannofossil distribution is related to depth in the cores (see also Hinz & others, 1978): whereas the tops are all barren, most lower parts are rich in nannofossils; a few cores lack nannofossils entirely. Water depths at the stations sampled in the Java Trench area range from 4590 m to 5790 m. Barren cores are all below 5720 m water depth, whereas cores above 5425 m water depth are fossiliferous; samples from intermediate depths were not available.

The bottoms of all Boomerang cores from 5251 m water depth and above are rich in calcareous nannofossils. The nannofossil record in these cores is continuous upwards over an average of 70 cm, and the upper 30 cm (in average) of the cores lack nannofossils. An exception is Core BL17 (5090 m water depth), in which the nannofossil record (114 to 15 cm levels) is interrupted by a barren interval from 62 to 30 cm.

Cores between 5290 m and 5424 m water depths contain calcareous nannofossils even though their bottoms and tops are barren. The lower part of Core BL21 (5290 m water depth) lacks nannofossils, but they do occur between 75 and 30 cm levels. Only the bottom part of Core KL14 (5240 m water depth) is barren, but the nannofossil record in this core is discontinuous. Hinz & others (1978, fig. 11) interpret these variations as representing periods of greater and lesser solution.

The assemblages recovered are similar. They resemble those from the northern Scott Plateau in containing Upper Cretaceous and Tertiary taxa co-occur-

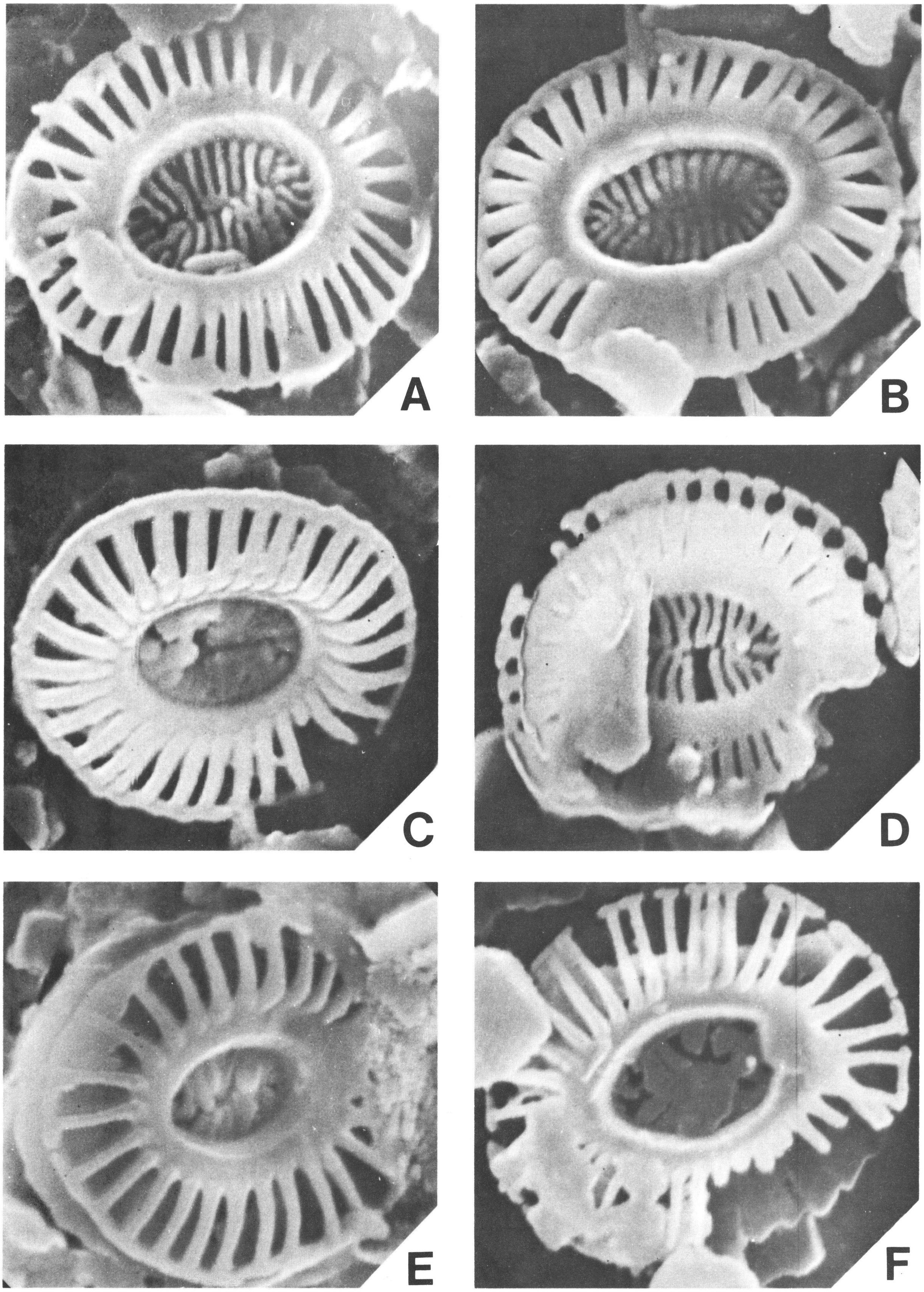

Figure 2. *Emiliania huxleyi* **(Lohmann) from the northern Scott Plateau.**
A-X26 000 from Core BL29 (100 cm); B-X24 000, C-D-X26 000 (B-D from Core BL34 (94 cm)); E-X30 000 from Core BL33 (103 cm); F-X24 000 from Core BL32 (100 cm). Elements counts of distal shields, plus observations on central areas and proximal shields suggest that specimens A, B, & D are warm-water variants, whereas other specimens are either cold-water variant (E) or probable gradations (C & F). Negatives of these specimens are deposited in the Commonwealth Palaeontological Collection: A = CPC 18686, B = CPC 18687, C = CPC 18688, D = CPC 18689, E = CPC 18690, F = CPC 18691.

ring with Quaternary species. However, the composition of the Quaternary species differs notably with the absence of *Emiliania huxleyi* (Lohmann) from the Java Trench cores.

Forms referable to *Gephyrocapsa oceanica* Kamptner are ubiquitous among the assemblages recovered from the cores. This species has been widely accepted as indicating a Pleistocene age (Bukry, 1973; Gartner, 1977; Haq & others, 1977), even though its earliest appearance has not been consistently placed on the time scale: Bukry (1973) places this datum at 0.9 m.y. (mid Pleistocene), Gartner (1977, fig. 5) regards it as between 1.65 and 1.51 m.y. (within the early Pleistocene), and Haq & others (1977) assign it a mean age of 1.57 m.y. (earliest Pleistocene); the age of the Pliocene/Pleistocene boundary at 1.6 m.y. (Haq & others, 1977) is accepted here. Based on this evidence, the nannofossil-bearing parts of the Java Trench cores are Pleistocene in age; the absence of *Emiliania huxleyi* (Lohmann) suggests that they are older than the near-surface sediment layer of the northern Scott Plateau. The ages of the nannofossil-free parts of the Java Trench (essentially the tops of all cores), as well as those cores below and including 5720 m water depth could possibly be determined from their abundant Radiolaria.

Reworked Cretaceous and Tertiary calcareous nannofossil species from the Java Trench cores are mostly the same as those from the northern Scott Plateau; both share almost all the same reworked species. However, among the Scott Plateau species regarded as possibly having been reworked from Neogene source sediment, *Cyclococcolithina macintyrei* Bukry & Bramlette, *Helicopontosphaera sellii* Bukry & Bramlette, and *Pseudoemiliania lacunosa* (Kamptner) may be *in situ* in the Java Trench cores. These species are known to range through the greater part of the Quaternary, and their extinction levels have been used to subdivide Pleistocene sediments (Gartner, 1977). The order of the sequential disappearance of these species (Gartner, 1977) in the Java Trench cores can only be described as erratic.

Discussion

Bottom currents

Bottom-currents data in the Scott Plateau and Java Trench areas are lacking, but it is considered that nannofossil distribution in the near-surface sediments cannot be explained fully without invoking such currents.

In the studied parts of the central Scott Plateau, Quaternary sediments are either absent or preserved as relics, and instead older rocks are exposed on the sea floor. The chalk unit (KL1), which is made up primarily of calcareous remains of the early Campanian plankton, lacks younger nannofossils. This unit contrasts with the older barren mudstone unit (KD11, KD7) which has nannofossil-rich relics of Quaternary sediments adhering to it. Quaternary sedimentation in parts of the central Scott Plateau was either insignificant or non-existent, whereas in the northern parts of the plateau and the Java Trench, such sediment is well represented. Nevertheless, wherever Quaternary calcareous nannofossils are recovered from the Scott Plateau and Java Trench, they are associated with Upper Cretaceous and Tertiary forms.

That the top part of the lower Campanian chalk, outcropping in the central Scott Plateau, lacks younger nannofossils suggests that strong bottom currents actively removed younger sediments and probably eroded the chalk itself; Late Cretaceous nannofossil species identified among the Quaternary assemblages of the younger parts of the central Scott Plateau dredge samples, and in the Quaternary cores of the northern Scott Plateau and the Java Trench, may have been transported by such currents. The poor preservation of the nannofossils in the upper part of the chalk suggests some dissolution, probably the result of corrosive action of cold, bottom currents.

The absence of Cretaceous and Tertiary calcareous nannofossil species indicative of marginal-marine sedimentation among the reworked forms of the Quaternary sediments of the northern Scott Plateau and the Java Trench suggests that the provenance sediments are oceanic; the lower Campanian chalk unit of the central Scott Plateau lacks marginal-marine nannofossil species. Thus, it seems that the central Scott Plateau outcrops have acted (and probably still do) as the source of the reworked nannofossils which occur in the Quaternary sediments of the plateau and Java Trench.

The abundance of the reworked taxa among the Quaternary assemblages of the northern Scott Plateau and Java Trench suggests that bottom currents are very actively stripping and redistributing old sediments exposed on the sea floor. These currents have apparently also been involved in the sedimentation of the younger sequences (containing reworked components) recovered at the nearby DSDP Sites 260 and 261. If this is so, these currents may have been acting since at least the middle Miocene: sediments with reworked species at the top of the Site 260 sequence, extend downwards to levels that are middle Miocene in age (Veevers, Heirtzler, & others, 1974).

Nanno Solution Depth

The sediment/water interface in the Java Trench is below the current NSD, as shown by the lack of calcareous nannoplankton remains in surface samples. In the Scott Plateau, the same interface is above the current NSD, as indicated by the occurrence of Quaternary calcareous nannofossils in all surface samples (i.e., where Quaternary sediments are not removed by bottom currents). The shallowest depth sampled from the Java Trench is 4950 m, whereas the deepest surface sample from the Scott Plateau came from 3290 m water depth. Thus the current NSD in the areas of the Scott Plateau and Java Trench lies between 3290 m and 4950 m water depths; refinement is not possible because of lack of surface samples from interim depths.

During the Pleistocene, the NSD apparently fluctuated between 5090 m and 5424 m water depths. This is shown by the occurrence of Quaternary calcareous nannofossils, older than those from the Quaternary near-surface sediments of the Scott Plateau, in the lower parts of the Java Trench cores taken from between these depths, and also by the occurrence of nannofossil-free intervals within the same parts of some of these cores.

Acknowledgements

The co-operation between geoscientists from West Germany and Australia is appreciated. Material examined in this paper was made available through this co-operation. Drs G. E. Wilford and J. M. Dickins critically read an earlier draft, and Dr N. F. Exon constructively criticised the final manuscript. I thank them all.

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BMR Journal of Australian Geology & Geophysics, 3, 1978, 345-349

Deep-water Quaternary Foraminifera from short cores taken between Australia and southeast Indonesia

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Twenty short cores were recovered from the northern Scott Plateau (water depths *ca* 3200 m) and the southern slope of the Java Trench (water depths 4950-5790 m) by R.V. Valdivia in 1977; selected cores have been studied in detail.

About 55 species of benthonic foraminifera were identified on the plateau, but only half as many in the trench. Only deep-water forms occur in the trench, suggesting an absence of transport from shallower depths. Fragile agglutinating forms are confined to the surface sediments, or are totally absent.

The planktonic foraminifera from the plateau generally belong to tropical associations. The assemblages show that the Holocene-Pleistocene boundary lies at about 60 cm in the cores, and that carbonate solution is more marked above than below the boundary.

Introduction

During a recent cruise by R.V. Valdivia two series of one-metre long boomerang cores were taken: one on an almost flat surface on the northern Scott Plateau, the other on the southern slope of the Java Trench. The station data are listed and some cores are described in Hinz & others (1978); all cores are described in Stackelberg & others (1978). The Scott Plateau samples lie along an east-west line from 12°22.0′S, 121°01.1′E to 12°22.1′S, 121°10.1′E in water depths ranging from 3180 m to 3290 m. The Java Trench samples lie along a north-south line from 11°23.4′S, 118°28.2′E to 11°25.2′S, 118°31.2′E in water depths ranging from 5790 m to 4950 m. The Scott Plateau area lies down a gentle slope from the Scott Plateau Dome which has its crest at 2000 m; the Java Trench area is completely isolated from areas of seabed shallower than 4900 m.

Samples from the tops and bottoms of all 20 of these cores were examined for Foraminifera and nannoplankton by D. Belford & S. Shafik (*in* Stackelberg & others, 1978) who showed that all the faunas were Quaternary (no older than Zone N22), and that the calcite compensation depth had moved upward with time, from more than 5420 m to less than 4950 m. A more detailed study of the nannoplankton by Shafik (1978) shows that the lower, calcareous, parts of the Java Trench cores are early or middle Pleistocene in age.

Selected cores from the Java Trench and the Scott Plateau were examined in detail to document the local faunas; to see whether vertical variations in faunas and dissolution existed, and if so whether they could be correlated from core to core; and to try to locate the Pleistocene-Holocene boundary.

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