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PLANKTONIC FORAMINIFERA FROM DSDP SITE 241 IN SOMALI BASIN, NORTHWESTERN INDIAN OCEAN

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ABSTRACT

Thirtyfive samples at regular interval from top 900 cm core of DSDP Site 241 (leg 25) have yielded planktonic foraminiferal assemblages constituting thirtyfive species included in three families. Ericson zones V(Sangamon-interglacial), W(Early-Wisconsin), X(Middle-Wisconsin - Y(Main-Wisconsin) and Z(Post-glacial) have been delineated on the basis of frequency (count/gram) distribution of *Globorotalia menardii*. The fluctuations in the abundance of total planktonic Foraminifera and eleven other commonly occurring species can be correlated with the above zones with varying degree of precision. Four indices of diversity, the species number (S), Yule's index (D), Shanon-Wiener function ($\bar{H}$) and equitability (E) show fuctuations along depth of core. At majority of levels the variation in values of diversity can be correlated with paleoclimatic changes as inferred from the above zonation.

INTRODUCTION

The study of foraminiferal assemblage, both living and extinct, has a great utilitarian value in both biostratigraphic subdivision, correlation and paleoclimatology. The composition of Neogene planktonic foraminiferal assemblages and its relationship to different water masses have been the subject of a number of recent studies.

Based on oxygen isotopic data of planktonic Foraminifera Emiliani (1955) showed that the temperature of superficial waters in the equatorial Atlantic and Caribbean underwent periodic oscillations with an amplitude of about 6°C. Ericson *et al.* (1961 and 1964) have used the abundance curves and coiling types of some selected planktonic Foraminifera as the basis of drawing paleoclimatic curves of the Atlantic during the Pleistocene period. Ghose and Jaiprakash (1988) have put forward a generalised paleoclimatic curve of the Late Pleistocene of the Northern Indian Ocean from the analysis of paleontologic time series based on planktonic foraminiferal abundance from DSDP cores from sites 214, 237 and 238. In the same sites Jaiprakash *et al.* (in press) established planktonic foraminiferal biostratigraphy and faunal provinces.

This paper includes a study of the distribution, fluctuations in species abundance and diversity of planktonic foraminiferal assemblages separated from thirtyfive samples at regular interval from the top nine hundred cm of DSDP (ODP) core at site 241 in the Somali Basin, Northwestern Indian Ocean.

LOCATION OF SITE AND LITHOLOGY

The DSDP Site 241 (fig. 1) is at a depth of 4054 m and the sedimentation rate at this site has been estimated to be 4 mm/100 years (Vallier and White, 1974 p.102). The sediments are predominantly clay and clay-rich nanno-ooze consisting of foraminifera (about 10 p.c.), radiolarians and diatoms (*op. cit.*p. 92). The salinity of interstitial waters of sediments of the core length investigated in the present work varies from 34.9% to 35.2%. (Gieskes, 1974, p.376).

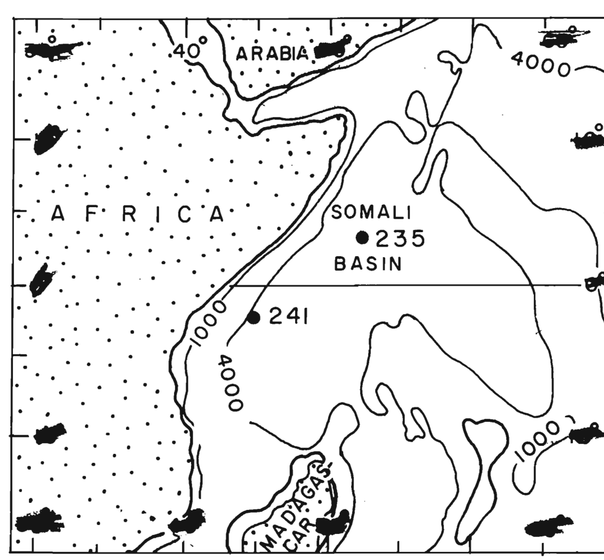

Fig. 1 Location of the DSDP site 241, Somali Basin, Northwestern Indian Ocean (After Vallier and White, 1974, p.6, fig. 1).

SAMPLES AND THEIR PREPARATION

Samples at 25 cm interval from top 900 cm core of this site were obtained from Scripps Institution of Oceanography, California, USA. About 1 gm. of the sample was taken and it was air dried for about twentyfour hours and it was then disintegrated by boiling in N/10 Na_2CO_3 solution at 60°C. Boiling was carried out very gently to prevent damage to the test of microfossils. The disintegrated sample was wet sieved into five size fractions, viz., + 0.5 mm, - 0.5 mm to 0.25 mm, - 0.25 mm to 0.125 mm, - 0.125 mm to 0.062 mm and - 0.062 mm. The wet sieving was followed by drying of the size fractions in oven below 100°C.

In the present study two size fractions (i.e., + 0.5 mm and - 0.5 mm to 0.25 mm) were taken for separation of taxa. All the tests of the coarser fraction (+ 0.5 mm) were separated. Since the other fraction (- 0.5 mm to 0.25 mm) contained several hundreds of tests, 'coning and quatering' technique was followed. The separated forms were identified and placed in faunal trays using water soluble tragacanth gum. The identified forms were counted and the resulting numbers were recalculated to give abundance values in count per gram.

DISTRIBUTION OF PLANKTONIC FORAMINIFERA

Thirty two planktonic foraminiferal species belonging to three families have been identified from this site. For systematics, Saito, *et al.* (1976), Stainforth *et al.* (1975) and Srinivasan and Kennett (1976) have been followed.

The identified species are *Hastigerina aequilateralis* (Brady, 1884), *H. murrayi* (Thomson, 1876), *H. siphonifera* (d'Orbigny, 1839), *Globorotalia flexuosa* (Koch, 1923), *G. menardii* (d'Orbigny, 1826), *G. truncatulinoides* (d'Orbigny, 1839), *G. tumida* (Brady, 1877), *G.* (*Turborotalia*) *crassaformis* (Galloway and Wissler, 1927), *G.* (*T.*) *obesa* (Bolli, 1957), *G.* (*T.*) *ronda* (Blow, 1969), *G.* (*T.*) *scitula* (Brady, 1882), *Globigerina bulloides* (d'Orbigny, 1826), *G. calida calida* (Parker, 1962), *G. conglomerata* (Schwager, 1866), *G.* (*Beela*) *digitata praedigitata* (Parker, 1967), *G. falconensis* (Blow, 1959), *Globnigerinoides conglobatus* (Brady, 1879), *G. diminutus* (Bolli, 1957), *G. obliquus* (Bolli, 1957), *G. quadrilobatus* (d'Orbigny, 1864), *G. ruber* (d'Orbigny, 1839), *G. sacculifer* (Brady, 1884), *G. triloba* (Reuss, 1850), *Globoquadrina altispira* (Cushman and Jarvis, 1936), *Neogloboquardrina dutertrei* (Bandy, *et al.*, 1967), *Pulleniatina finalis* (Banner and Blow, 1967), *P. obliquiloculata* (Parker and Jones, 1865), *Sphaeroidinella dehiscens* (Parker and Jones, 1865, *Sphaeroidinellopsis paenedehiscens* (Blow, 1969), *S. subdehiscens* (Blow, 1959), *Orbulina bilobata* (d'Orbigny, 1846) and *O. universa* (d'Orbigny, 1839). Out of the above, *G. ronda, G. diminutus, G. altispira, S. paenedehiscens* and *S. subdehiscens* are reworked forms and their frequency of occurrence is also very low. They have not been considered within the "total Planktonic" count.

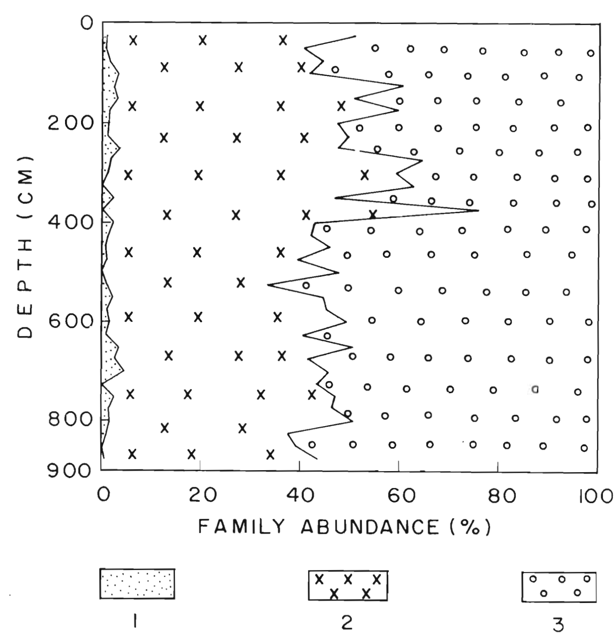

Fig. 2. Variation in proportion of three families of planktonic foraminifera at site 241. 1-Hantkeninidae, 2-Globorotalidae and 3-Globigerinidae.

Family Hantkeninidae is represented by a single genus *Hastigerina* with three species, Globorotalidae by *Globorotalia* and *G.* (*Turborotalia*) shared by eight species, while the Globigerinidae are most diverse both at generic and species levels, being represented by twentyone species belonging to eight genera.

Relative dominance of the three families in this site has been shown in figure 2. Hantkeninids are least important at all levels and globigerinids are dominant in majority of samples. The abundance data of globorotalid and globigerinids show some interesting fluctuation which can be roughly correlated to the V, W, X, Y and Z zones of Ericson *et al.* (1961) (see also figures 5 and 6). Above the 400 cm core depth at this site Globoratalids are more important while below that level globigerinids are dominant. This would be clear from the fact that the "maxima" peaks of globorotalids below that level are somewhat colinear with the "minima" points above it. Thus, this level, coinciding with the initiation of the Sangamon interglacial is a marker horizon at this site. It may further be noted that when the globorotalids attain its maximum relative dominance (76 p.c. of total Planktonic Forminifera at 375 cm core depth) over other two, the abundance of *Globorotalia menardii* is at its nadir (see fig. 3).

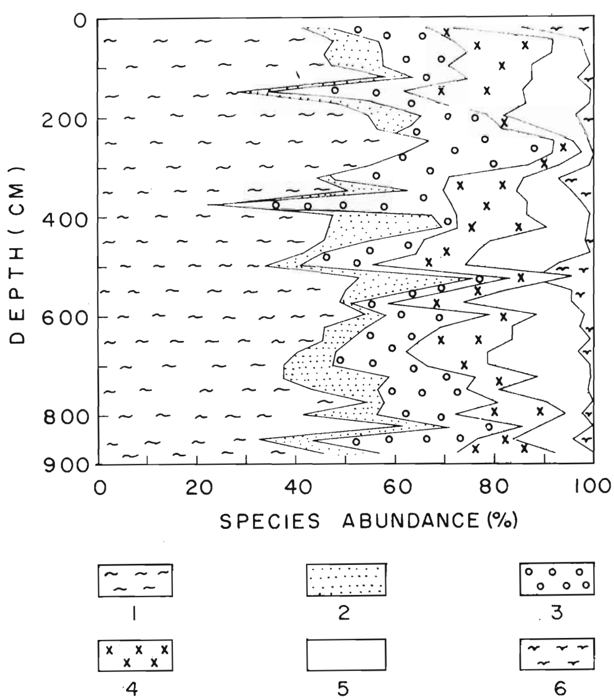

Fig. 3 Variation in Relative abundance (percentage) of five commonly occurring globorotalid species within the same family. 1 - *G. menardii*, 2 - *G. truncatulinoides*, 3 - *G. tumida*, 4 - *G. crassaformis*, 5 - *G. obesa* and 6 - other globorotalid species.

Among the globorotalids (fig. 3) *G. menardii* is the most dominant species followed by *G. tumida*. At depths where proportion of *G. menardii* increases (viz. 125 cm, 250 cm, 525 cm, 600 cm and 825 cm) that of other globorotalid species decreases distinctly, i.e., *G. menardii* increases at the expense of others of the same clan. At 275 cm depth, where *G. menardii* attains its maxima, *G. tumida* takes a high position at the cost of other globorotalids.

At majority of sample points in the globigerinid plot (fig. 4), *Neogloboquadrina dutertrei* is the most dominant species followed by *P. obliquiloculata*. At 250 cm, 275 cm, 300 cm and 375 cm levels this order is reversed, while at all other depths there is some

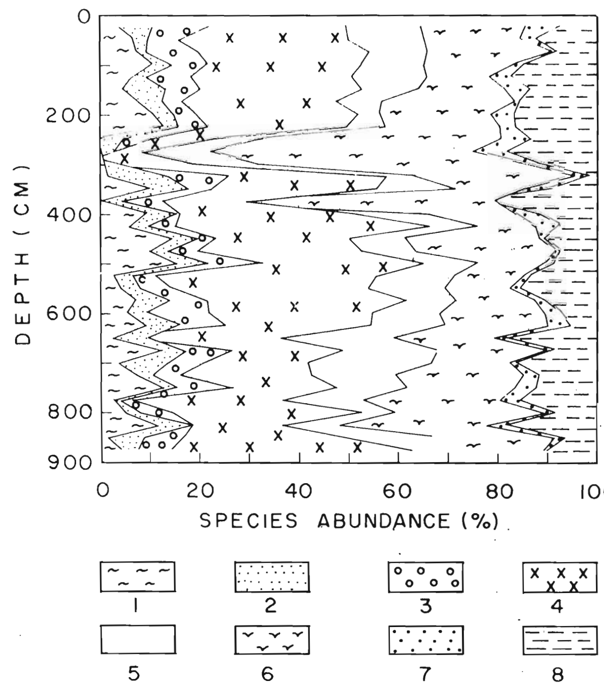

Fig. 4. Variation in Relative abundance (percentage) of seven commonly occurring globigerinid species within the same family. 1 - *G. ruber*, 2 - *G. sacculifer*, 3 - *G. triloba*, 4 - *N. dutertrei*, 5. - *P. finalis*, 6 - *P. obliquiloculata*, 7 - *O. universa* and 8 - other globigerinid species.

degree of parallelism in the distribution of commonly occurring globigerinid species. A comparison of the species abundance in the two dominant families at this site would show that the globigerinid faunule have a more equal sharing by their co-existing species, while *G. menardii* is singularly the major contributor among the globorotalids.

ANALYSIS OF ABUNDANCE DATA

Among others, salinity and temperature are the chief factors that control the fluctuations in abundance of foraminifera in the pelagic realm (Ghose and Jaiprakash, 1988). Since changes in salinity at the top 900 cm length of the core is insignificant (Gieskes, op cit.) and the site being in the open ocean away from continental margin, the variations in abundance of different taxa in these assemblages are thought to be due to changes in paleotemperature. The frequency distribution (count/gram) of total Planktonic Foraminifera and eleven commonly occurring species along the depth of the core has been shown in figures 5 and 6.

G. menardii is a tropical species that thrives best at oceanic water temperature in excess of 18°C and occurs with high density between 10°–20°N in the

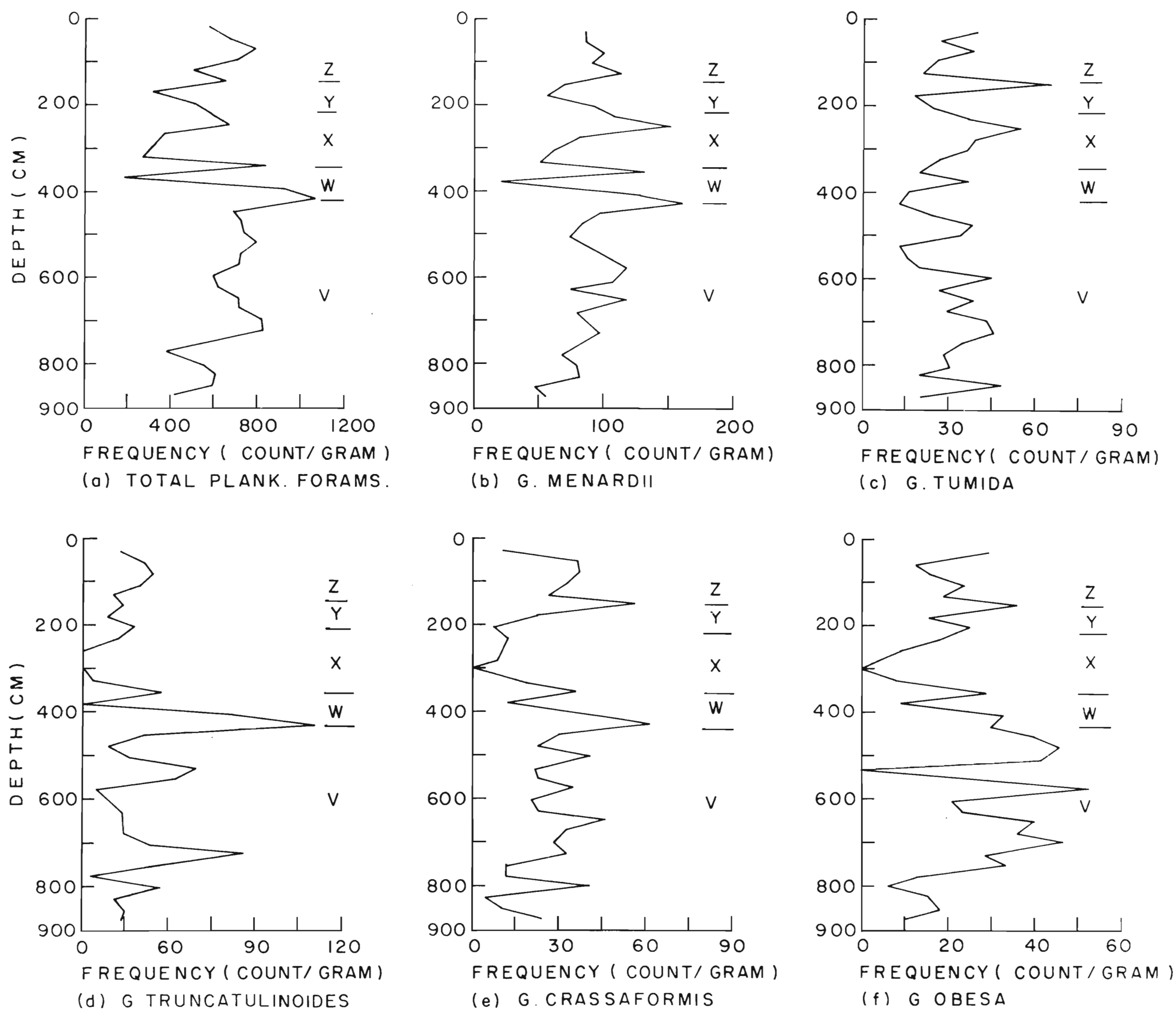

Fig. 5. Frequency distribution of total planktonic Foraminifera, and four other common globorotalid species.

Atlantic Ocean and just north of Equator in the Indian Ocean (Sengupta *et al.*, 1982). In the present site G;. *menardii* is the most abundant species (range 17 to 163 counts/gram). Based on fluctuation of abundance of *G. menardii*, Ericson zones (V, W, X, Y and Z) are delineated for this site (fig. 5b). The plot of *G. menardii* abundance show that the major peaks occur at 125 cm, 250 cm, 375 cm and 425 cm depth. The Ericson zones for the site 241 have been given in the table 1 with the corresponding glacial and interglacial periods set for the Atlantic region (Ericson *et al.*, 1961).

In the present study, the boundary between V-zone (Sangamon interglacial period), and W-zone (Early Wisconsin glacial period) has been demarcated at a depoth of 425 cm. The X-zone (Middle-Wisconsin) is separated from W-zone at a depth of

Table 1: Ericson zones based on *G. menardii* abundance for DSDP (ODP) Site 241.

Depth (cm)	Ericson-zones	Abundance of *G. menardii*
0–150	Z (Post-glacial)	Abundant
150–225	Y (Main-Wisconsin)	Low to considerably low.
225–350	X (Middle-Wisconsin)	Increasing trend
350–425	W (Early-Wisconsin)	Considerably low
425- to below downwards	V (Sangamon-Interglacial)	Moderate

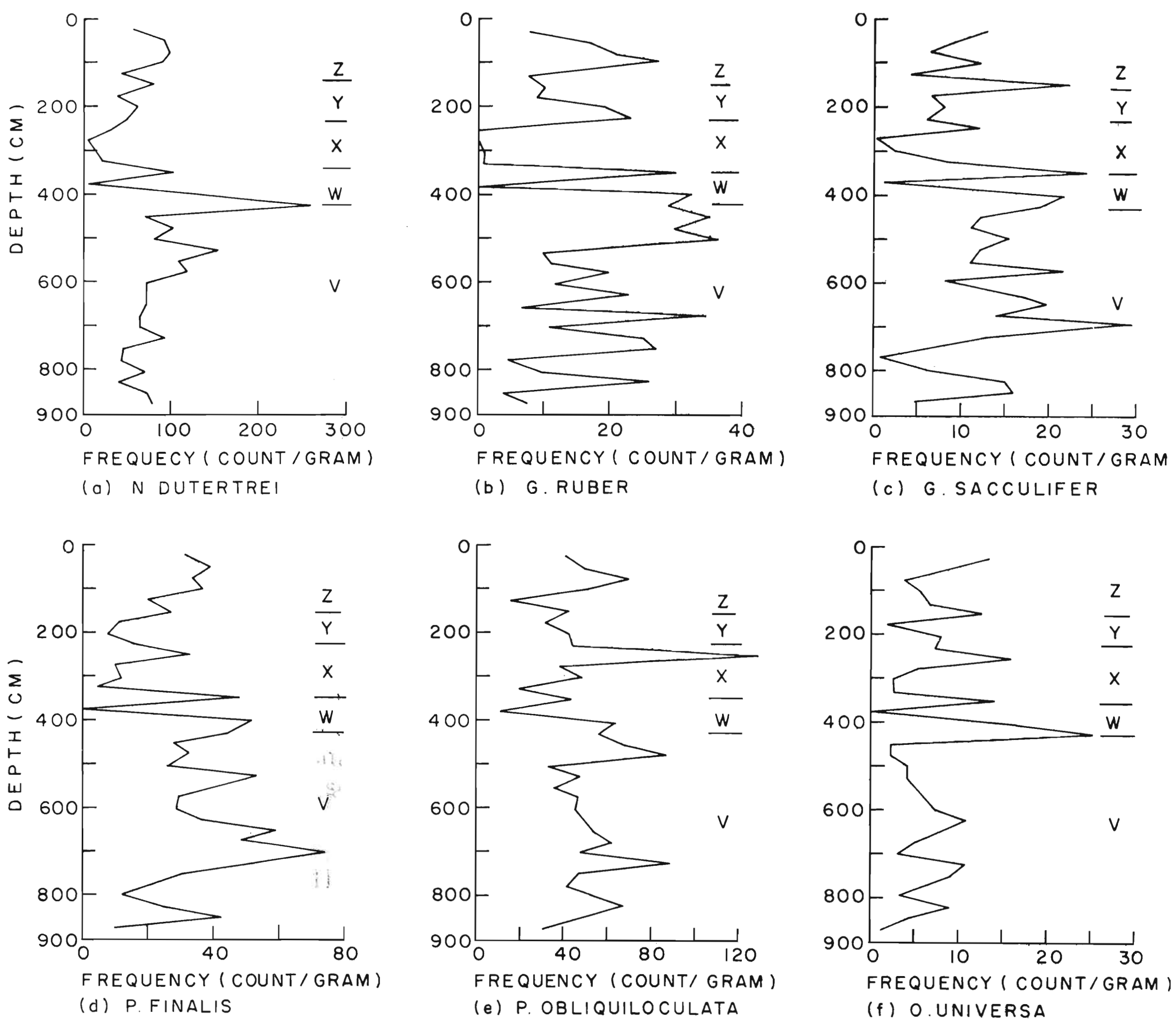

Fig. 6 Frequency distribution of six common globigerinid species.

350 cm. The boundary between Y-zone (Late-Wisconsin) and X-zone stands at a depth of 225 cm. The zone-Z (Post-glacial) begins at a depth of 150 cm.

The plot of *G. menardii* (fig. 5b) matches extremely well with that of total planktonics (fig. 5a). With a very few exceptions (fig. 5f), the fluctuations in abundance of other globorotalid species (figs. 4c, d and e) match with the *G. menardii* plot more than those of globigerinid species (figs. 6a-f).

Barring a few (viz. *Globorotalia tumida, Globigerinoides ruber* and *G. sacculifer*) all the nine curves (fig. 5 and 6) show a very prominent peak at a depth of 425 cm indicating the presence of a definite marker horizon. The boundary of V and W-zones has been marked at that level.

The zonation of W, X, Y and Z above 425 cm level can be marked in all the frequency curves with varying degree of precision. Below the 425 cm level some fluctuations in abundance are observed. This feature is more prominent in globigerinid species.

DIVERSITY

To obtain an estimate of diversity of the assemblages four indices have been used. They are (a) S, the total number of species present in a sample, (b) D, Yule's index of diversity (Williams, 1964) calculated as

$$D = N^2/\Sigma\, n\,(n-1)$$

where N is the total number of individuals present in a population and n is the number of individuals in a particular species within the population, (c) H, Shanon-Wiener function (Pielou, 1977) given by the formula

$$\bar{H} = -\sum_{i=1}^{s} pi \ln pi$$

where pi is the proportion of i-th species in a sample and (d) E, Equitability given by Buzas and Gibson's (in Pielou, 1969) equation

$$E = \frac{e^{\bar{H}}}{S}$$

The values of S, D, $\bar{H}$ and E are plotted along the depth (fig. 7). The levels of Ericson zones V, W, X, Y and Z at this site as indicated in figures 5 and 6 are also noted so as to compare the relation of fluctuations in diversity with the above zonation. The distribution of points in S and D show a high degree of parallelism except at 125 cm and 625 cm levels. At 125 cm level the relative abundance of *G. menardii* is the highest (34.13 p.c.) thus reducing the diversity of the assemblage. Again at 625 cm level the proportion of *G. menardii* is quite low (17.75 p.c.) and the assemblage shows the highest degree of evenness (E = 0.75) in this site. When the curves of H and D are compared, the trends towards 'highs' and 'lows' of H curve have similarity with those of D but fluctuations in the former are much less pronounced than in the latter. This is due to the fact that, while D considers the total number of individuals in a population and in a particular species as well. The measure H deals with both the number of species in an assemblage and the relative abundance of the species in it, i.e., with both richness and evenness. As a result the species that are very abundant or extremely rare have little effect on the value of H and the index is greatly influenced by a species of medium abundance. From a study of S, D and H curves it may be noted that fluctuations at 425 cm, 350 cm, 225 cm and 150 cm are quite significant and comparable to those of figures 5a and 5b. Thus Ericson zones W, X, Y and Z can be correlated with these diversity indices.

E, the equitability, measures the evenness of species present in it are in equal proportions regardless their number (S). In the present site the plot of E shows three distinct 'highs' ($E > 0.7$) at 150 cm, 500 cm and 625 cm levels, and two 'lows' ($E < 0.5$) at 125 cm and 275 cm. In majority of the assemblages the value of E is higher for samples with a low species number. At many levels the trend of E-curve at this site matches well with those of D and H plots. However, the fluctuations of E between 125 cm and 400 cm have general resemblance with other plots indicating an overall relation to the Ericson zones W, X, Y and Z.

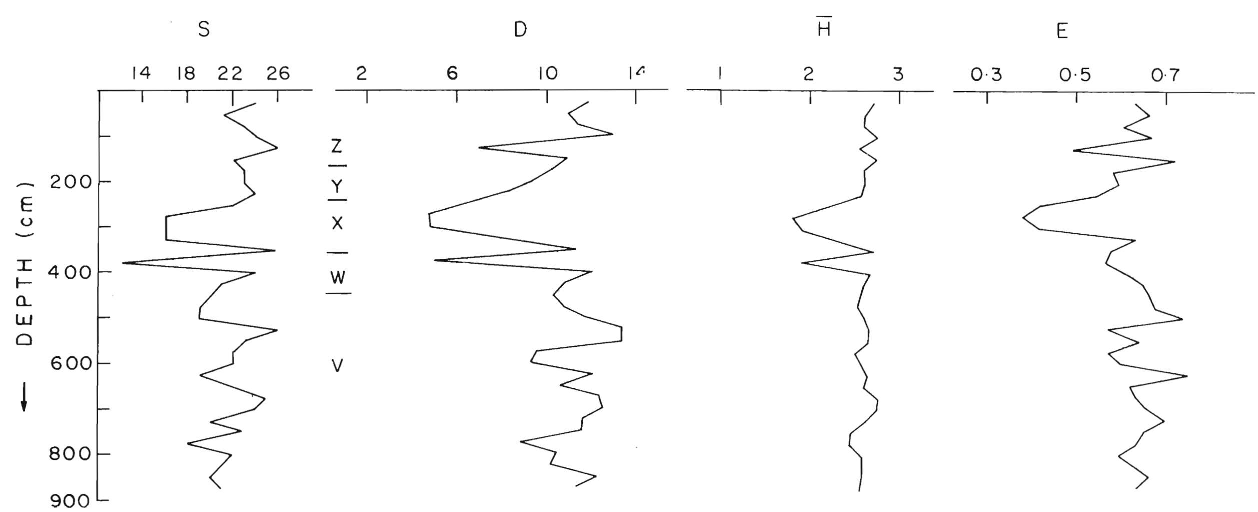

Fig. 7 Variation of S, D, H and E along depth in site 241.

CONCLUSION

The study of planktonic forminiferal faunules from 35 samples at regular interval from top 900 cm core of DSDP site 241 (leg 25) reveals the following:

(a) *Globorotalia menardii* is the most dominant species at majority of levels.
(b) While the globorotalids are conspicuously dominant above 400 cm depth, the globigerinids are important below that level.
(c) Where the globorotalids attain their maxima (at

275 cm core depth) *G. menardii* is at its lowest.

(d) In the globigerinid assemblages there is more equal-sharing by their co-existing species than by those in the globorotalid faunules.

(e) With the variation in the abundance data of total planktonic foraminifera and eleven commonly occurring species along depth of core, the V, W, X, Y and Z paleoclimatic zones of the Late Pleistocene (after Ericson *et al* 1961) can be delineated at this site.

(f) Fluctuations in the abundance of globorotalids and globigerinids and values of S, D, $\bar{H}$ and E of planktonic foraminiferal assemblages along the depth of core match the above zonation with varying degrees of precision.

(g) The initiation of the Sangamon Interglacial (V zone) at this site is a marker horizon where all the variation curves show a prominent peak around that level (400 cm).

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