29. BIOSTRATIGRAPHY

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UPPER TERTIARY BIOSTRATIGRAPHY, SITES 32 THROUGH 37

Foraminifera

Biostratigraphic Units

Upper Tertiary planktonic foraminifera found at Sites 32, 33, 34, 36 and 37 range in age from late Miocene to Pleistocene. The most important site for developing planktonic foraminiferal biostratigraphy is the continuously cored Site 36 in which planktonic foraminifera were present in all samples, except the 4 meters of sediment immediately overlying basalt. This site contains a foraminiferal sequence from the uppermost Miocene into the Pleistocene, therefore providing a valuable reference section to which the spot cores of the other sites can be compared.

Seven planktonic foraminiferal assemblages are apparent in the Site 36 section (Figure 1). Many of these assemblages resulted from climate-related shifting of ocean water masses, the most dramatic of which occurred in the Pleistocene. The assemblages outlined here are not proposed as formal zones but rather as informal biostratigraphic units useful for purposes of biostratigraphic and paleoclimatic analyses in the northeastern Pacific.

The first faunal unit (Figure 1) encountered in Site 36 is one dominated by the species *Globigerina bulloides* d'Orbigny and *Globigerina pachyderma* (Ehrenberg). *Globigerina quinqueloba* Natland, *Globigerinita glutinata* (Egger), *Globigerinita uvula* (Ehrenberg) and *Orbulina universa* d'Orbigny are species that persistently occur in this assemblage. *Globorotalia crassaformis* s.l. (Galloway and Wissler), *Globorotalia inflata* (d'Orbigny) and *Globorotalia hirsuta* (d'Orbigny) are species which appear sporadically, and at certain intervals are somewhat common. The subspecies *Globorotalia acostaensis pseudopima* Blow occurs rarely in the lower parts of the unit but, nevertheless, serves as an important indicator for this part of the unit.

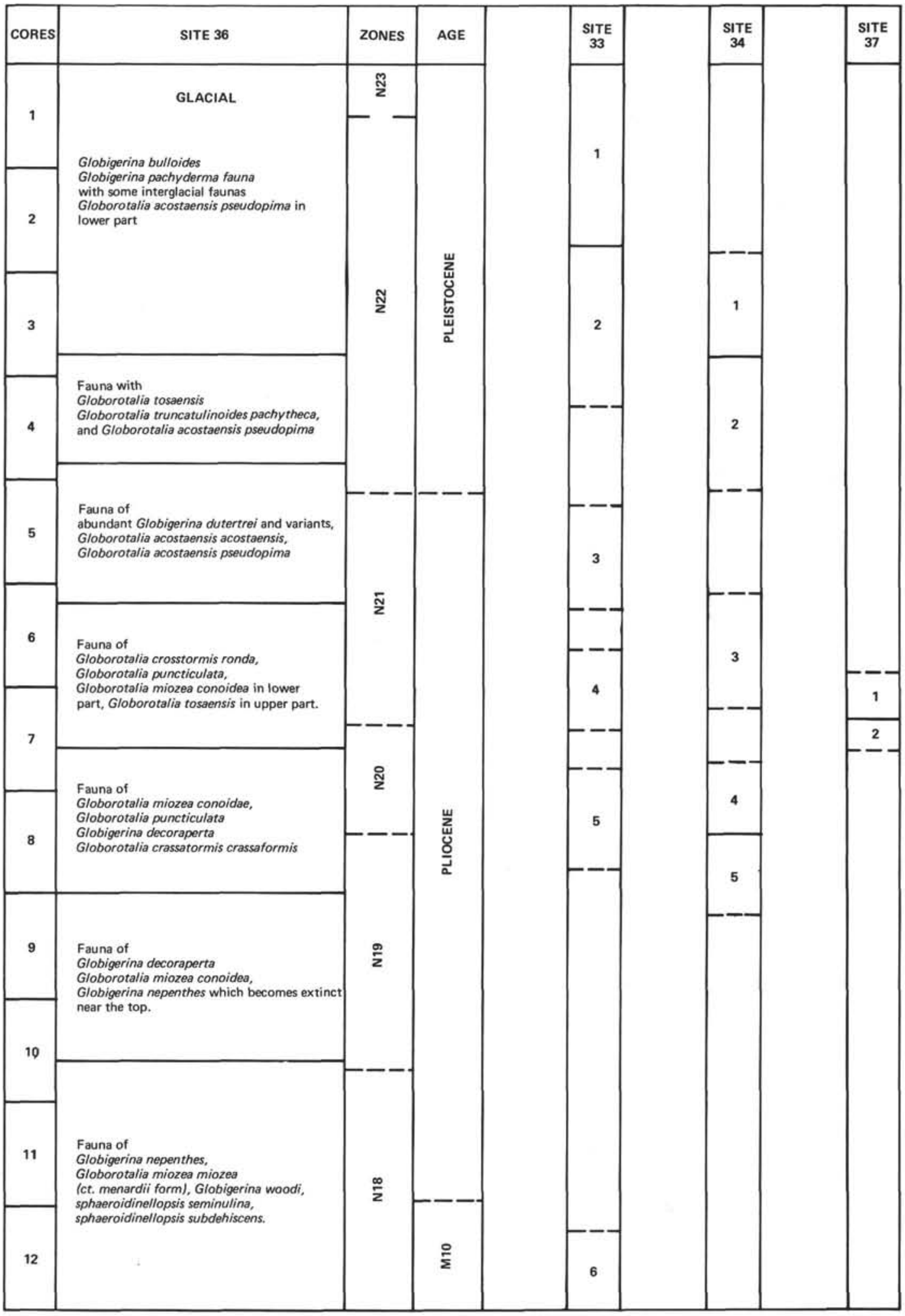
The second faunal unit (Figure 1) is characterized by common occurrences of *G. bulloides, G. acostaensis pseudopima, G. crassaformis* s.l. and *G. inflata*. In addition to these, two important biostratigraphic species, *Globorotalia tosaensis* Takayanagi and Saito and *Globorotalia truncatulinoides* (d'Orbigny) are present in this unit. *Globigerina pachyderma* is rare in marked contrast to its occurrence in the faunal unit above. Very rare occurrences of *Globorotalia acostaensis* Blow are also observed in the basal parts of this unit. The genus *Globigerinoides* is represented by very rare specimens of *G. ruber* (d'Orbigny) and *G. conglobatus* (Brady). Other species (Figure 2) are found in minor frequencies in this unit.

The third faunal unit (Figure 1) recognized here is characterized by an abundance of *Globigerina dutertrei* d'Orbigny and its variants, *G. acostaensis acostaensis,* and *G. acostaensis pseudopima*. Also present in varying frequencies are: *O. universa, G. crassaformis* s.l., *G. inflata, G. acostaensis humerosa* Takayanagi and Saito, *G. quinqueloba, G. glutinata and G. uvula.* The latter species does not range below this unit. *Globigerina pachyderma* is a very rare element of the fauna and it is not observed in the faunal unit below.

The fourth faunal unit contains an assemblage with an abundance of *G. crassaformis,* which for the most part can be identified to the subspecies *G. crassaformis ronda* Blow. *Globigerina dutertrei* is common, and some specimens seem to approach *Globigerina eggeri multiloba* Romeo in morphology. *Globorotalia puncticulata* (Deshayes) makes its first appearance in this unit and *Globorotalia miozea concoidea* Walters first occurs in the lower part of the unit. The upper part of the unit is characterized by specimens of *G. tosaensis,* which show transitional morphology to *G. crassaformis.*

The fifth faunal unit that can be recognized is identified by the association of *G. puncticulata, G. miozea conoidea, Globigerina decoraperta* Takayanagi and Saito, and *G. crassaformis* which for the most part is referable to *G. crassaformis crassaformis* (Galloway and Wissler). *Sphaeroidinellopsis seminulina* (Schwager) and *Sphaeroidinellopsis subdehiscens* Blow make their first appearance in the unit, and seem to become extinct close to the top.

The sixth faunal unit is distinguished by the association of *G. decoraperta* and *G. miozea conoidea* in the absence of *G. puncticulata. Globigerina nepenthes* Todd occurs rarely and becomes extinct near the top of the unit.



GLACIAL

Globigerina bulloides
Globigerina pachyderma fauna
with some interglacial faunas
Globorotalia acostaensis pseudopima in lower part

Fauna with
Globorotalia tosaensis
Globorotalia truncatulinoides pachytheca,
and *Globorotalia acostaensis pseudopima*

Fauna of
abundant *Globigerina dutertrei* and variants,
Globorotalia acostaensis acostaensis,
Globorotalia acostaensis pseudopima

Fauna of
Globorotalia crosstormis ronda,
Globorotalia puncticulata,
Globorotalia miozea conoidea in lower part, *Globorotalia tosaensis* in upper part.

Fauna of
Globorotalia miozea conoidae,
Globorotalia puncticulata
Globigerina decoraperta
Globorotalia crassatormis crassaformis

Fauna of
Globigerina decoraperta
Globorotalia miozea conoidea,
Globigerina nepenthes which becomes extinct near the top.

Fauna of
Globigerina nepenthes,
Globorotalia miozea miozea
(ct. menardii form), *Globigerina woodi*,
sphaeroidinellopsis seminulina,
sphaeroidinellopsis subdehiscens.

Figure 1. *Correlation of Sites 33, 34, 36, 37.*

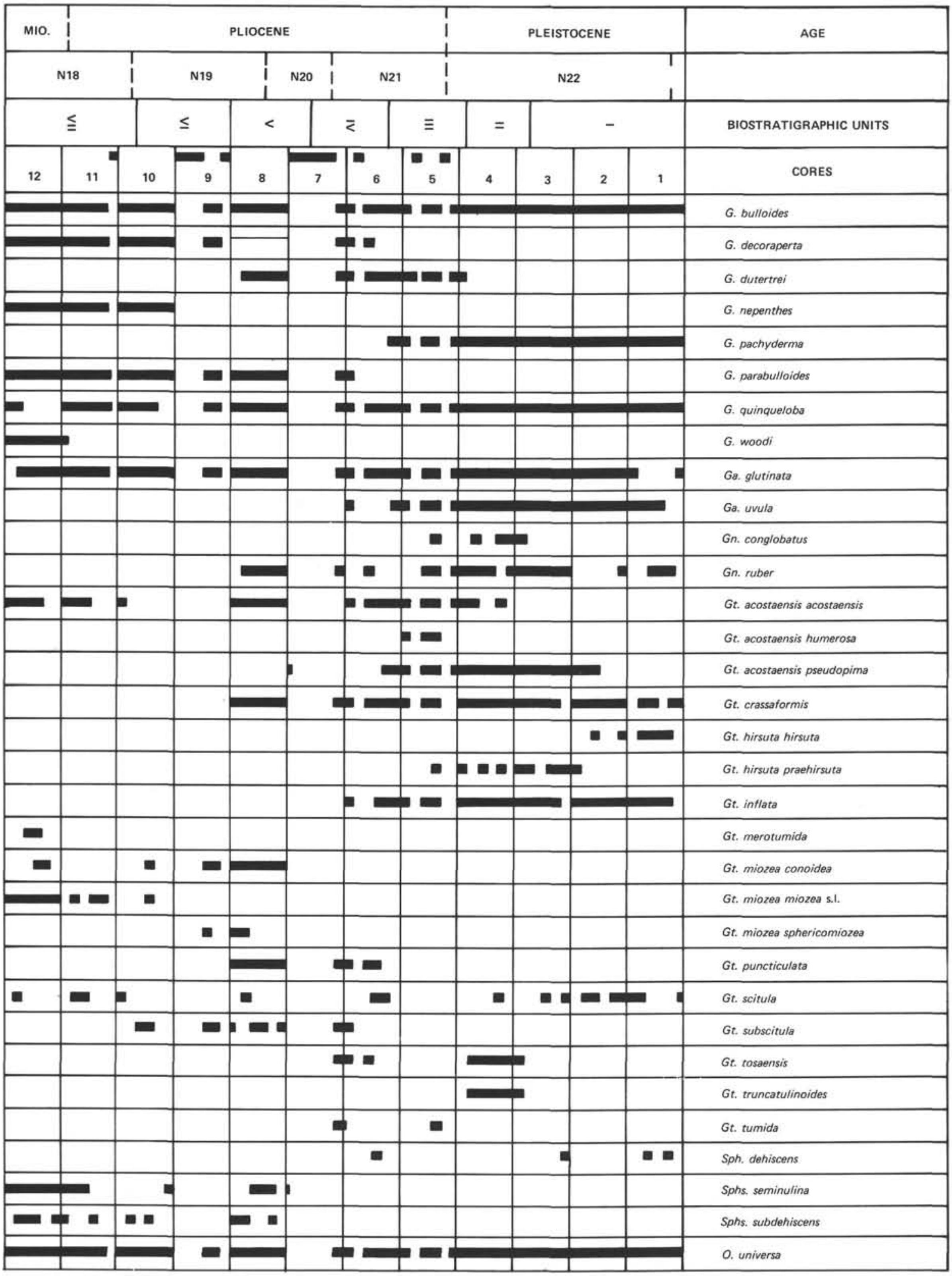


Figure 2. *Range of Species at Site 36.*

Globigerina parabulloides Blow is a fairly common faunal element along with *G. bulloides*.

The seventh faunal unit contains an assemblage with common occurrences of *G. nepenthes, S. seminulina, S. subdehiscens, Globigerina woodi* Jenkins and *Globorotalia miozea miozea* s.l. Finlay. The specimens of *G. miozea miozea* exhibit the morphology of the *G.* cf. *menardii* group of *G. miozea* that Walters (1965) described from the Upper Miocene strata of New Zealand. In association with this now extinct assemblage are: *O. universa, G. bulloides, G. quinqueloba* and *G. glutinata*, species which range throughout the entire section of Site 36.

Correlation

Approximate correlations of these biostratigraphic units can be made with Sites 33, 34 and 37; and, these are shown in Figure 1. Cores which lacked sufficient foraminifera are excluded. The upper and lower boundaries of spot cores can only be approximated in this correlation.

A very clear example of ecologic control on the geographic distribution of planktonic foraminiferal species is seen when one attempts to correlate the faunal sequences of Site 36 with the standard biostratigraphic zonation established in low latitude upper Miocene to Pleistocene sections (Figure 2). Most of the easily recognizable and diagnostic zonal species of the low latitudes are absent, so precise recognition of zone boundaries is not possible. Furthermore, superimposed on the biostratigraphic sequence of species is the effect of climate-related fluctuations of water masses. In the Site 36 section, however, certain species relationships do exist which aid in correlation with low latitude zonation. Of considerable help in attempting this correlation is the work of Hays *et al.* (1969) on deep-sea, Pliocene-Pleistocene cores from the tropical Pacific zone just south (about 37° of longitude) of Site 36. They have related planktonic foraminiferal biostratigraphy to the zonation of Blow (1969) and to paleomagnetic stratigraphy. They have also related certain events of foraminiferal evolution and extinction to magnetic events, which in turn have been fixed to an absolute time scale.

The mutual association of *Globorotalia tosaensis* and *Globorotalia truncatulinoides* in faunal unit II of Site 36 indicates that this unit lies within Zone N.22 of Blow (Figure 3). Because *G. tosaensis* becomes extinct below the top of N.22, the boundary of this zone with N.23 probably lies somewhere within faunal unit I. It is also possible that N.23, a late Pleistocene?-Holocene zone may not have been included in the first core because there was great uncertainty of contact with the bottom when the core was taken. *Globorotalia tosaensis* and *G. truncatulinoides* are not present in faunal unit III (Figure 3). *Globorotalia tosaensis* reappears in faunal unit IV so that its absence in Unit III is best explained by ecologic reasons. The absence of *G. truncatulinoides* is due apparently to evolutionary factors as well as to ecologic factors. The first evolutionary appearance of *G. truncatulinoides* from *G. tosaensis* was shown by Banner and Blow (1965) to take place near the base of the Pleistocene in the marine beds of the stratotype Calabrian Stage. Berggren *et al.* (1967) in a study of a North Atlantic deep-sea core found the first evolutionary appearance of *G. truncatulinoides* in the transition from *G. tosaensis* to occur within the Olduvai normal magnetic event and estimated the age of the Pliocene-Pleistocene boundary to be about 1.85 million years old. Hays *et al.* (1969) in their study of tropical Pacific deep-sea cores observed *G. truncatulinoides* to occur rarely in the Pleistocene, but they could not detect its level of evolutionary appearance. The level at which *G. truncatulinoides* evolves from *G. tosaensis* would seem to be within unit III of the Site 36 section. It is thought that this level lies in the upper part of unit III because of the abundance there of the distinctive Pliocene species *Globorotalia acostaensis acostaensis*, a form not known to range into Pleistocene sections elsewhere.

The extinction of discoasters was first used by Ericson *et al.* (1963) to approximate the Pliocene-Pleistocene boundary. Nanofossil data from Site 36 shows that discoasters were first identified in the uppermost part of Core 6, which would fall within faunal unit III. McIntyre *et al.* (1967) discussed the difficulty of relating discoasters to the boundary, and the work of Glass *et al.* (1967) and Berggren *et al.* (1967) shows significant disagreement. Of the four cores used by Hays *et al.* (1969), two showed some consistency whereas in the other two, discoasters were absent in one and showed an anomalous occurrence in the other. The first two showed discoasters to be sharply reduced in number close to the base of the Olduvai event. The occurrence of discoasters in the Site 36 section would suggest correspondence with the data of Hays *et al.*, but the faster rate of deposition at Site 36 might be expected to cause some differences. The analysis of the paleomagnetic stratigraphy of the Site 36 section, needless to say, would be most useful.

The appearance in faunal unit IV of specimens of *G. tosaensis*, transitional in morphology to *Globorotalia crassaformis*, is useful in identifying the lower parts of Zone N.21 (Figure 3). The zonal boundary between N.21 and N.20 would appear to lie within Core 7, somewhere near the division between faunal units IV and V. Unfortunately, most of Core 7 was not available for sampling (Figure 3). However, *Sphaeroidinellopsis subdehiscens* and *Sphaeroidinellopsis seminulina* are seen to range to the bottom of Core 7, and their mutual extinction level would seem to lie within the unsampled portion. The study of Hays *et al.* (1969) has shown

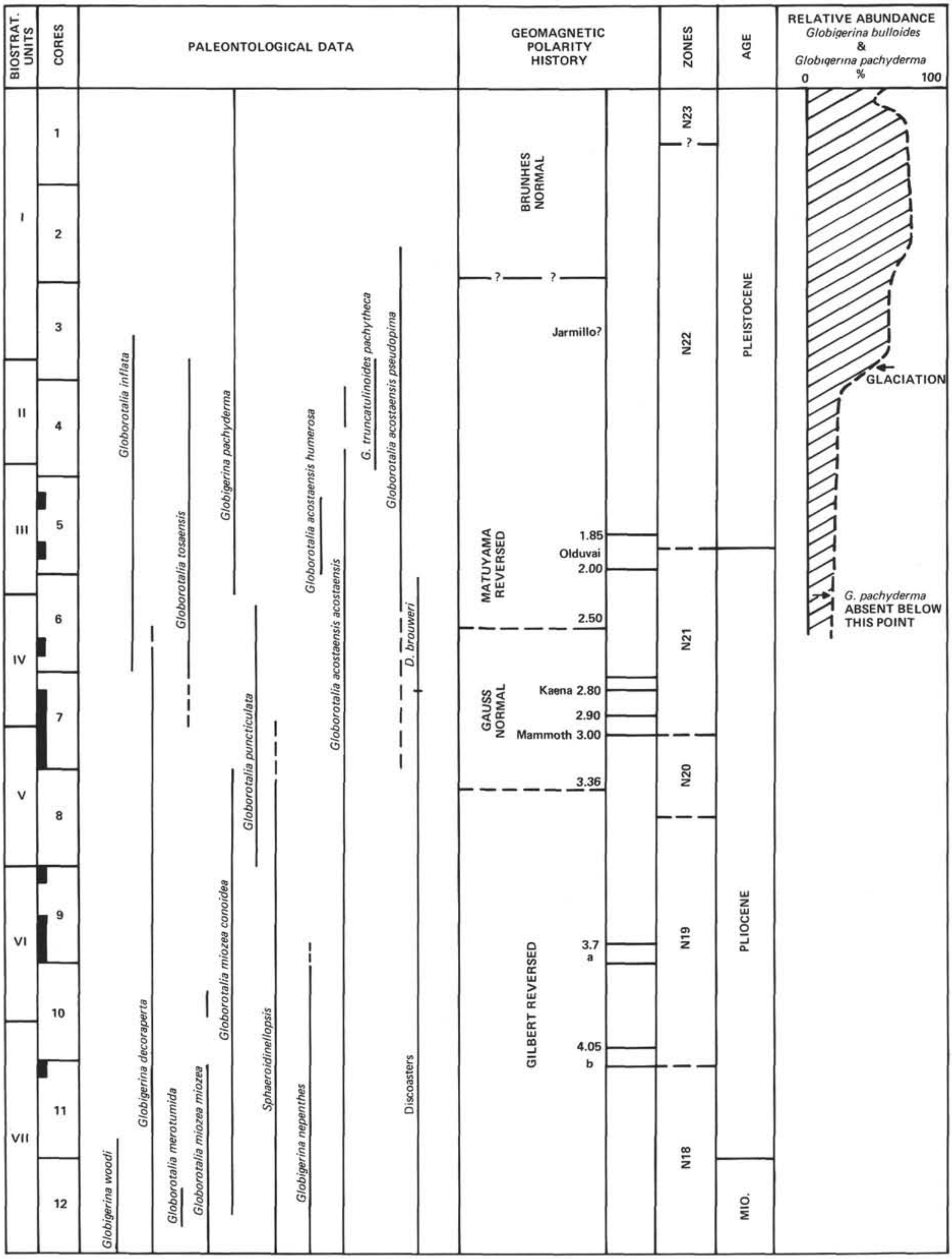


Figure 3. *Correlation of Site 36.*

that the extinction of *Sphaeroidinellopsis* occurs in the basal part of N.21 and is associated with the top of the Mammoth paleomagnetic event, dated as approximately 2.9 million years ago. Thus, it is reasonable to assume that the lower boundary of N.21 lies between the overlapping ranges of *Sphaeroidinellopsis* and *G. tosaensis* in Core 7. The range of *Globorotalia inflata* in the Site 36 section corresponds, in general, to the range of this species as reported in the upper Pliocene sections of Italy (Cati *et al.*, 1968) which are correlated approximately with N.21.

The N.20-N.19 boundary is rather uncertain in the Site 36 section. Blow (1969) has redefined the N.20 Zone, and bases the lower boundary on the first appearance of *Globorotalia acostaensis pseudopima.* This species, a common to abundant element in faunal units II and III, appears rarely in faunal unit IV. A few specimens of less typical morphology for this species are present in the bottom of Core 7. This occurrence perhaps suggests correspondence to N.20, but ecological conditions at this time have probably obscured a clear indication of this zone.

The extinction of *Globigerina nepenthes* is a useful datum for indicating the upper portion of N.19. Hays *et al. (1969)* have shown that this datum corresponds with the top of the Gilbert "a" magnetic event which is placed at 3.7 million years ago. This datum is judged to occur in the lower portion of Core 9, and lies within faunal unit VI.

The boundary of N.18-N.19 is also very uncertain, but the occurrence of *Globorotalia miozea miozea* s.l. in faunal unit VII gives a Miocene affinity to the assemblage. The presence of *Globorotalia merotumida* Blow and Banner in Core 12 supports a late Miocene age for the lower part of unit VII. The rather common occurrence of *Globigerina woodi* at this level may prove to be useful in identifying the upper Miocene in mid-to high-latitude sections.

Paleoclimatology

The vertical sequence of faunal assemblages observed in the Site 36 section appears to have resulted to a large degree from climatic deterioration and amelioration. The informal biostratigraphic units approximate geologic-climate units, because most of the assemblages of these units seem representative of water masses with definitive temperature characteristics. Consequently, the succession of these faunal units will bear directly on the climatic history of the northeastern Pacific.

Faunal unit I is composed of a subarctic fauna dominated by the species *Globigerina bulloides* and *Globigerina pachyderma*, the coiling direction of which is dominantly in the sinistral direction. These two species make up 60 to 75 per cent of faunas from this interval (Figure 3). Below this there is a very sharp drop in their abundance. *Globigerina pachyderma* occurs rarely below unit I (generally less than 5 per cent), and it disappears completely in faunal unit III. The very sharp boundary of unit I with unit II is indicative of severe climatic deterioration (Figure 4) caused by the onset of the Pleistocene glacial climate. One interglacial trend appears within Core 1 (Figure 4), but no clear pattern of alternating glacial and interglacial cycles is evident. Such a pattern may possibly emerge from more detailed sampling and a more detailed analysis of faunal abundance than was possible for this report. There is, however, some indication that the relative appearances of *Globorotalia inflata* and *Globorotalia crassaformis* may be a sensitive indicator of interglacial cycles.

Faunal unit II seems to best fit a transitional water assemblage because of the abundance of *G. inflata.* Living populations of *G. inflata* reach their maximum concentrations in transitional waters with surface temperatures between 15°C to 20°C. The presence of *Globorotalia truncatulinoides* in low frequencies and the increase in faunal diversity also supports this analysis.

Faunal unit III, with an abundance of large typically developed *Globgierina dutertrei,* is indicative of even warmer waters than unit II. Similar populations of living *G. dutertrei* occupy the outer margins of subtropical water masses and the fringes of transitional waters. *Globigerina dutertrei* is less common in faunal unit IV and, also, is represented by less typical forms with fewer chambers in the ultimate whorl. *Globorotalia crassaformis*, a common element of unit II and a rare element in unit III, again becomes common in unit IV and is associated there with *Globorotalia tosaensis. Globorotalia inflata* s.l. increases in frequency, although it is not as abundant as it was in unit II. These faunal characteristics of unit IV suggest a transitional water mass similar to that indicated for unit II.

The paleoclimatology of units V to VII is less certain because one is dealing increasingly with extinct species. Several generalities can be made, however, regarding possible climatic conditions.

The presence of the long ranging species *Orbulina universa, Globigerina quinqueloba, Globigerinita glutinata* and *Globigerina bulloides*; the general rarity of the genus *Globigerinoides*; and, the moderately high faunal diversity suggest water masses close to transitional in character. The species *Globorotalia miozea conoidea,* which is present in low frequencies in units V and VI, duplicates *Globorotalia truncatulinoides* to a considerable degree and thereby implies similarity in habitat. The slight increase in frequency of the genus *Sphaeroidinellopsis* in faunal unit VII might indicate, however, slightly warmer water masses during late Miocene-early

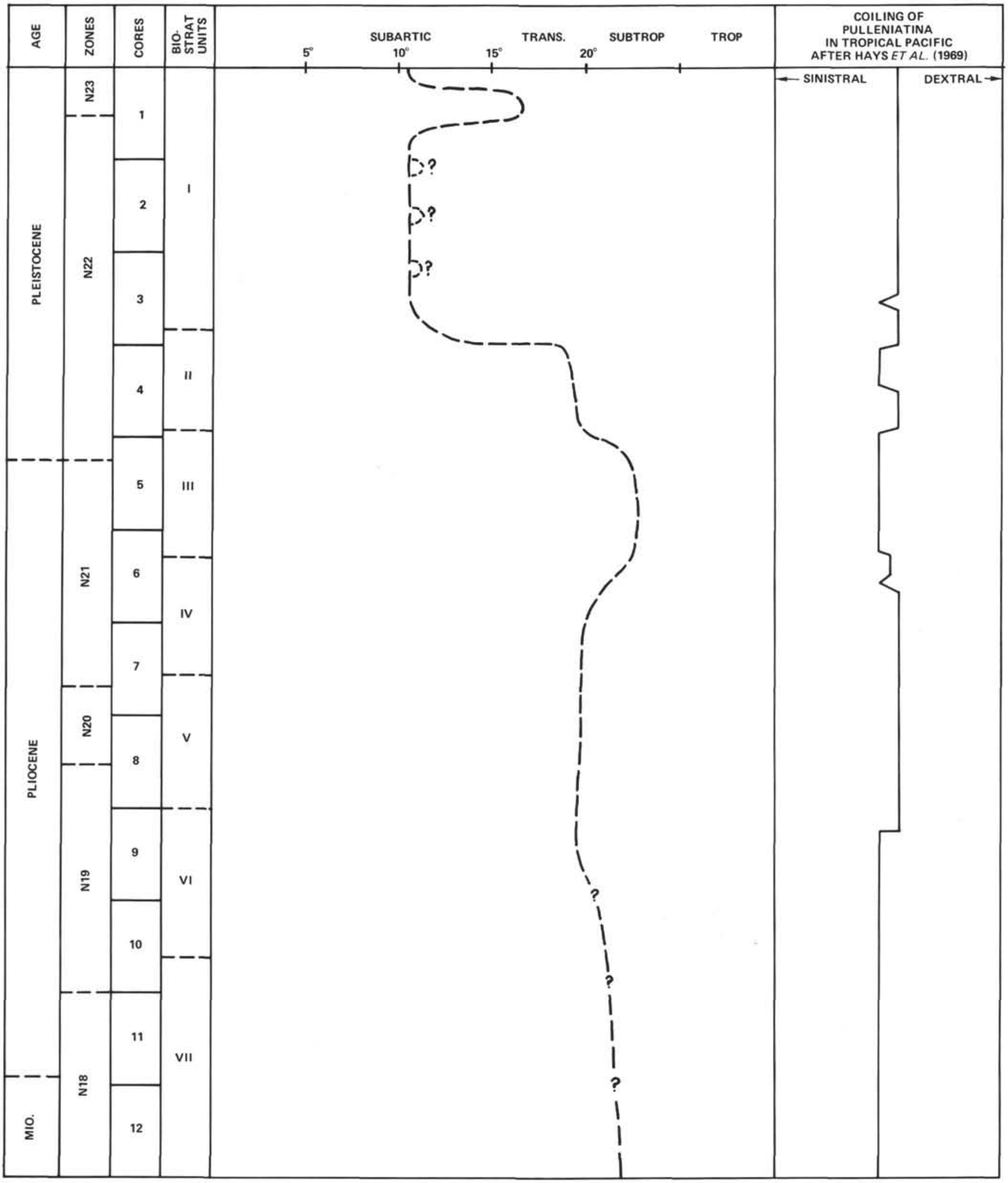


Figure 4. *Paleoclimate Curve Site 36.*

Pliocene time. The presence in units V and VII of *G. miozea* s.l. and the absence of various other species described from low latitude sections also shows the strong similarities of these assemblages with the upper Miocene-lower Pilocene planktonic assemblages reported from New Zealand (Jenkins, 1967, and various other workers). Thus, some insight is gained on the bipolar distribution of planktonic formainifera during this interval of geologic time. The work of Hays *et al.* (1969) on tropical Pacific cores south of Site 36 indicated a number of changes in the coiling direction of the genus *Pulleniatina* in the Pliocene and Pleistocene. Comparison of these changes with a paleoclimatic curve for Site 36 shows some interesting correlations (Figure). A change in the coiling direction of *Pulleniatina* occurs just after the extinction of *Globigerina nepenthes* and is used as a datum plane by Hays *et al.* Possibly, this datum correlates with the slight cooling trend suggested by the lower Pliocene of Site 36. A stronger correlation is seen with the next shift in coiling direction of *Pulleniatina* which occurs above the extinction datum of *Sphaeroidinellopsis* in mid N.21. It is at this approximate level that a warming trend occurs, as indicated by faunal unit III. *Pulleniatina* again shifts coiling direction near the Olduvai magnetic event and the Pliocene-Pleistocene boundary. It is at this point in the Site 36 section where cool transitional waters are indicated and, after a time, give way to subarctic waters. There seems to be little relationship between the Pleistocene coiling directions of *Pulleniatina* and the paleoclimatic curve for Site 36. Some might be related to interglacial stages, but the data of Hays *et al.* on carbonate cycles suggest that since the onset of glaciation no coiling changes have occurred.

Ericson *et al.* (1963) first recognized a level of extinction of discoasters in deep-sea cores which, along with other faunal criteria, was interpreted as indicating the onset of classical Pleistocene glaciation. Akers' (1965) work in the Gulf Coast showed discoaster extinctions occurring during a marine transgression. He concluded that the time of extinction was during the Aftonian interglacial. McIntyre *et al.* (1967) agreed with Akers that the time of extinction was probably during the warming trend of the first interglacial stage. The evidence from Site 36 shows that discoasters became extinct within a warming cycle but, in contrast to Akers' belief, prior to the onset of Pleistocene glaciation (Figure 4).

It has been shown recently (Selli, 1967) that "glacial" and "pre-glacial" Pleistocene are two distinct parts of the total Pleistocene Epoch. Selli's work has been supported by that of Berggren *et al.* (1967) and Hay *et al.* (1969). It is also supported by the data from Site 36, where a marked shift to a subarctic water mass is seen in the upper parts of the Pleistocene.

Radiolaria

The use of Radiolaria as precise age indicators for the cores collected from Sites 32 to 37 was hampered by several factors. Radiolaria were not found at Sites 35, 36 and 37, and they are present in significant numbers only for the middle Miocene to upper Pliocene interval of the sedimentary column cored at Sites 32, 33 and 34. In younger and older sediment, Radiolaria were either absent or scarce and poorly preserved. Few of the index species, whose biostratigraphic ranges are known in low latitudes, were found in these cores. Those index species that were identified were rare and their occurrences here may differ considerably from their stratigraphic ranges elsewhere. Finally, the species which constitute the majority of the Neogene radiolarian faunule of this region are temporally long ranging.

Despite these difficulties, these Radiolaria deserve more intensive investigation. Many of the species are undescribed, and their examination may contribute to our understanding of the radiolarian assemblage of the siliceous facies in the subarctic Pacific Basin. Diversity of the radiolarian faunule at Sites 32, 33 and 34 declines during the Pliocene, and more detailed investigation of this phenomenon may help explain the restricted nature of modern high-latitude radiolarian assemblages.

It is of interest to compare the ranges of the Radiolaria shown on the Biostratigraphy Charts of Sites 32, 33 and 34 with the system and subsystem boundaries in these cores as the latter have been interpreted from analysis of nannofossils and planktonic foraminifera. Radiolaria such as *Theocapsa cayeuxi* and *Cyrtocapsa pyrum*, which are common Miocene species in low latitudes, have a very limited occurrence in these cores. *Eucyritdium delmontense* first appears almost synchronously with *Ommatocampe hughesi* and disappears in the lower portion of the upper Miocene. The distinction between *Eucyrtidium delmontense* and *Eucyrtidium elongatum peregrinum* is especially difficult in samples with high percentages of incomplete specimens and other undescribed species appear to have morphologies intermediate to these two species. However, as they are strictly defined, *E, delmontense* and *E. elongatum peregrinum* do not have overlapping ranges in these cores. The occurrence of E. *elongatum peregrinum* is limited to late late Miocene and early Pliocene time. The complete absence of *Pterocanium prismatium* is unfortunate, because this species has been found to be a reliable marker for the Pliocene-Pleistocene boundary (Riedel *et al.*, 1963; Hays *et al.*, 1969).

Many of the species from high southern latitudes, which have been described by Hays (1965), also occur in the cores from Sites 32, 33 and 34. *Lamprocyclas heteroporus* becomes extinct at approximately the Pliocene-Pleistocene boundary in the Antarctic region (Hays, 1965; Hays *et al.*, 1969). At Sites 32, 33 and 34, the extinction of this species occurs at a horizon somewhat above the base of the Pleistocene as that boundary is interpreted on the basis of the disappearance of discoasters. This discrepancy may be the result of improper placement of the Pliocene-Pleistocene boundary. More probably, it reflects a real difference in the time of extinction of widely separated populations of *L. heteroporus*.

Caution must be exercised in drawing paleoenvironmental inferences from fossil abundances. The occurrences of Radiolaria in deep-sea sediment is controlled not only by their presence in the overlying water column, but by bottom water and interstitial water chemistry as well. At Sites 32, 33 and 34, the maximum abundance of Radiolaria is reached during the middle and late Miocene, and is coincident with increased diversity of the assemblage. The combined weight of these two factors supports the conclusion that production of Radiolaria in the overlying water mass was higher during the Middle and Late Miocene than in subsequent time. Because of the absence of Radiolaria at Sites 35, 36 and 37 it is concluded that this phenomenon was not contemporaneous for the North Pacific as a whole, but only occurred in the California Current System.

LOWER TERTIARY BIOSTRATIGRAPHY, SITES 38 THROUGH 42

Foraminifera

Paleocene, Eocene, and Oligocene planktonic foraminifera were found at Sites 39, 38 and 42, respectively. Solution of tests of foraminifera is particularly noticeable in the Paleocene samples where dissolution was almost complete, and relatively few specimens were recovered intact. At Site 42, penetration into the Middle Eocene was accomplished; however, except for the rare specimen, only the upper part of the Oligocene section yielded a sufficient number of species for a biostratigraphic analysis. Even here, the faunas were partly affected by solution with most of the small thin-walled species suffering destruction.

Although many species in the Paleocene fauna from Site 39 are lacking because of solution effects, a number of diagnostic species have been recovered so that a correlation can be established. The presence of *Globorotalia chapmani* Parr, *Acarinina primitiva* (Finlay), *Globorotalia aequa* Cushman and Renz, *Globorotalia planoconica* Subbotina and *Acarinina soldadoensis* (Bronnimann) suggest correlation with the uppermost Paleocene *Globorotalia velascoensis* Zone of Bolli (1957). The occurrence of specimens that exhibit morphology similar to the species *Acarinina pseudotopilensis* (Subbotina) and *Globorotalia formosa gracilia* Bolli would support correspondence with the higher parts of the *G. velascoensis* Zone. The appearance of *Globorotalia dolabrata* Jenkins, a species described from the New Zealand Paleocene and Lower Eocene sections, presents evidence on the bipolarity of Paleocene faunas. In this connection, *A. primitiva* and *G. chapmani* are species first described from southern hemisphere sections in New Zealand and Australia, respectively. Thus, even though recovery of fossils was poor at this site, the faunal data appears to indicate that a mid-latitude assemblage of latest Paleocene age was encountered at Site 39.

The Lower Eocene at Site 38 is represented by a rich well-preserved fauna. *Globorotalia aragonensis* Nuttall, *Acarinina quetra* (Bolli), *Globorotalia caucasica* Glaessner, *Globorotalia crassata*, and *Acarinina densa* (Cushman) are species, present at Site 38, which establish correlation with the uppermost part of the Lower Eocene [= *Globorotalia? palmerae* Zone of Bolli (1957) and the *Acarinina densa* Zone as used by Berggren (1969)]. The most characteristic aspect of the Site 38 fauna is the association of *G. aragonensis* and *G. caucasica*. The *G. aragonensis* and *G. caucasica* assemblage was first studied by Glaessner (1937) in the Eocene sections of the Caucasus Mountains. Pokorny (1960) noted this fauna in the Eocene sections of the Carpathians; Luterbacher (1964) noted the fauna from Eocene beds in southwestern France; and, Gohrbandt (1967) has studied the fauna from sections of the Austrian Eocene. This assemblage apparently was widely distributed in mid-latitude regions during late Early Eocene time. Also present at Site 38 are *Globorotalia wartsteinensis* Gohrbandt and *Subbotina inaequispira* (Subbotina), species which are only known from mid-latitude sections elsewhere.

Site 42 is located in a low latitude region and contains a typical low-latitude upper Oligocene fauna. The presence of *Globorotalia opima opima* Bolli, *Globorotalia opima nana* Bolli, *Globorotalia siakensis* LeRoy, *Globigerinita dissimilis* (Cushman and Bermudez) and *Globigerinita unicava* (Bolli, Loeblich, and Tappan) equate this fauna with the *Globorotalia opima opima* Zone of Bolli (1957). The occurrence of *Globoquadrina baroemoenensis* (LeRoy) indicates a correspondence with the upper parts of the *G. opima opima* Zone, since the genus *Globoquadrina* first evolves in the middle parts of this zone. The species *G. dissimilia* and *G. unicava* were also noted in the lower Oligocene section at Site 34. Several other species described from low-latitude sections were present at Site 34. These include: *Globigerina ampliapertura* Bolli, *Globigerina angulioficinalis* Blow, *Globigerina praebulloides* Blow, *Globigerina ouachitaensis ciperoensis* Bolli, and *Globigerinita martini martini* Blow and Banner.

Thus, it can be seen in contrast to the upper Tertiary planktonic faunas recorded during Leg 5, that planktonic foraminiferal species are more broadly distributed on a latitudinal basis in the lower Tertiary sections. Latitudinal differences between faunas appear to show low numbers of latitudinally restricted species. This suggests that significant faunal differences along the direction of latitude may lie in the relative abundance of species. The broad distribution of species during the early Tertiary corresponds with the general knowledge of climatic history at this time which indicates little in the way of severe climatic alteration.

Radiolaria

A stratigraphic comparison of high- and low-latitude fossil assemblages was one of the initial objectives of the suite of Sites along 140 W. longitude. For the Radiolaria, such a comparison cannot be made because these fossils were not found at Sites 37, 38 and 39. Site 43 was undertaken in order to test new drilling procedures which were largely unsuccessful. The cores from this hole were considered to be highly disturbed and to have little stratigraphic value. Abundant Radiolaria are present in the recovery from Sites 40, 41 and 42.

At Site 41, a shallow sediment basin only 34 meters thick overlies the basement. The lower 16 meters of the section is radiolarian ooze of middle and late Eocene age, which is overlain by zeolitic red clay. Thin intercalations in this red clay contain Eocene Radiolaria with a few poorly preserved late Tertiary species. Although this site was originally believed to be typical of this region of the Pacific, which is characterized by a very thin sedimentary section, the basal sediment is significantly younger than the age of the basement based on magnetic anomaly studies. Moreover, the age of the deepest sediment recovered at Site 40 was as much as five million years older than the basal sediment at Site 41, and drilling stopped at Site 40 at an unknown depth above the igneous basement. From these results, it can be concluded that the section at Site 41 contains large scale hiatuses, and the oldest sediment recovered does not reflect the true age of the basement rock.

Sites 40 and 42 provide excellent material for biostratigraphic studies of early Tertiary Radiolaria. The upper 143 meters of the section at Site 40 was continuously cored with 99 per cent recovery. With the exception of the upper ten meters of zeolitic red clay, this section is entirely radiolarian ooze of early to late Eocene age. At Site 42, 113 meters of ooze and chalk ooze, which ranges in age from middle Eocene to late Oligocene, were continuously cored with 92 per cent recovery. The cores from these two sites can be arranged to form a composite section of radiolarian sediment that encompasses much of Eocene and Oligocene time. As is almost universally true, discontinuities exist in this section, although at the time of this writing, it is not possible to determine their exact position and magnitude. It will be necessary to compare this composite section with the Radiolaria from Site 29 (Leg 4) of the Caribbean Sea and the Oceanic Formation of Barbados. Work in progress on this project leads me to conclude that a significant portion of middle Eocene time is not recorded by sedimentation at Site 40. In addition, a distinct faunal change occurs in the bottom of Core 5 of Site 42, and the author believes that portions of the *Globigeraypsis semiinvoluta* and *Globigerina sellii* zones are missing at this horizon. This work is still in a preliminary stage, however, and these conclusions must remain tentative.

E. D. Milow found that the majority of the nannofossils in Sections 1 through 5, Core 7, Site 42 are Oligocene in age. This Oligocene sequence, which is overlain and underlain by Eocene sediment, must be explained by drilling or structural disturbances. However, the great majority of the Radiolaria in Core 7 are late Eocene species that are present in Cores 6 and 8. Less than 5 per cent of the Radiolaria in Core 7 are species presently regarded as being restricted to the Oligocene. Therefore, the process causing displacement of Oligocene nannofossils in Core 7 had a very minor effect on the radiolarian assemblage.

Nannoplankton

A discussion of the comparative tropical and cool-water calcareous nannoplankton flora will be presented in Volume 9 under the authorship of E. D. Milow.

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