

8. BIOSTRATIGRAPHIC SUMMARY, DEEP SEA DRILLING PROJECT LEG 73¹

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ABSTRACT

Biostratigraphic data from Leg 73 sites on the eastern flank of the Mid-Atlantic Ridge (Angola Basin) and Walvis Ridge are remarkably complete. Only portions of the early Eocene were uncored. Where both calcareous nannofossils and planktonic foraminifers were present and well preserved (late Maestrichtian, Paleocene, middle Eocene, latest Eocene, Oligocene, earliest Miocene, middle Miocene (parts), Pliocene, and Quaternary), the correlations between the zones of the two groups corroborate correlations previously described in the literature.

INTRODUCTION

One of the principal objectives of DSDP Leg 73 was to develop the correlation between the reversal history of the earth's magnetic field and biostratigraphic zonations. To accomplish this end requires the acquisition and synthesis of detailed biostratigraphic observations. The purpose of this paper is to provide a summary and survey of the biostratigraphic observations made on various microfossil groups. Details of floral and faunal distributions and taxonomy are given in Clark and Wright (this vol.), Gombos (this vol.), Percival (this vol.), Poore (this vol.), and Smith and Poore (this vol.), as well as the separate site chapters. Two synthesis chapters also deal with biostratigraphic observations and chronostratigraphy (Poore et al., this vol.; and Hsü et al., this vol.).

Of the six sites occupied by the *Glomar Challenger* during Leg 73, five yielded excellent biostratigraphic data. Hole 520 was drilled in ponded sediments in a sea-floor depression; extensive slump and turbidite deposits made the development of high resolution biostratigraphy difficult. Of the other five sites, four (519, 521, 522, and 523) were cored with the hydraulic piston corer (HPC).

The primary sources of biostratigraphic data for Leg 73 are the calcareous nannofossils and planktonic foraminifers. Diatoms proved to be useful in the late Paleocene, and benthic foraminifers were helpful near the Oligocene/Eocene boundary. In general, the calcareous nannofossils were the most consistently useful, because they persisted in some intervals where the foraminifers were strongly dissolved (in parts of the early and middle Miocene, late Oligocene, late Eocene, and late Paleocene).

The biostratigraphic zonations used for different parts of the stratigraphic column depend on the par-

ticular assemblages present. The calcareous nannofossil zonation of Martini (1971) is used throughout the Cenozoic section; it is supplemented in the middle Eocene to late Oligocene and parts of the Miocene by that of Bukry (1975). The planktonic foraminiferal zonation of Stainforth et al. (1975) was used wherever possible, which is to say, throughout most of the Cenozoic. This zonation was supplemented in the middle Eocene by that of Toumarkine and Bolli (1970) and in the Oligocene by a new zonation (Poore, this vol.). The zonation of Blow (1969) proved to be helpful in the Miocene, as did that of Berggren (1973, 1977) in the Pliocene. The diatom zonation of Gombos (1977) was used in the Paleocene.

The following discussion describes the biostratigraphic evidence found at the Leg 73 sites.

CRETACEOUS

Nannofossil and calcareous claystones interbedded with volcanoclastic sandstones contain a diverse Maestrichtian flora and fauna. Calcareous nannofossils were used to define the Cretaceous/Tertiary boundary, which occurred at Sample 524-20-3, 106 cm (Hsü et al, 1982; Percival, this vol.). The *Micula mura* Zone of the Maestrichtian is underlain by the *Nephrolithus frequens* Zone of the same stage. Sediments from the *Abathomphalus mayaroensis* and *Globotruncana gansseri* foraminiferal subzones are present; detailed studies of the planktonic foraminifers place most of the Cretaceous sediments recovered during Leg 73 in the early late Maestrichtian (Smith and Poore, this vol.).

PALEOCENE

All the Martini calcareous nannofossil zones of the early Paleocene are identified by their primary datums. The Stainforth et al. planktonic foraminifer zones are also recognized by their primary datums. The correlations between the early Paleocene nannofossil and foraminifer zonations in Leg 73 are consistent on the whole with those described from the literature (see Hardenbol and Berggren, 1978).

¹ Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP, 73*: Washington (U.S. Govt. Printing Office).

Of the six late Paleocene calcareous nannoplankton zones (NP4 through NP9), four are delimited by their primary markers. The base of NP7 is estimated by the lowest occurrence (LO) of *Discoaster mohleri*, which is, however, the primary marker for Zone CP6 of Bukry and appears to be equivalent to NP7. The location of the base of NP8 is estimated by the secondary marker, *Heliolithus kleinpellii*, the highest occurrence (HO) of which lies very near the top of NP7 and is a good approximation of the NP8/NP7 boundary.

The late Paleocene foraminifer zones are less well documented. The late/early Paleocene boundary is defined biostratigraphically by the first appearance datum (FAD) of *Morozovella angulata*. This species occurs at the same level as *M. conicotruncata* in Leg 73 sediments, and the base of the *M. angulata* Zone is placed in Hole 524 by interpolation. The base of the *M. pusilla* Zone is located by the LO of the nominate species. The FAD of *Planorotalites pseudomenardii* defines the base of the zone of the same name. It is, however, not clear if the LO of this taxon in Leg 73 is also its FAD. The LO of this species occurs at approximately 66 m sub-bottom in Core 524-5. This is within an interval of relatively strong dissolution (from 60 to 95 m sub-bottom), and the true FAD of *P. pseudomenardii* probably lies below its LO. An additional problem arises if the LO of *P. pseudomenardii* is placed in Core 524-5; it causes the correlation of the FAD of *P. pseudomenardii* with the FAD of *Discoaster multiradiatus*, that is, the correlation of the base of the *P. pseudomenardii* Zone with NP9 (base). Most observations of calcareous nannofossil and planktonic foraminifer distributions place the FAD of *P. pseudomenardii* at or very near the base of NP6 (Bolli and Cita, 1960; Hay and Mohler, 1967; Cita et al., 1968; Hardenbol and Berggren, 1978).

The uppermost foraminifer zone of the late Paleocene, the *M. velascoensis* Zone, is not defined in Leg 73 sediments.

Except for the *P. pseudomenardii* Zone, the correlations between nannofossil zones and foraminifer zones correspond well to those described in the literature.

An additional cross correlation between microfossil zonations is provided by the presence of late Paleocene diatoms in Hole 524. These diatoms are placed in the *Hemiaulus inaequilaterus* Zone (Gombos, this vol.) and correspond to the calcareous nannofossil zone NP9.

EARLY EOCENE

All except the uppermost lower Eocene sediments were recovered during Leg 73. Sediments from all the calcareous nannofossil zones (NP10 to NP13) were identified, although the NP14/NP13 boundary (the middle/early Eocene boundary) was not observed. Secondary nannofossil markers were used to identify two of the four NP zones. The HO of *Fasciculithus tympaniformis* provided a good estimate of the NP10/NP9 boundary (the Eocene/Paleocene boundary). The HO of *Discoaster multiradiatus* was used as a secondary indicator to estimate the base of NP11. Unfortunately, planktonic foraminiferal recovery from the early Eocene sediments

was not good, and it was not possible to develop a foraminiferal zonation.

MIDDLE EOCENE

The middle Eocene calcareous nannoplankton are diverse and well represented in Leg 73. The zonation of Bukry (1975) proved to be more useful than that of Martini (1971), in large part because the former zonation scheme is based on deep sea (albeit low latitude) sections, whereas the latter scheme is based on Paleocene sections from the continental margin.

The earliest sediments of the middle Eocene were not cored during Leg 73. The earliest sediments recovered are assigned to Zone NP15 (Martini) or CP13b (Bukry). Of the middle Eocene zonal boundaries of Martini, only the NP17/NP16 boundary is recognized by the presence of a primary indicator. However, all of the post-CP13b zones of Bukry can be identified by their primary datums. The middle Eocene planktonic foraminifer zones of Toumarkine and Bolli (1970) can be recognized more readily in the Leg 73 material than can the zones of Stainforth et al. (1975). The use of the Toumarkine and Bolli zonation creates some difficulty in checking the correlation between the calcareous nannofossils and planktonic foraminifers. This zonation is based on the middle to late Eocene section at Possagno in northern Italy. Although the calcareous nannofossils from this section have been described biostratigraphically (Proto Decima et al., 1975), a significant degree of reworking in the nannoplankton precludes the use of the HOs for zonation; only the LOs are reliable. Unfortunately, in that part of the middle Eocene included in Leg 73 material, only one zonal boundary is defined by an FAD. That one is the base of CP14a, which is defined by the FAD of *Reticulofenestra umbilica*. Even in this case, no clear correlation can be made because the synonymy and discussion in Proto Decima et al. (1975) do not make it clear whether *R. hillae* is included in the concept of *R. umbilica*.

LATE EOCENE

The late Eocene sections in Holes 522 and 523 are affected by intense carbonate dissolution. This dissolution has little apparent effect on the calcareous nannofossils; all of the Bukry zones are recognized by their primary datums, and only NP19 is unclear among the Martini zones. This zone is unclear in Leg 73 because the LO of *Isthmolithus recurvus*, which defines the base of NP19, lies above the LO of *Sphenolithus pseudoradians*, which defines the base of NP20. This reversal of datum positions could raise questions about the synchronicity, and consequently the utility, of these two datums for fine resolution biostratigraphy were it not for the degree of dissolution that occurs at this level in Hole 523. *I. recurvus* is a holococcolith and as such is more easily dissolved. Its FAD may lie below its LO in Hole 523.

The dissolution of late Eocene sediments precludes good planktonic foraminifer zonation. Between 80 and 100% of the planktonic tests are fragmented in this interval, and from 40 to 80% of the foraminiferal tests

observed in samples are benthic. Although typical assemblages of the *Globigerinatheka semiinvoluta* Zone can be recognized in Hole 523, the boundaries of the zone cannot be located precisely. The lowest sediments of Hole 522 and 522A are part of the *Globorotalia cerroazulensis* Zone, the upper limit of which (the Oligocene/Eocene boundary) is well defined in Hole 522 by the HO of the nominate species. The correlations between calcareous nannofossils and planktonic foraminifers are like those described elsewhere, where they can be observed.

OLIGOCENE

Despite some intervals of moderately strong carbonate dissolution, the Oligocene biostratigraphic record recovered in Holes 522 and 523 is remarkably complete. Almost all the calcareous nannofossil zones of Martini are present and can be delineated by their primary datums. Only the top of NP25, defined by the last appearance datum (LAD) of *Helicopontosphaera recta*, is estimated by a secondary indicator, the HO of *Reticulofenestra bisecta*. All the zones and all except one of the subzones of Bukry are present and identified by their primary datums. Only the CP16b/CP16a boundary is unidentified. This boundary, which approximates the Oligocene/Eocene boundary, is defined by the end of the acme of *Coccolithus subdistichus*, a taxon not present in Leg 73 sediments.

The planktonic foraminiferal zones of Stainforth et al. are all present, although the base of the *Globorotalia opima opima* Zone is somewhat unclear. This datum is defined by the FAD of *G. opima opima*. Although the species is clearly present in Hole 522, the precise LO is confused by specimens of *Globorotalia* sp. aff. *G. opima opima* (see Poore, this vol.). The distribution of planktonic foraminifers in Hole 522 lends itself to a higher resolution zonation than that afforded by the Stainforth et al. scheme. Poore (this vol.) developed six zones (OL1 to OL6) to provide this zonation.

The correlation between the calcareous nannofossil zones and those of the planktonic foraminifers generally conforms to that synthesized by Hardenbol and Berggren (1978). There is one problem area. The position of the last consistent occurrence of *Pseudohastigerina* spp. in Hole 522 corresponds to the LO of *Sphenolithus distentus* and lies just above the LO of *R. umbilica*. This correlation places the top of the *Cassigerinella chipolensis-P. micra* Zone of Stainforth et al. (top of OL1 of Poore) in the very lowest part of NP23, a correlation that differs from standard correlations. In Hole 522 there are isolated specimens of *Pseudohastigerina* spp. lying ~11 m above their last consistent occurrence. If this occurrence is used as the HO of the taxon, the cross correlation with nannofossil biostratigraphy is in agreement with the literature (Hardenbol and Berggren, 1978). Additional work is necessary to test the new calibration suggested by the Hole 522 results.

MIOCENE

Extensive dissolution in all except parts of the early middle Miocene and latest Miocene has removed sub-

stantial carbonate from the Miocene sediment record. Consequently, only portions of the Miocene biostratigraphic record can be documented. Even where calcareous-nannofossil-rich sections are present, the degree of dissolution resulted in condensed intervals that make biostratigraphic resolution difficult.

The Miocene/Oligocene boundary lies in relatively undissolved sediments and is defined with calcareous nannofossils by the CN1a/CP19b boundary of Bukry. The absence of *Helicopontosphaera recta* in Leg 73 sediments precludes the placement of the NN1/NP25 boundary of Martini. The NN2/NN1 boundary is located by its primary datum, but no other early Miocene calcareous nannofossil datums are present. Among the planktonic foraminifers the N4/P22 boundary is clearly located, but no other datum-marking foraminifers of the early Miocene survived the dissolution episodes.

The middle/early Miocene boundary as defined by calcareous nannofossils is located approximately by a secondary datum, the HO of *Helicosphaera euphratis*. Other middle Miocene zonal boundaries of Martini that can be recognized are the NN6/NN5 (by primary datum), the NN7/NN6 (by the HO of *Cyclicargolithus floridanus*, a secondary datum in the Martini zonation but the primary indicators of the CN5b/CN5a boundary of Bukry), and the NN8/NN7 (by primary datum). Although neither the base nor the top of NN9 can be recognized, a mid-NN9 datum is present (the LO of *Catinnaster calyculus*, which defines the CN7b/CN7a boundary).

The middle Miocene planktonic foraminifers are poorly represented except for Blow's Zones N8 and N9. The LO of *Orbulina*, which defines the boundary between these two zones, correlates with the nannofossil zone NN5.

The late Miocene sequences are also subject to dissolution, and it is only in sediments of the shallowest of the five sites with magnetostratigraphy (Site 519) that *Discoaster quinqueramus* is present. Even there, the range of this taxon (which defines both the base and the top of NN11) seems quite condensed and may be shortened by dissolution. Although assemblages of the planktonic foraminifer zones N16 and N17 can be recognized in Hole 519, none of the bounding datum species are present.

PLIOCENE AND QUATERNARY

All the calcareous nannofossil zones are recognized by their primary datums in the Pliocene and Quaternary portions of the Leg 73 sediments. The planktonic foraminiferal zonation of Berggren (1973, 1977) is the most useful in delineating the Pliocene biostratigraphy in Leg 73 sediments. The earlier Zones PL1 through PL3 are recognized by their primary datums. The erratic occurrence of *Globorotalia punctulata* in the cores prevents the recognition of PL1a and PL1b, although PL1c can be separated. The later zones of Berggren are not easily recognized because of the absence of marker species and slumping in Hole 519 in parts of this interval. The N22/N21 boundary of Blow is recognized by its primary datum.

Where both calcareous nannofossils and planktonic foraminiferal zones were recognized, the cross correlations between them correspond well with those established in the literature. The one point of departure is in the early Pliocene. In Holes 519 and 521 the LO of *G. crassaformis* (base of PL1c) lies below the LO of *Ceratolithus rugosus* (base of NN13). In piston cores on the Rio Grande Rise, where Zone PL1c was defined, however, the LO of *G. crassaformis* lies considerably above the LO of *C. rugosus* and in fact lies very near the LO of *Discoaster asymmetricus* (base of NN14) (Berggren, 1977; Haq and Berggren, 1978). The cause of this discrepancy in the correlation is unclear. The Rio Grande Rise and the Leg 73 sites lie in the same ocean basin at the same latitude. Differences in the taxonomic interpretation of early *G. crassaformis* may account for the mismatch, inasmuch as the phylogeny of this taxon, especially during its early stages, is subject to considerable interpretation (see Berggren, 1977).

ACKNOWLEDGMENTS

Enlightening discussion with Gretchen Blechschmidt and Bilal Haq proved very helpful in the preparation of this manuscript.

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Date of Initial Receipt: October 1, 1982