PLANKTONIC-FORAMINIFER ASSEMBLAGES ACROSS THE MIOCENE/PLIOCENE
BOUNDARY AT DEEP SEA DRILLING PROJECT SITES 415 AND 416, AND
CORRELATIONS WITH OTHER NORTH-ATLANTIC SUCCESSIONS

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ABSTRACT

The Miocene/Pliocene boundary appears to correspond to an un-
conformity at DSDP Site 415 (northern flank of Agadir Canyon),
whereas it falls in a strongly condensed section at Site 416A (Moroc-
can Basin). Condensation at the latter site, however, may be artificial
and due to the coring process. The duration of the sedimentary gap
at Site 415 is estimated to be approximately 2 m.y. by correlation
with DSDP Site 397 (upper continental rise off Cape Bojador),
where several datum levels in a high-sedimentation-rate continuously
cored hemipelagic sequence are calibrated with a magnetic-reversal
sequence.

Forms transitional from Globorotalia miotumida to G. cononio-
zea were recorded; however, there were no typical specimens of the
latter taxon, whose areal distribution in the eastern North Atlantic
apparently does not extend beyond 33° latitude.

The middle-Miocene (Serravallian) erosional episode, consistently
recorded at drill sites in the eastern North Atlantic, interpreted as a
response to the change in circulation pattern resulting from the cut-
off of the Mediterranean seaway, might be recorded at Site 416.
Uncertainty of the exact position of cores with respect to sub-bottom
depth, however, prevents a full documentation of its occurrence at
this site.

BACKGROUND

The sample request submitted to the scientific staff of
DSDP Leg 50 and resulting in the present contribution
was motivated by our interest (1) in the Miocene/Plio-
cene boundary in the open ocean, compared to that re-
cently typified stratigraphically in the Mediterranean ar-
tea (Cita, 1975a), and (2) in the evolution of planktonic-
foraminifer faunas in the time interval corresponding to
the isolation of the Mediterranean. Our previous experi-
ence on the eastern North Atlantic had shown that con-
tinuous marine successions straddling the Miocene/Plio-
cene boundary could be found (Cita, 1974; Salvatorini
and Cita, 1979).

In particular, we were curious to investigate (1)
whether at a latitude intermediate between that of Site
397 (~ 26° N) and that of Rabat (~ 33° N) (Figure 1)
the same reduction in the number of species of keeled
Globorotalia would be recorded when passing from the
late Miocene to the early Pliocene, and (2) whether Glo-
borotalia cononiozea, a supposedly medium- to high-
latitude taxon, is present or not. This species in fact was
consistently recorded in the Bou Regreg section near Ra-
bat (Bossio et al., 1976; Wernli, 1977), whereas it was
conspicuously absent in the Cape Bojador cores (DSDP
Site 397) (Salvatorini and Cita, 1979; Mazzei et al.,
1979): its eventual occurrence in either the northern Site
416 or in the southerly 415 could permit tracing of the
limits of its distribution in the eastern North Atlantic.

SITE 415

The four analyzed samples are from Sections 1 and 2
of Core 2, cut from 74 to 83.5 meters sub-bottom. A
range chart of selected foraminifer species is represented
in Figure 2, and some characteristic taxa are illustrated
in Plate 1.

The sample from 29 to 31 cm in Section 1 of Core 2
yielded a rich and well-diversified faunal assemblage re-
ferable to Zone MP1 3 of Cita (1975b), which is charac-
terized by the concurrent range of Globorotalia margar-
itae and G. puncticulata. This biozone belongs to the
later part of the Zanclean Stage (early Pliocene). Also
present are Globorotalia crassaformis and right-coiling
Globigerina pachyderma. G. crassaformis overlaps the
ranges of G. puncticulata and G. margaritae also at
DSDP Site 397 (from Core 35 upward). The absence of
Globigerina nepentes suggests that the level under dis-

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erinoides obliquus extremus, and by Globorotalia humerosa humerosa.

Samples 415-2-1, 115-117 cm and 415-2-2, 46-48 cm are very similar and consequently are discussed together. They are very rich in siliceous microfossils (radiolarians, siliceous sponge spicules) and show evidence of strong dissolution at depth, as proved by extended fragmentation of the foraminifer tests, and by thinned walls and enlarged pores. Dissolution is selective, which results in enrichment of solution-resistant taxa.

These samples yield typical specimens of Globorotalia drina dehiscens whose last occurrence according to Berggren and Amdurer (1972) is a late Miocene biostatigraphic event (see also Berggren, 1977). The absence of Globigerinoides obliquus extremus and the occurrence of Globorotalia lenguansis are suggestive of an early-Tortonian age; however, none of these biostatigraphic indications is unambiguous. Indeed, the absence of extremus could be due to dissolution, whereas the presence of lenguansis (which becomes extinct prior to the first occurrence of G. tumida plesiostumida) could be due to reworking. In fact, in the lowermost investigated sample (Core 2, CC, 21-23 cm) the coexistence of G. obliquus extremus, of Globorotalia tumida plesiostumida, and of Sphaeroindelios subdehiscens indicate Zone N.17, which is in agreement with the attribution of the radiolarian fauna to the Sticchochrysos peregrina Zone. The base of this radiolarian zone is calibrated to the middle part of paleomagnetic Epoch 6 and falls in the middle part of Zone N.17 (Ryan et al, 1974).

With reference to the zonation recently proposed by Salvatorini and Cita (1979), the two samples under discussion can be referred to the later part of Zone N.16, which has been emended in its upper boundary (first occurrence of Sphaeroindelios seminulina paenedehiscens, instead of first occurrence of Globorotalia tumida plesiostumida) so that it is more restricted upward, corresponding to the lower part of Zone N.17. This interval corresponds to the latest part of the Tortonian Stage (see Ryan et al, 1974).

The lowermost sample is considered more biostratigraphically reliable than the two higher ones, because it is less affected by dissolution: we did not record any specimen referable to G. lenguansis from the core-catcher sample. Siliceous microfossils, especially radiolarians, are less common than in the two overlying late-Miocene samples.

**SITE 416**

The three investigated samples are from Section 1 of Core 416A-1 (Figure 3). This core was cut from a nominal interval between 146 and 155.5 meters below sea floor but because of the coring technique employed it is possible that firm sediments from well above that interval entered the barrel inadvertently (see Site Report 416, this volume). The lowest sample (78-80 cm) was taken above an "apparent" unconformity recorded by the shipboard paleontologists (Figure 4), corresponding to a time gap of some 6 m.y. This unconformity, however, could also be (at least in part) an artifact of coring.

The faunal assemblages are rich and diversified: planktonic foraminifers outnumber the benthic ones by orders of magnitude.

The topmost sample (25-27 cm) is referred to the upper part of the Globigerina nepenthesis Interval-Zone of Salvatorini and Cita (1979), which is early Pliocene (lower Zanclean). Globorotalia margaritae is abundant and occurs with a large species, also fairly abundant, which we provisionally refer to as G. sp. cf. G. cibaoensis. Also present are specimens of G. humerosa humerosa, which is restricted to the Pliocene (Natori, 1976; Salvatorini and Cita, 1979).

The second sample from the top (38-40 cm) is referred to the earlier part of the G. nepenthesis Zone, of the latest Miocene (late Messinian). It yields Globorotalia margaritae in lesser abundance than the topmost sample. We frequently recorded in this sample Globorotalia miotumida, also including specimens transitional to G. conomiozea. The latter is a middle- to high-latitude species originally described from New Zealand (Kennett, 1966). According to Jenkins (1971), to Berggren and Amdurer (1972) and to Berggren (1977), G. miotumida and G. conomiozea belong to the same lineage, the latter deriving from the former. The main difference between the two taxa is a greater ventral inflation of the chambers in G. conomiozea. Our identifications of G. miotumida were corroborated by examination of hypotypes from southern Australia, kindly made available by Dr. C. Mallett.

We recorded in this sample sparse specimens of Globorotalia crassaformis and of G. sp. cf. G. puncictulata, which we consider probable down-hole contaminants from higher Pliocene levels, but which could also be related to the highly condensed section.

The third and lowermost sample investigated (78-80 cm) does not yield G. margaritae, and is referable to Zone N.17 (Sphaeroindelios seminulina paenedehiscens Zone of Salvatorini and Cita, 1979), of late-Miocene age.
PLANKTONIC-FORAMINIFER ASSEMBLAGES

<table>
<thead>
<tr>
<th>Core 415-2</th>
<th>Section 1</th>
<th>Section 2</th>
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<tbody>
<tr>
<td></td>
<td>29-31 cm</td>
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<tr>
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<td>Zanclean</td>
<td>Tortonian</td>
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Figure 2. Distribution of 40 species and subspecies of planktonic foraminifers in Core 415-2.

CORRELATIONS

Correlation Between Sites 415 And 416

The correlation is shown in Figure 4. We believe that all the investigated samples from Site 416 are older than the youngest studied sample from Site 415, and younger than the remaining three samples of Sites 415. There is evidence of a highly condensed sequence at Site 416, where biozones follow in their correct order, although strongly condensed and with some anomalies. This condensation may be real (as represented in Figure 4), or it may be artificial.

On the flank of the Agadir Canyon (Site 415) there is a biostratigraphically documented hiatus corresponding at least to the Globigerina nepenthes Interval-Zone which extends from the middle part of paleomagnetic Epoch 5 to the middle part of the Gilbert epoch (see Mazzei et al, 1979). The hiatus probably extends back in time to include the latter part of Zone N.17. Indeed, we referred to Zone N.17 both the lower part of the investigated interval at Site 415, and the lowermost sample from Site 416. Although the difference is so small as not to be proved paleontologically in a straightforward manner, it is strongly supported by the difference in dissolution, and by content of biogenic silica. Dissolution is much stronger at the shallower Site 415, where siliceous microfossils are abundant, whereas it is conspicuously absent at Site 416. These observations suggest (1) that the sediments under discussion are not contemporaneous, and (2) that the sediments from Site 415 are older.
In fact, previous studies by Berger and Von Rad on the North Atlantic (1972) showed that CCD progressively shallows as a function of increasing time in the Miocene, so that one can expect to find more dissolved sediments in the lower part of Zone N.17, referable to the Tortonian, than in its upper part, referable to the Messinian. At Site 397, where quantitative studies were carried out on several parameters connected with dissolution, the highest dissolved sediments were recorded in the late Tortonian (Cita and Spezzi Bottiani, 1979), and this agrees well with the present observations.

In conclusion, the sequence investigated at Site 416 is highly condensed; however, no significant time gap could be proved.

Correlation with the Bou Regreg Section of Central Morocco

A continuous marine section straddling the Miocene/Pliocene boundary has been described by several authors along the valley of the Bou Regreg River, near Rabat (see Feinberg and Lorenz, 1970; Cita, 1974; Bosso et al., 1976; Wernli, 1977). The outcrops are in part discontinuous, and the transitional beds between a silty marl unit of late-Miocene age and a blue marl unit of early-Pliocene age are not well exposed; however, the continuity of the section is fairly good.

The rich and diversified foraminifer assemblage of the late Miocene yields *Globorotalia conomiozea* in...
some abundance, along with several other taxa belonging to the *Globorotalia cultrata* plexus. *G. margaritae* is first recorded in a transitional unit characterized by cyclic alternations of coarse sands and silty marls. The first occurrence of *G. margaritae* stratigraphically overlies a level where a rapid change in the coiling ratio of *Globorotalia acostaensis* from senestral (below) to dextral (above) is recorded. Both biostratigraphic events were also recorded at Site 397, respectively in the middle part of paleomagnetic Epoch 5 and at the base of Epoch 5 (Mazzei et al., 1979). The dominantly left-coiling of *G. acostaensis*, recorded in the core-catcher sample of Core 415-2, points to an age older than Epoch 5.

The condensed nature of the sections penetrated at both Sites 415 and 416 prevents following in detail the evolution of foraminifer faunas. The early Pliocene recorded at Site 416 can be correlated with the exposed section at Briquetiere de Sale, on the right bank of the Bou Regreg, whereas the early Pliocene of Site 415 is younger (Zone MPI 3, characterized by the concurrent range of *G. margaritae* and *G. punctulata*); indeed, all the exposed section of the Bou Regreg predates the first occurrence of *G. punctulata*.

**Correlation With DSDP Site 397**

The few samples from Sites 415 and 416 here considered can be correlated with the expanded late-Neogene succession continuously cored off Cape Bojador (DSDP Site 397), where biostratigraphic zonations could be calibrated to the paleomagnetic stratigraphy (see Ryan, von Rad, et al., 1979; Mazzei et al., 1979, in press). Figure 4 shows such a correlation. In particular, the topmost investigated sample from Site 415 (29-31 cm in Section 1 of Core 415-2, approximately 74 m sub-bottom and approximately 2868 m sub-sea) can be correlated with Cores 34 to 35 of Site 397 (313 to 332 m sub-bottom, 3223-3242 m sub-sea).

The topmost sample from 416A (25-27 cm in Section 1 of Core 1; 146 m sub-bottom, approximately 4337 m sub-sea) can be correlated with Cores 38 to 39 of Site 397 (351–370 m sub-bottom, 3261-3280 m sub-sea).

A precise correlation of the late-Miocene samples is hampered (1) by the condensed sedimentary succession at Sites 415 and 416, and (2) by dissolution, especially at the shallower Site 415.

Factor (1) results in abnormal occurrences of taxa whose ranges do not overlap in more-expanded sections. For instance, *Globorotalia miotumida* does not co-exist with *G. margaritae* at Site 397 according to Salvatorini and Cita (1979), whereas both taxa are recorded together at 415 and 416. Factor (2) acts as “noise” in the biostratigraphic record.

It is worthwhile mentioning that the Miocene section of Site 397 is the most complete one from the eastern...
Atlantic; however, one interval with slumps (within the late-Miocene foraminifer Zone N.16) and two minor hiatuses in the middle Miocene could be documented biostratigraphically.

The gap possibly existing at Site 416 in the Serravallian, where it encompasses Zone N.15, could be correlated with a similar one recorded not only at the upslope Site 369 (off Cape Bojador), but also in the Sierra Leone Rise (Site 366; Leg 41) and in the Rio Grande Rise (Site 357; see Boersma, 1977; Berggren, 1977). The wide areal distribution of this submarine erosional phase of Serravallian age in the North Atlantic is pointed out. The hypothesis is put forward that this erosion is related to an important change in oceanographic regime and geostrophic thermohaline current pattern, related to the closure of the Mediterranean to the east, which resulted in the interruption of the equatorial current system, and hence in a reactivation of the North/South Atlantic boundary currents.

ACKNOWLEDGMENTS

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We thank E. Vincent, I. Premoli-Silva, and G. Salvadorini for critical revision of the text.

REFERENCES


PLATE 1

Figures 1–4, 7  *Globorotalia miotumida* Jenkins.
1. spiral view, × 90. Sample 416A-1-1, 78-80 cm. Zone N.17, Tortonian.
2. as above.
3. as above, in umbilical view.
4. as above, in side view.
7. as above, in spiral view.

Figures 5, 6  *Globorotalia tumida plesiotumida* Blow and Banner.
5. spiral view, × 90. Sample 425-2, CC, 21-23 cm. Zone N.17, Tortonian.
6. as above, in umbilical view.

Figures 8–10  *Globorotalia miozea miozea* Finlay.
8. spiral view, × 90. Sample 416A-1-1, 78-80 cm. Zone N.17, Tortonian.
9. as above, in umbilical view.
10. as above in side view.

Figures 11–14  *Globorotalia cultrata* (d’Orbigny).
11. spiral view, × 45. Sample 415-2, CC, 21-23 cm. Zone N.17, Tortonian.
12. as above, in umbilical view.
13. as above, in spiral view.
14. as above, in umbilical view.