Mascle, J., Lohmann, G.P., and Moullade, M. (Eds.), 1998
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 159

27. CRETACEOUS PLANKTONIC FORAMINIFERS, EASTERN EQUATORIAL ATLANTIC[1]

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ABSTRACT

During Ocean Drilling Program Leg 159, several Cretaceous sections were drilled at Sites 959, 960, and 962 in the Côte d'Ivoire-Ghana Margin. The lowermost sediments of Site 962, which contain planktonic foraminifers, are given an upper Albian age. The fauna is rich and mainly consists of unkeeled forms, a possible indication that a cool environment was predominant during this period. The assemblages show some similarities with those previously described from the Angola Basin and the Walvis Ridge. At the other sites, Cretaceous planktonic foraminifers are rare and poorly preserved. They are of Turonian and Coniacian–Santonian age at Site 960, and of Coniacian–Santonian age at Site 959. The Upper Cretaceous assemblages comprise Tethyan elements, an evidence of warmer waters and also of the opening of the Atlantic to the North.

INTRODUCTION

The main objectives of drilling Sites 959 to 962 of Leg 159 were to study a type example of transform passive margin. The Côte d'Ivoire-Ghana Marginal Ridge (see Fig. 1) formed part of an oceanic gateway region between the central and southern Atlantic during much of the Cretaceous (Förster, 1978; Moullade and Guérin, 1982; Moullade et al., 1993). At that time, periods of anoxia and stagnation of oceanic circulation were widespread phenomenon (Magniez-Jannin and Muller, 1987; Massala et al., 1996). Unfortunately, an important part of the Cretaceous sediments recovered at these sites is barren of planktonic foraminifers, or contains only scarce and poorly preserved specimens (Turonian from Site 960 and Coniacian–Santonian from Sites 959 and 960). Diagenetic recrystallization and/or dissolution were so intense that the diagnostic characters are often altered and species identification at the specific level is made difficult or impossible, with the exception of the Albian beds from Site 962 in which the tests are unusually well preserved.

Some additional difficulties were encountered in the identification of morphotypes, due to morphological variations in the populations. Forms of *Hedbergella*-type are predominant, and deviations (with few chambers) from this type seem to be endemic to the South Atlantic Ocean (*Ticinella* cf. *roberti, Biticinella* sp.), as well as significant local species (*Hedbergella angolae*).

MATERIALS AND METHODS

One hundred sixty-seven samples were examined: 98 from Site 959, six from Site 960, two from Site 961, and 61 from Site 962; 119 samples were washed through 250-, 150-, and 63-µm mesh sieves under running water, and 48 were examined in thin section. Samples for thin sections come mainly from the lowermost cored intervals of Hole 959D. The distribution of planktonic foraminifers is given in Tables 1 and 2. Sample notation follows the standard Ocean Drilling Program (ODP) format, and all the samples yielding planktonic foraminifers are listed.

The biostratigraphic interpretation resulting from the composition of the planktonic assemblages follows the zonal scheme of Caron (1985), which is partly based on the schemes proposed by Robaszynski et al. (1979, 1984).

PLANKTONIC FORAMINIFERAL ASSEMBLAGES

Cores 159-959D-66R through 65R (Coniacian–Santonian)

According to shipboard palynological analyses, the Cretaceous/Tertiary boundary lies at 830 mbsf in Hole 959D. Cretaceous sediments were then penetrated through 1158 mbsf, with a good recovery in the upper 175 meters. The interval from 830 mbsf through 1043 mbsf consists of black claystones. The underlying interval from 1043 mbsf to 1081 mbsf includes sandy limestones, sandy dolomites, calcareous sandstones, and limestones. The sequence from 1081 mbsf to 1159 mbsf consists of quartz sandstones and silty claystones.

Approximately 115 m of the lowermost sediments (Core 159-959D-78R [1159 mbsf] to Core 67R [1045 mbsf]) do not contain planktonic foraminifers. Those found in calcareous hemipelagic sediments of Core 159-959D-66R (1043 mbsf) were identified in thin sections: *Hedbergella* sp. cf. *H. delrioensis, H.* cf. *flandrini, Whiteinella* (?) *inornata, Archaeoglobigerina blowi, A. cretacea, Dicarinella* (?) *concavata,* and *Heterohelix globulosa* (Pl. 5, Figs. 1–6). This assemblage indicates a Coniacian–early Santonian age. A single specimen of *Globigerinelloides* sp. is present in Core 159-959D-65R (1033 mbsf). According to calcareous nannofossils, Core 159-959D-65R falls in the Santonian. Calcareous benthic foraminifers are also present in this sample. In contrast with the lower part of the Cretaceous sequence, Cores 159-959D-59R (976 mbsf) to 49R (830 mbsf) yield nearly exclusively benthic agglutinated assemblages.

Core 159-960A-20R (Coniacian)

The poorly recovered Cretaceous sediments of Hole 960A (175 mbsf to 329 mbsf) consist of grainstones and packstones with variable amounts of quartz sand.

Rare, very poorly preserved benthic and planktonic foraminifers are restricted to Core 159-960A-20R (175 mbsf). The latter sample contains a low-diversity assemblage composed of calcite-filled and recrystallized foraminifers (Pl. 4, Figs. 1–6). Examination by using scanning electron microscope (SEM) revealed shipboard misidentifications, due to artifacts. The assemblage actually includes *Dicarinella concavata* group, *Marginotruncana* (?) sp., *Hedbergella* (?) *delrioensis,* and *Whiteinella* (?) *paradubia.* If not reworked, this assemblage points to a Coniacian age. The absence of foraminifers probably results from adverse environmental conditions and dissolution.

[1]Mascle, J., Lohmann, G.P., and Moullade, M. (Eds.), 1998. *Proc. ODP, Sci. Results*, 159: College Station, TX (Ocean Drilling Program).
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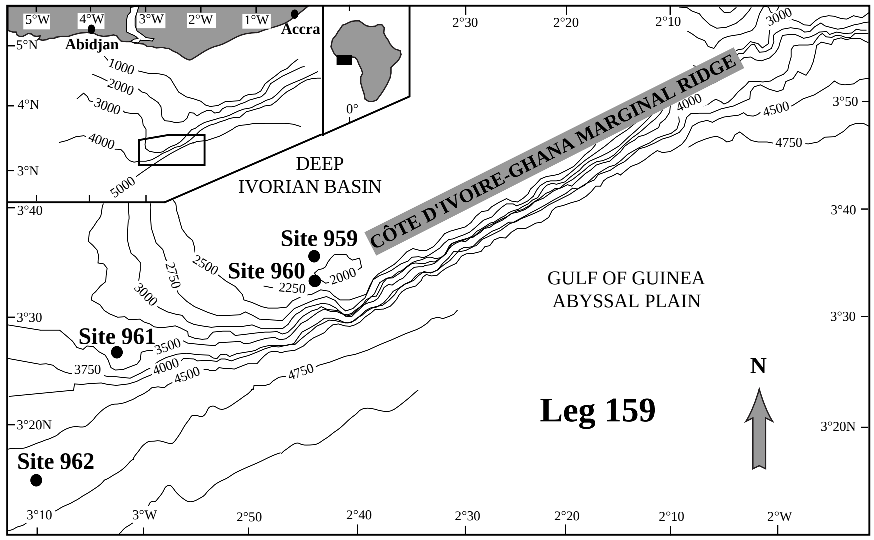

Figure 1. Location of drilling sites on the Côte d'Ivoire-Ghana Margin and surroundings (bathymetry is in meters), after Benkhelil et al. (1995).

Table 1. Occurrence of Cretaceous foraminifers, Holes 959D (Coniacian–Santonian), 960A (Coniacian), 960C (Turonian–Santonian), 962B (upper Albian), and 962C (?).

Core, section, interval (cm)	
159-959D-	
65R-CC	*Globigerinelloides* sp.
66R-4, 118-120*	*Hedbergella* sp. cf. *H. delrioensis*, *H.* cf. *flandrini*, *Whiteinella* (?) sp., *Archaeoglobigerina blowi*, *A. cretacea*, *Dicarinella concavata*, *Heterohelix globulosa*
159-960A-	
20R-CC	*Hedbergella* (?) *delrioensis*, *Whiteinella* (?) *paradubia*, *Dicarinella conavata* group, *Marginotruncana* (?) sp.
159-960C-	
23X-CC	*Hedbergella* sp., *A. cretacea*, *A. blowi*, *D. concavata*, *D. concavata-asymetrica*, *Marginotruncana sinuosa* ?, *Contusotruncana fornicata*, *Heterohelix globulosa*
25X-1, 54-57*	*Hedbergella* sp.
25X-1, 102-106*	*Hedbergella* sp.
26X-1, 94-97*	*Hedbergella* sp.
26X-2, 25-28	*Hedbergella* (?) *delrioensis*, *Whiteinella* sp. cf *W. aprica*, *Dicarinella hagni*, *Heterohelix globulosa*
26X-CC	*Hedbergella delrioensis*, *Dicarinella hagni*, *Heterohelix globulosa*
159-962B-	
8H-CC	*Hedbergella delrioensis*, *Hedbergella* sp.
9H-CC	*Hedbergella delrioensis*, *Hedbergella* sp.
10H-CC, 23-25	*Hedbergella delrioensis*, *Ticinella* (?) *madecassiana*, *Heterohelix moremani*
10H-CC	*Hedbergella delrioensis*, *H.* cf. *angolae*, *Costellagerina libyca*, *Ticinella madecassiana*, *T.* cf. *roberti*, *Globigerinelloides caseyi*, *Heterohelix moremani*
159-962C-	
3R-CC	*Hedbergella delrioensis*, *Heterohelix* sp.

Note: * = thin section.

Cores 159-960C-26X through 23X (Turonian-Santonian)

Cretaceous sediments drilled in Hole 960C (198–352 mbsf), also poorly recovered, are lithologically similar to those of Hole 960A.

Core 159-960C-26X contains a poor fauna. Nearly all specimens of Sample 159-960C-26X-CC (352 mbsf) are fragmented and show an overgrowth of carbonate cement (Pl. 4, Figs. 16–18). Only some *Dicarinella hagni, Hedbergella* (?) *delrioensis* and *Heterohelix globulosa* were identified in this Turonian sample. In Sample 159-960C-26X-2, 25–28 cm, thin sections contain a similar assemblage, with the addition of *Whiteinella* sp. cf. *W. aprica* (Pl. 5, Figs. 7–10). In the upper part of Core 159-960C-26X (344 mbsf) and in Core 159-960C-25X (340 mbsf), planktonic foraminifers are limited to cuts of *Hedbergella* sp.

In Core 159-960C-23X (307 mbsf), the fauna is calcite-filled and/or fragmented (Pl. 4, Figs. 7–15); nevertheless, stratigraphically significant again and diversified, with more species dominated by *Contusotruncana fornicata, Archaeoglobigerina cretacea, A. blowi,* and *Heterohelix globulosa.* The most representative group indicative of the Coniacian–Santonian interval is the *Dicarinella concavata* plexus (*Dicarinella concavata* and intermediate forms between *D. concavata* and *D. asymetrica*)*.* The occurrence of *Marginotruncana sinuosa* is doubtful.

All the species listed above are well known in the Tethys. These species are evidence of a warm Late Cretaceous environment in the Cote d'Ivoire-Ghana Margin and of the opening of the Atlantic to the north.

Core 159-962B-10H (Late Albian) and Cores 159-962B-9H and 8H

In Hole 962B approximately 25 m of Cretaceous sediment (75–100 mbsf) was cored before poor recovery forced abandonment of this hole. Most of the recovered beds are barren of calcareous microfossils.

Preservation of planktonic foraminifers (devoid of chamber infilling) is good in Sample 159-962B-10H-CC (93 mbsf). The identified species include *Hedbergella delrioensis, Costellagerina libyca, H.* cf. *angolae, Ticinella madecassiana, T.* cf. *roberti, Globigerinelloides caseyi,* and *Heterohelix moremani* of late Albian age (probably

Table 2. Occurrence of Cretaceous foraminifers, Hole 962D (upper Albian).

Core, section, interval (cm)	*Hedbergella delrioensis*	*Hedbergella angolae*	*Hedbergella* cf. *gorbachikae*	*Hedbergella* cf. *simplex*	*Hedbergella* sp.	*Costellagerina libyca*	*Ticinella* (?) *madecassiana*	*Biticinella* sp.	*Praeglobotruncana delrioensis*	*Globigerinelloides caseyi*	*Globigerinelloides bentonensis*	*Schackoina* cf. *cenomana*	*Heterohelix moremani*
159-962D-													
6R-1, bottom	.	.	.	.	×	.	.	.	.	.	.	.	.
6R-CC	cf	.	×	.	.	.	.	.	.	.	.	.	.
7R-CC	.	.	.	.	×	.	.	.	.	cf	.	.	.
8R-CC	×	×	.	.	.	×	×	.	.	×	.	.	.
9R-1, 26-28	cf	.	.		.	.	×	.	cf	.	.	.	cf
9R-2, 57-59	.	×	.	.	×	.	.	.	.	.	.	.	.
9R-4, 131-133	.	.	.	.	.	×	.	.	.	.	.	.	.
9R-5, 4-8*	.	.	.	.	×	.	.	.	.	.	.	.	×
9R-5, 27-29*	.	.	.	.	×	.	.	.	.	.	.	.	.
9R-CC	cf	cf	.	.	×	.	.	.	cf	.	×	.	.
10R-1, 19-21	.	.	.	.	×	.	.	.	.	.	.	.	.
10R-2, 128-130	.	.	.	×	.	.	.	.	.	.	.	.	.
10R-CC	.	.	.	.	×	.	.	.	.	.	.	.	.
11R-1, 34-36	×	×	.	.	×	.	×	.	.	×	cf	.	×
11R-CC	×	×	.	.	.	×	.	×	.	×	.	.	.
12R-1, 90-91	×	×	.	.	.	.	×	.	.	×	.	.	×
12R-2, 80-82	×	.	.	.	×	.	.	.	.	.	cf	.	.
13R-1, 100-103	.	.	.	.	×	.	.	.	.	.	.	.	×
13R-2, 95-96	×	.	.	.	×	.	.	.	.	.	.	.	.
13R-CC	×	×	.	.	×	×	×	.	.	.	.	.	.
15R-CC	cf	cf	×	.	.	.	.	.	.	.	.	.	.
16R-CC	×	×	×	.	.	.	×	.	.	×	.	.	.
18R-CC	×	×	.	.	.	.	.	.	cf	.	cf	.	.
19R-CC	×	×	×	×	.	.	.	.	cf	×	.	.	cf
20R-2, 6-12	.	.	.	.	×	.	.	.	.	.	.	.	.
20R-4, 68-72	.	.	.	.	×	.	.	.	.	.	.	×	×
20R-CC	×	×	.	.	×	.	.	.	.	.	.	.	.
21R-CC	×	cf	.	.	×	.	.	.	cf	.	.	.	.
23R-CC	×	cf	.	.	×	.	.	.	cf	.	.	.	.
24R-CC	×	×	.	.	.	.	×	.	.	.	cf	.	.
25R-1, 46-48*	.	.	.	.	×	.	.	.	.	.	.	.	.
25R-CC	×	×	×	.	×	×	×	.	×	.	.	.	.
26R-CC	×	×	.	.	.	×	×	.	×	.	×	.	.
27R-1, 87-90	×	.	.	.	×	.	.	.	×	.	.	.	.
27R-CC	×	×	.	.	×	.	.	.	×	.	.	.	cf
28R-CC	×	.	×	.	.	.	.	.	.	.	.	.	.
29R-1, 45-48	.	.	.	.	×	.	.	.	.	cf	.	.	×
29R-CC	.	×	.	.	×	.	.	.	.	.	.	.	.
30R-CC	×	cf	.	×	.	.	.	×	.	.	.	×	.
31R-CC	×	cf	.	×	×	.	.	.	cf	.	.	.	.
33R-CC	.	.	.	.	×	.	.	.	.	.	.	.	.
34R-2, 80-82	.	cf	.	.	.	.	.	.	.	.	.	.	.
34R-CC, 7-9	.	cf	.	.	×	.	.	.	.	.	.	.	.
34R-CC	×	cf	.	.	.	.	.	.	.	×	.	.	.
35R-CC	.	.	.	.	.	.	.	.	.	.	.	.	.
36R-CC	.	.	.	.	.	.	.	.	.	.	.	.	×
37R-CC	.	×	.	.	.	.	.	.	.	.	.	.	×

Notes: × = present, cf = probable identification. * = thin section.

Rotalipora appenninica Zone: the index species is missing, but the entire assemblage dates the interval).

Poorly preserved planktonic foraminifers are present in Samples 159-962B-9H-CC (83 mbsf) and 8H-CC (74 mbsf): they are represented as silica casts, without the external shell, and seem to belong to several species of *Hedbergella,* including *H. delrioensis.*

Core 159-962C-3R

Hole 962C was drilled from 0 to 73 mbsf and then cored through 102 mbsf. The poor recovery from this hole also forced premature abandonment. Only a few very poorly preserved specimens of *Hedbergella delrioensis* and *Heterohelix* sp. were found in Sample 159-962C-3R-CC (102 mbsf).

Cores 159-962D-37R through 6R (Late Albian)

In Hole 962D, approximately 270 m of Cretaceous sediment (recovery: only 29%) were cored (123–393 mbsf). Much of the upper 80 m consists of porcellanites and calcite-cemented sandstones. Below this upper interval, the section is composed of claystones, siltstones, and sandstones.

Samples 159-962D-37R (393 mbsf) through 6R (133 mbsf) contain planktonic foraminifers of late Albian age: *Hedbergella delrioensis, Costellagerina libyca, H. angolae, H.* cf. *gorbachikae,* rare *Hedbergella* cf. *simplex* and *Biticinella* sp., *Ticinella* (?) *madecassiana, Globigerinelloides caseyi,* and *G. bentonensis.* The presence of *Heterohelix* cf. *moremani* and *Praeglobotruncana* cf. *delrioensis* within and below Sample 159-962D-9R-1, 26–28 cm (153 mbsf), of *Ticinella* (?) *madecassiana* within and below Sample 159-962D-8R-CC (143 mbsf) suggest that the sequence may be attributed to the *Rotalipora appenninica* Zone of the late Albian. *Praeglobotruncana delrioensis* was positively identified in Samples 159-962D-27R-CC (316 mbsf) to 25R-CC (306 mbsf), and *Heterohelix moremani* in Samples 159-962D-37R-CC (393 mbsf), 36R-CC (388 mbsf), 29R-1, 45–48 cm (327 mbsf), 20R-4, 68–72 cm (262 mbsf), 13R-1, 100–103 cm (192 mbsf), 12R-1, 90–91 cm (182 mbsf), and 11R-1, 34–36 cm (172 mbsf). Poorly preserved specimens of *Schackoina* cf. *cenomana* found in Samples 159-962D-30R-CC (345 mbsf) and 20R-4, 68–72 cm (268 mbsf) also suggest a very late Albian age. The presence of this early Cenomanian species in older beds is unusual and seems to be characteristic of the South Atlantic realm, as it has already been reported by Caron (1978) from upper Albian sediments in the Angola Basin.

Except in Sample 159-962D-8R-CC (143 mbsf), preservation is poor: the foraminifer chambers are infilled with calcite, and many specimens are partly crushed.

Populations are dominated by *Hedbergella* morphotypes in which the ornamentation is strongly developed, as in the *Hedbergella* "à costellae" described by Saint-Marc (1973) from Cenomanian neritic facies of Lebanon. However, in our material this ornamentation does not consist of true costulae but of sharp pustules, more or less radially oriented (Pl. 1, Figs. 4–9).

COMPARISON OF THE PLANKTONIC FORAMINIFERAL FAUNA WITH OTHER SITES

Albian

The greatest affinities of the Côte-d'Ivoire-Ghana Margin (CIG Margin) planktonic foraminifer assemblages are with those found in the "nearshore" sites of the Angola Basin and Walvis Ridge (DSDP Leg 40, Caron 1978). The *Hedbergella* group is predominant, and the *Ticinella* group consists of atypical forms. The *Costellagerina libyca* morphotypes are abundant, and "*Whiteinella*" occur at this time in the Angola Basin (Caron, 1978), where the microfauna was enriched in shallower, epipelagic, and possibly neritic forms (*Hedbergella* "à costellae," *Clavihedbergella, Schackoina*). The *Ticinella* are small sized in the three areas, and show only supplementary apertures on the one or two last chambers. On the CIG Margin, as on the Walvis Ridge, the fauna are not as rich and specimens are of smaller size (sorted by currents?) than in the Angola Basin.

The general characteristics of these assemblages may be related to a cool environment prevailing during the Albian time in the southeastern Atlantic (Premoli Silva and Boersma, 1977; Caron, 1978), and not only by upwelling effects. The "austral" character of the planktonic foraminifer assemblages could thus explain the absence of the rotaliporids (Sliter, 1977). The paleogeographic features of the Albian oceanic gateway were certainly very different from the modern ones. One also has to remember that Tethyan influence was detected in the eastern Atlantic only in the Early Cretaceous faunas at and above the latitude of the Canary Islands from 12° to 32°N (Pflaumann and Krasheninnikov, 1978).

Turonian

Poorly preserved planktonic foraminifers, found only in Core 159-960C-26X, point to an apparently thin section of Turonian-age sediment on the CIG Margin, as in the Angola Basin.

Coniacian–Santonian

Planktonic foraminifers contribute very little to the identification of the Coniacian Stage on the CIG Margin. A typical but possibly reworked assemblage occurs only in Hole 960A. On the other hand, the Coniacian–Santonian interval is represented by a poor planktonic fauna in Holes 959D and 960C.

On the Walvis Ridge all tests are dissolved, whereas, in the Angola Basin, the microfauna are well preserved. The Angola Basin assemblages are rich in cool-water species (*Whiteinella*) but are also mixed with warm-water taxa (Caron, 1978). In the middle South Atlantic, Coniacian sediments contain Tethyan species, an indication that a permanent north-south connection was established by this time (Premoli Silva and Boersma, 1977).

No planktonic foraminifers of Santonian age are preserved on the Walvis Ridge. In the Angola Basin, dissolution was very strong, indicating that during this interval at least certain parts of the basin were at depths near or below the lysocline (Caron, 1978).

TAXONOMIC REMARKS

The study of the Cretaceous planktonic foraminifers of Leg 159 is of interest mainly because of the unusual diversity and good preservation of the Albian assemblages. The Turonian–Coniacian to (?) Santonian morphotypes are poorly preserved; since these forms have been well described and illustrated in the micropaleontological literature dealing with the South Atlantic or elsewhere (Caron, 1985), taxonomic remarks are restricted to the planktonic foraminifers of the late Albian. The classification scheme follows Loeblich & Tappan (1988).

Genus *HEDBERGELLA* Brönnimann and Brown, 1958

Genus *COSTELLAGERINA* Petters, El-Nakhal, and Cifelli, 1983

Hedbergella delrioensis (Carsey, 1926)
(Pl. 1, Figs. 1–3)

This species occurs in typical form, size, and ornamentation. Specimens are usually sinistrally coiled. The chamber's periphery is more or less perforated. The apertural flap may be developed.

Costellagerina libyca (Barr, 1972)
(Pl. 1, Figs. 4–9)

As observed on the ship, numerous specimens from Hole 962D may be assigned to this morphotype, which was named *Hedbergella* cf. *costellata* Saint-Marc in the *Initial Reports* (Shipboard Scientific Party, 1996a through 1996d). SEM photographs reveal that the specimens of Leg 159 have no true "costulae," but the surface is strongly rugose with pustules, which are more or less arranged in a meridional pattern, as noticed by Premoli Silva & Sliter (1995). Investigation of Cores 159-962D-6R through 37R does not show the generic diversity (*Ticinella* and *Praeglobotruncana* with oriented ornamentation) as reported by Caron in Leg 40.

Some *Hedbergella* with oriented rugosities has been recorded from the Santonian–lower Campanian of California (Douglas, 1969), the U.S. western interior (Frerichs, 1979), the upper Santonian of Tunisia (*Costellagerina bulbosa* (Belford) of Petters, El-Nakhal & Ciffeli, 1983), the Santonian of Australia (Belford, 1960), the Coniacian of Nigeria (Petters, 1980), the Coniacian of the Pyrénées (*Herbergella aubertae* of Fondecave, 1975), the Cenomanian of Lebanon (Saint-Marc, 1973), the Albian–Cenomanian of Libya (Barr, 1972), the Albian of the Angola Basin (Caron, 1978), and others. The presence of the costulae seems to have an environmental significance; most of the time the ornamentation is correlated with a neritic environment. In the case of Leg 159 material, the state of development and arrangement of the pustules cannot be related to any evidence of real neritic environment.

Hedbergella angolae Caron, 1978
(Pl. 1, Figs. 10–15)

The main feature of this taxon is the very rapid increase in size of the last chamber, which gives the test its peculiar aspect. Some specimens have pustules as developed on *Costellagerina libyca.* The chamber periphery is often less perforated. Sinistrally coiled specimens are very common. Some specimens are very close to *Whiteinella bornholmensis* (Douglas, 1969) as identified by Caron (1978) in the Angola Basin, but the generic attribution is not really convincing.

Hedbergella cf. *gorbachikae* Longoria, 1974
(Pl. 2, Figs. 1–3)

This species differs from *Hedbergella delrioensis* by the last chamber, which is less regularly rounded and protrudes into the umbilical area, and by the rather flat spiral side.

Hedbergella cf. *simplex* (Morrow, 1934)
(Pl. 2, Figs. 4–6)

Hedbergella simplex is known to show a great morphological variability. Chambers in the early portion are globular. The radial elongation of the penultimate and final chambers is not very marked.

Genus *GLOBIGERINELLOIDES* Cushman and Ten Dam, 1948

Globigerinelloides caseyi (Bolli, Loeblich and Tappan, 1957)
(Pl. 2, Figs. 7–9)

Relict apertures are clearly visible on both sides of the test. The last chambers are usually longer than high and wide, the umbilicus is wide. Often, specimens have fewer chambers in the last whorl compared with the holotype.

Globigerinelloides bentonensis (Morrow, 1934)
(Pl. 2, Figs. 10–12)

The difference with *Globigerinelloides caseyi* is that the last chambers are wider than high and long and the coiling is more compact. *G. bentonensis* also displays fewer chambers than the holotype as *G. caseyi.*

Genus *TICINELLA* Reichel, 1950

Ticinella madecassiana Sigal, 1966
(Pl. 2, Figs. 13–16)

The SEM was required to prove the presence of supplementary apertures in the umbilical area. The trochospire of *Ticinella madecassiana* is as low as in other species, which contradicts the observations of Caron (1985). More typical are the more inflated chambers and the smaller number of chambers.

Ticinella cf. *roberti* (Gandolfi, 1942)
(Pl. 3, Figs. 1–4)

Under this name are comprised very rare specimens, which show a tendency toward the genus *Biticinella.* The trochospire is low and the number of chambers is always lesser than in typical *Ticinella roberti.* Similar specimens have already been described by Caron (1978) in the Angola Basin as *Ticinella* cf. *roberti* -› *Biticinella.* Here, the evolutionary stage is more advanced, with the last chamber unequally divided. These specimens seem to be restricted to the South Atlantic and may represent a new taxon, if the small final chamber is not a gametogenic one (Hemleben, Splindler & Anderson, 1989).

Genus *BITICINELLA* Sigal, 1956

Biticinella sp.
(Pl. 3, Figs. 5–7)

The umbilical characters are obscure, and even with the SEM it was not possible to detect the presence of relict apertures like those of *Globigerinel-*

loides or supplementary apertures like those of *Ticinella.* The specimens show only five chambers in the last whorl. Specimens from the Angola Basin, with six chambers in the last whorl, have been previously illustrated and named *Biticinella* cf. *breggiensis* (Gandolfi) by Caron (1978). If these forms actually belong to the genus *Biticinella,* they may represent a new taxon, which probably evolved from "*Ticinella* cf. *roberti*," the whole stock being typical of the South Atlantic realm.

Genus *PRAEGLOBOTRUNCANA* Bermùdez, 1952

Praeglobotruncana delrioensis (Plummer, 1931)
(Pl. 3, Figs. 8–10)

The test periphery is imperforate and pustules are concentrated along a peripheral band. The ultimate chambers are pinched, and in this aspect this species differs from *Hedbergella delrioensis,* its phylogenetic ancestor. The trochospire is usually as high as in *Praeglobotruncana stephani* (Gandolfi), but the pustulose peripheral band is still wide.

Genus *SCHACKOINA* Thalmann, 1932

Schackoina cf. *cenomana* (Schacko, 1896)
(Pl. 3, Fig. 11)

These specimens, with a single tubulospine on each chamber, are sporadic. The presence of the species in the upper Albian, as reported in Leg 40 (Caron 1978), is likely confirmed.

Genus *HETEROHELIX* Ehrenberg, 1843

Heterohelix moremani (Cushman, 1938)
(Pl. 3, Figs. 12–14)

The pairs of chambers slowly and regularly increase in size. The test surface is smooth. In some specimens the globular late chambers increase more rapidly (Figs. 13, 14), and very faint costae are present on the test surface.

CONCLUSIONS

The oldest sediments dated by planktonic foraminifers from the Côte d'Ivoire-Ghana Margin were recovered from Site 962 and are assigned to the upper Albian. The assemblages are composed of predominantly unkeeled forms and are very similar to those previously found in the Angola Basin and on the Walvis Ridge. Their characteristics may signify a cool environment.

Planktonic foraminifers of the Turonian (incomplete) and Coniacian–Santonian interval are recorded at Site 960; those of the Turonian are rare and poorly preserved; those of the Upper Cretaceous testify to Tethyan influences.

Planktonic foraminifers of Coniacian–early Santonian age were recognized only in thin sections at Site 959.

In contrast to the Turonian–Santonian morphotypes, the Albian planktonic foraminifers discovered during Leg 159 are well preserved; specimens exhibit unusually little dissolution or recrystallization.

ACKNOWLEDGMENTS

I thank ODP, the crew, marine technicians, and scientific shipmates of Leg 159 for an enjoyable and stimulating experience. I am greatly indebted to the Publication Services staff and M. Moullade, who checked the English manuscript. I. Premoli Silva and W.V. Sliter are thanked for their strong constructive reviews of the manuscript. For technical assistance in typing, I wish to thank A. Audoual. The micrographs were taken by D. Guillaumin at the electronic microscopy interuniversity center ("CIME Jussieu") of the Paris 6 University.

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Date of initial receipt: 9 July 1996
Date of acceptance: 2 April 1997
Ms 159SR-014

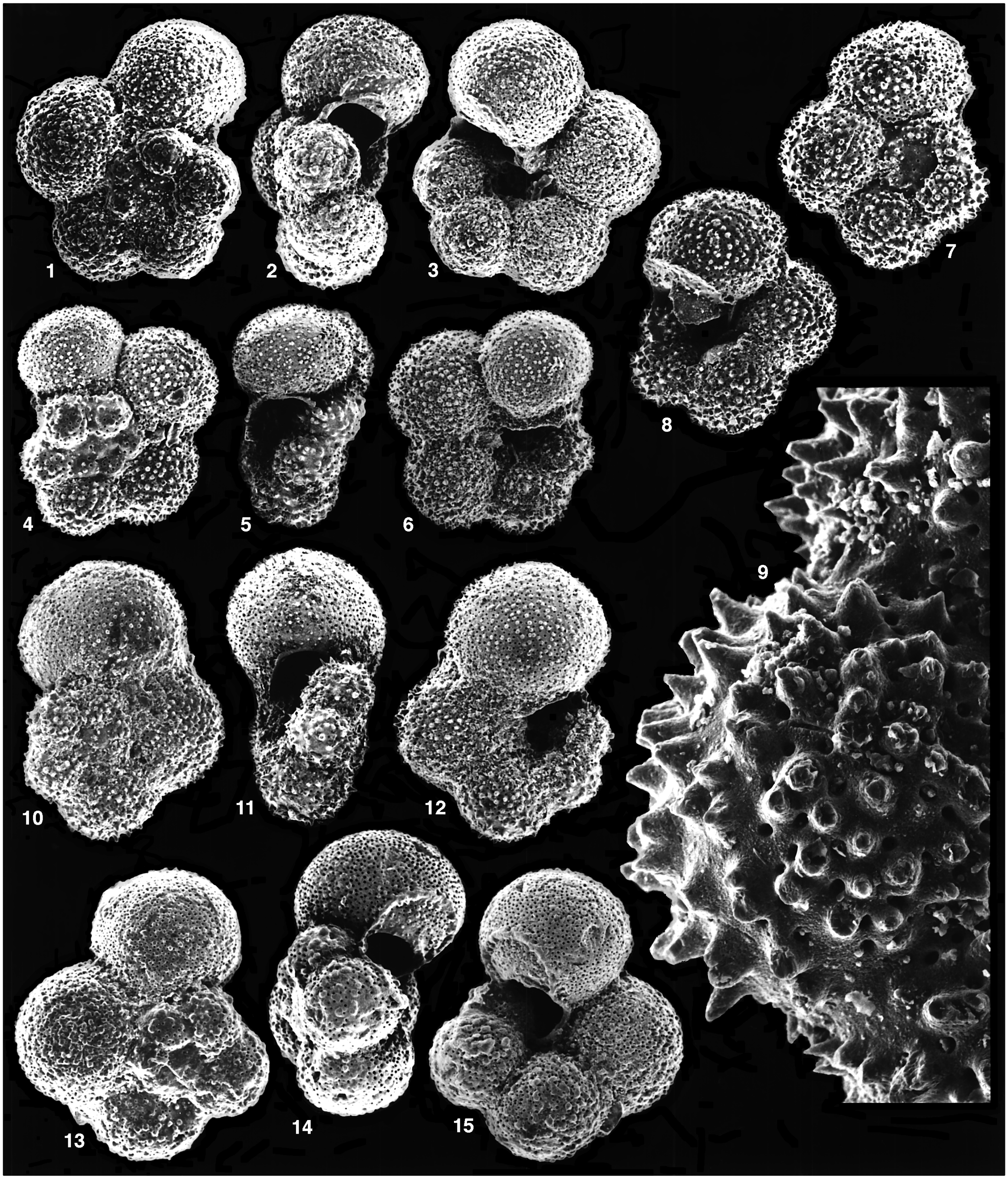

Plate 1. **1–3.** *Hedbergella delrioensis* (Carsey), spiral, side, and umbilical views, Sample 159-962B-10H-CC, 23–25 cm, 160×. **4–9.** *Costellagerina libyca* (Barr), same views, 9 detail of 8, Sample 159-962B-10H-CC, 160× and 950× (detail). **10–12.** *Hedbergella angolae* Caron, Sample 159-962B-10H-CC, 160×. **13–15.** *Hedbergella angolae* Caron (= *Whiteinella bornholmensis* [Douglas] of Caron, 1978), Sample 159-962D-8R-CC, 160×.

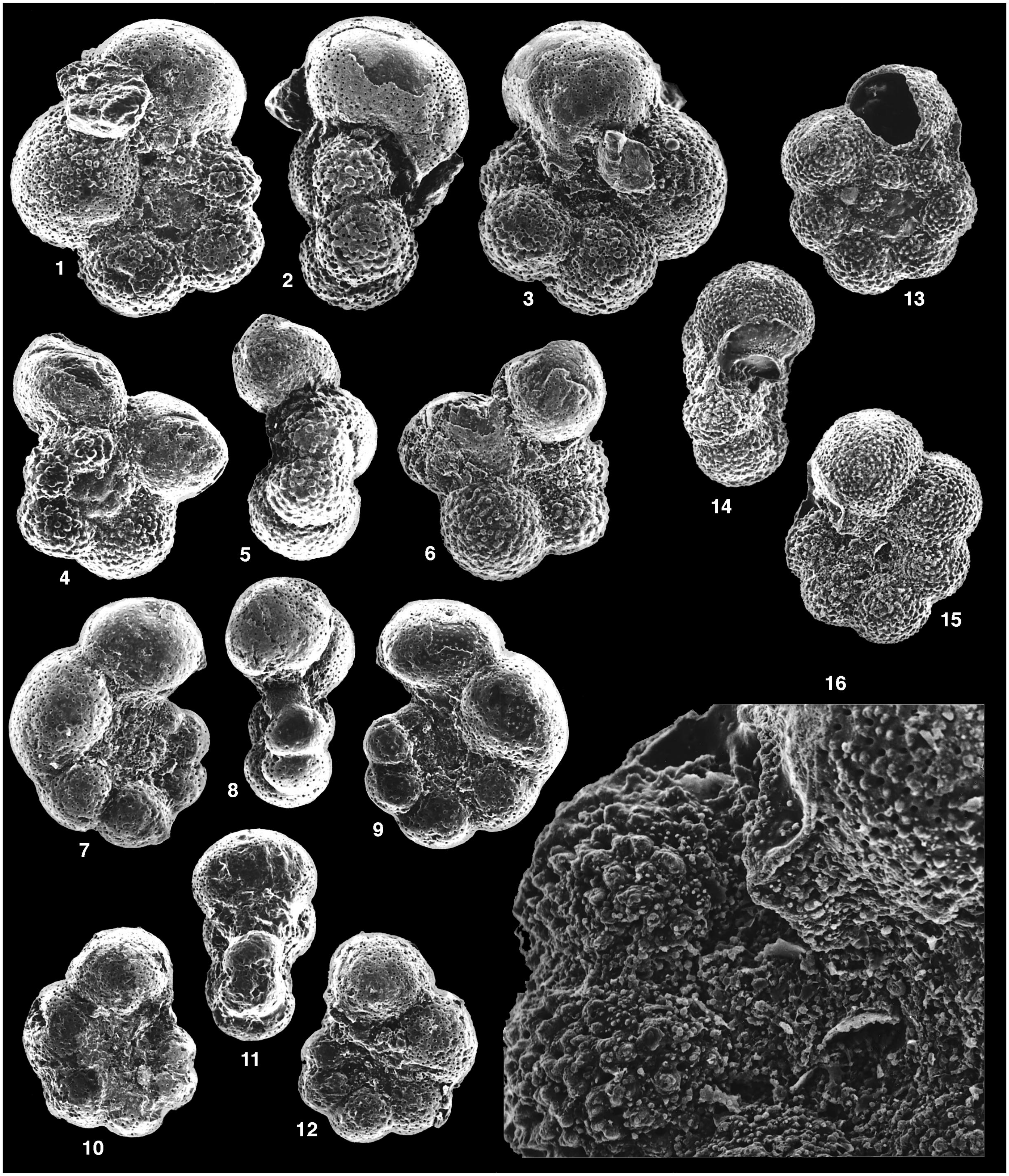

Plate 2. **1–3.** *Hedbergella* cf. *gorbachikae* Longoria, Sample 159-962D-19R-CC, spiral, side, and umbilical views, 160×. **4–6.** *Hedbergella* cf. *simplex* (Morrow), same views, Sample 159-962D-19R-CC, 160×. **7–9.** *Globigerinelloides caseyi* (Bolli, Loeblich and Tappan), edge and side views, Sample 159-962D-19R-CC, 160×. **10–12.** *Globigerinelloides bentonensis* (Morrow), same views, Sample 159-962D-26R-CC, 160×. **13–16.** *Ticinella madecassiana* Sigal, spiral, side, and umbilical views, 16 detail of 15, Sample 159-962B-10H-CC, 160× and 650× (detail).

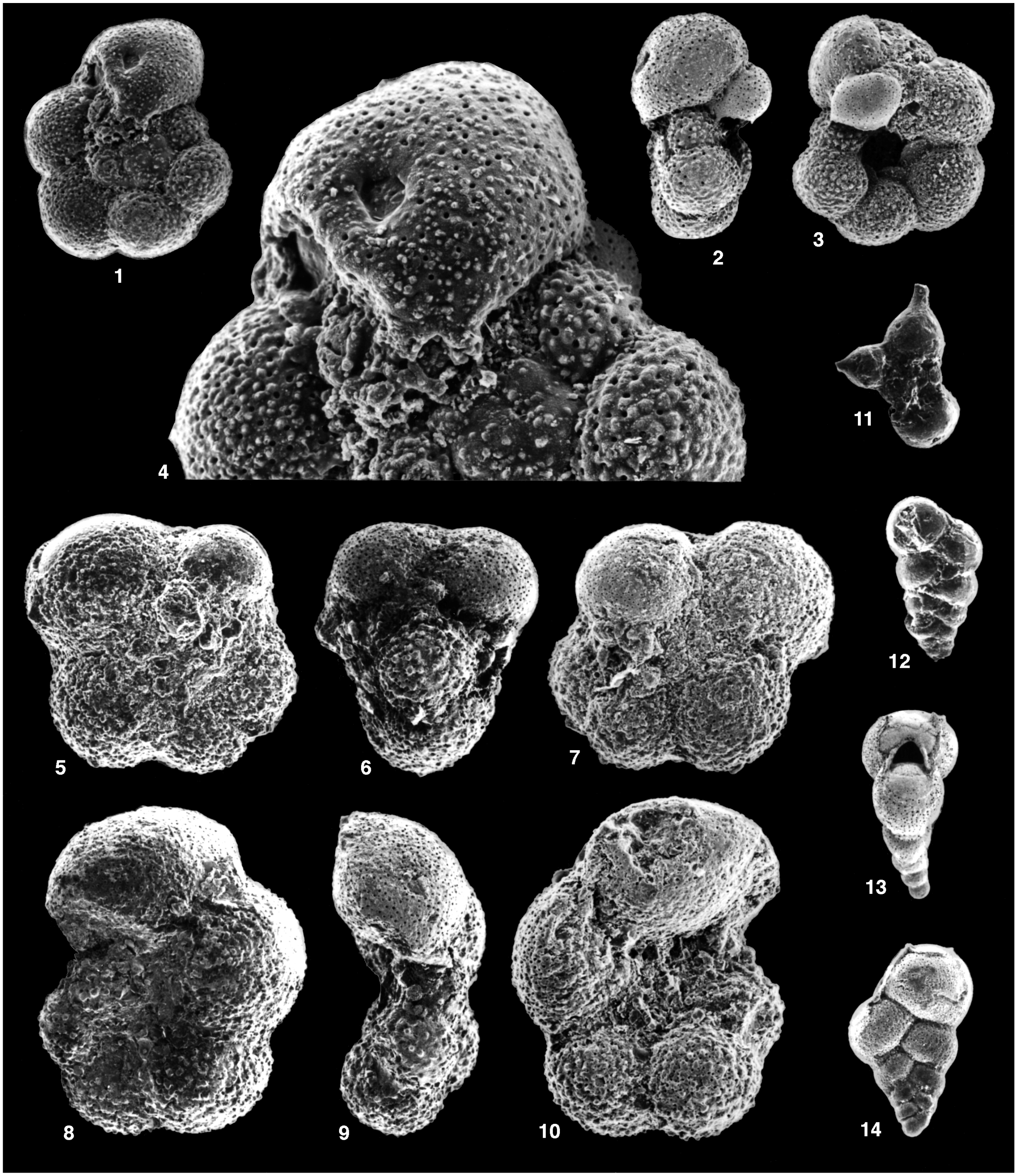

Plate 3. **1–4.** *Ticinella* cf. *roberti* (Gandolfi), spiral, side, and umbilical views, 4 detail of 1, Sample 159-962B-10H-CC, 160× and 450× (detail). **5–7.** *Biticinella* sp., edge and side views, Sample 159-962D-11R-CC, 160×. **8–10.** *Praeglobotruncana delrioensis* (Plummer), spiral, side, and umbilical views, Sample 159-962D-26R-CC, 160×. **11.** *Schackoina* cf. *cenomana* (Schacko), side view, Sample 159-962D-20R-4, 68–72 cm, 160×. **12–14.** *Heterohelix moremani* (Cushman), side views, 12: Sample 159-962D-20R-4, 68-72 cm, 160×; 13–14: Sample 159-962B-10H-CC, 23–25 cm, 160×.

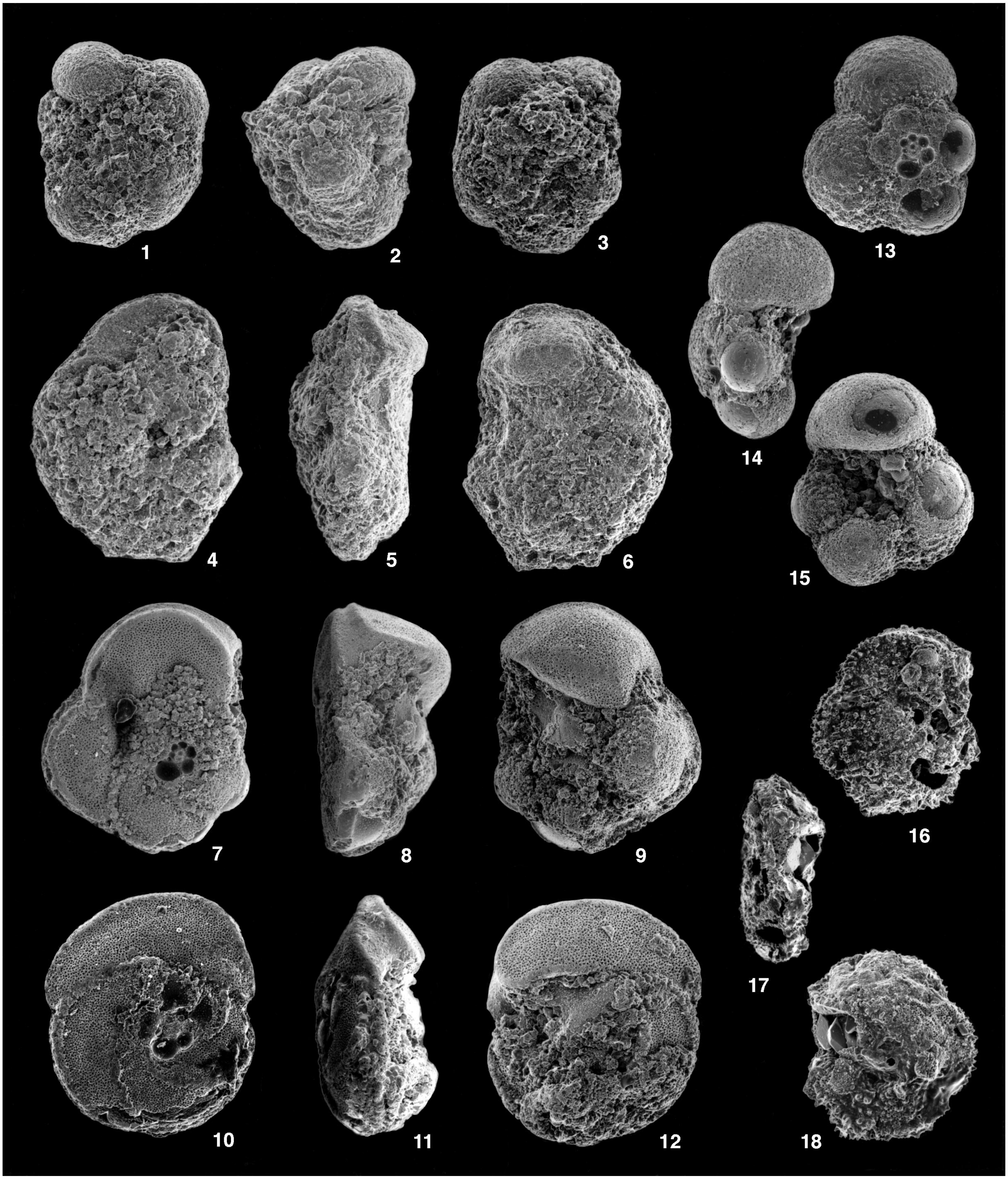

Plate 4. **1–3.** *Whiteinella* (?) *paradubia* (Sigal), spiral, side, and umbilical views, Sample 159-960A-20R-CC, 80×. **4–6.** *Marginotruncana* (?) sp., same views, Sample 159-960A-20R-CC, 80×. **7–9.** *Dicarinella concavata* (Brotzen) –› *asymetrica* (Sigal), Sample 159-960C-23X-CC, 80×. **10–12.** *Contusotruncana fornicata* (Plummer), Sample 159-960C-23X-CC, 80×. **13–15.** *Archaeoglobigerina blowi* Pessagno, Sample 159-960C-23X-CC, 80×. **16–18.** *Dicarinella* sp., Sample 159-960C-26X-CC, 80×.

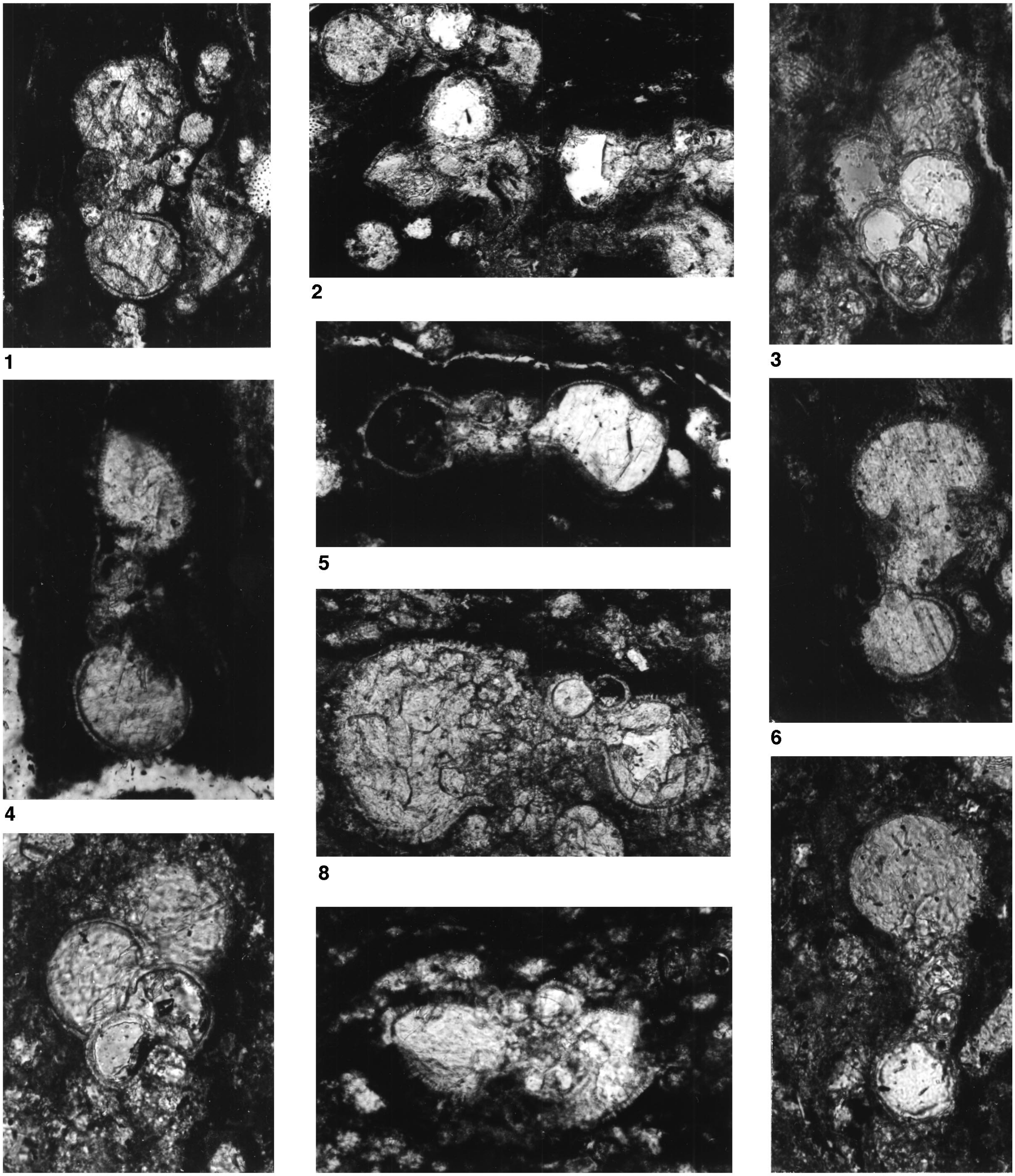

Plate 5. Thin section photomicrographs of Cretaceous planktonic foraminifers from Hole 959D and Hole 960C. All Figures are 135× (27 mm = 200 µm). **1.** *Archaeoglobigerina blowi* Pessagno, axial section, Sample 159-959D-66R-4, 118–120 cm. **2.** *Hedbergella* sp. cf. *H. delrioensis* (Carsey), *Hedbergella* cf. *flandrini* Porthault, *Dicarinella concavata* (Brotzen), axial, transverse, and subaxial sections, Sample 159-959D-66R-4, 118–120 cm. **3.** *Heterohelix globulosa* (Ehrenberg) lateral section, sample 159-959D-66R-4, 118–120 cm. **4.** *Whiteinella* (?) *inornata* (Bolli), axial section, Sample 159-959D-66R-4, 118–120 cm. **5.** *Archaeoglobigerina cretacea* (d'Orbigny), axial section, Sample 159-959D-66R-4, 118–120 cm. **6.** *Whiteinella* (?) sp., subaxial section, Sample 159-959D-66R-4, 118–120 cm. **7.** *Heterohelix globulosa* (Ehrenberg), lateral section, Sample 159-960C-26X-2, 25–28 cm. **8.** *Hedbergella delrioensis* (Carsey), axial section, Sample 159-960C-26X-2, 25–28 cm. **9.** *Dicarinella hagni* (Scheibnerova) axial section, Sample 159-960C-26X–2, 25–28 cm. **10.** *Whiteinella* sp. cf. *W. aprica* (Loeblich and Tappan), axial section, Sample 159-960C-26X-2, 25–28 cm.