

18. BARREMIAN AND ALBIAN FORAMINIFERA, SITE 549, LEG 80¹

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ABSTRACT

The Early Cretaceous series of Site 549 have been analyzed from both an ecological and a chronostratigraphical viewpoint. Lithology and microfaunal assemblages allow the division of these deposits into two parts. The lower part extends from the lower Barremian to the basal upper Barremian and possibly down into the upper Hauterivian. Three foraminiferal associations suggest an orderly evolution from a low-energy, littoral environment, in which continental influences dominated, to progressively more open marine conditions. A dolosparite bed (which has not yet been dated) separates these synrift deposits from lower to basal middle Albian postrift sediments that developed in a pelagic bathyal environment on the middle to nearby lower continental slope.

INTRODUCTION

Coring at Site 549 recovered sediments of Early to middle Cretaceous age including, below the lower Cenomanian, 190 m of lower to basal mid-Albian (Core 32 to Section 52-1, or 479–664.65 m BSF); a dolosparite (Core 52); and 285 m of lower to lower upper Barremian (and possibly upper Hauterivian) (Cores 53 to 91, and probably Cores 92 and 93 [almost devoid of microfossils], or 673.85–964.5 m BSF). The hole is bottomed in quartzite belonging to the Hercynian (Devonian?) basement (Cores 94 to 99, or 964.5–1001.5 m BSF).

This site is located in the Celtic Sea in 2535.5 m of water near the southern or seaward edge of a tilted block of the Hercynian basement belonging to the Pendragon Escarpment. One of the principal objectives was to examine the sedimentary history and paleoenvironment of the synrift and postrift phases of the northeastern Atlantic opening. The synrift deposits here are at least Barremian in age (the Hauterivian not being excluded). The postrift discontinuity took place in the interval from the late Barremian to the early or basal mid-Albian. However, seismic stratigraphy shows that laterally the series below the discontinuity may be appreciably extended at the top (containing layers which could be of late Barremian and possibly Aptian age).

METHODS

For biostratigraphy, thin sections of the more indurated levels of this Lower Cretaceous sedimentary series were examined at the University of Dijon (which was assigned the sedimentary study), and washed residues of the less indurated deposits were studied as usual. In addition to the foraminifers, calcareous nannofossils (Müller, this volume) which had already been used aboard the *Glomar Challenger*, Ostracoda and Radiolaria have been included in this study.

The thin-section study concentrated particularly on fossil constituents, and this paper primarily discusses observations of the Foraminifera.

A total of 137 samples were examined (111 from the Barremian and 26 from the Albian). The soft material, after washing, was sieved at 63 μm , and the microfossils recovered were used to make an ecostratigraphic inventory similar to recent studies at other DSDP sites (Sigal, 1979 and de Graciansky et al., 1982). In total, 180 samples were examined (150 from the Barremian and 30 from the Albian).

The results of these examinations concerning the soft sediments are assembled in Figures 1 (in back pocket) and 2. Data from the thin sections are shown in Figures 3, 4, and 8 of Rat et al. (this volume).

Figures 1 and 2 present a semiquantitative abundance analysis of the various recorded components: pyrite, glauconite, quartz, mica, rock fragments, Radiolaria, plant debris, macrofossil fragments, fish remains, spicules, otoliths, Ostracoda, and Foraminifera, both planktonic and benthic. Also included are symbols (in Greek characters) for the characterization of the foraminiferal assemblages and the degree of the reaction with HCl acid on sedimentary microfragments recovered in the residue as observed under the binocular microscope. Also, the foraminiferal species identified are tabulated. Space limitations allow us to record only the most important forms for chronological and/or ecological studies. Some of these species have already been described in the literature, whereas others are new, the latter being listed in open nomenclature. The other species included in these assemblages are informally grouped under their generic name (e.g., *Lenticulina* spp., *Hedbergella* spp., etc.). Whether or not they have been previously specifically identified, they are separately listed in the text under the genus to which they belong. The reader thus has ample opportunity to assess the total composition of the assemblage, particularly to draw possible ecological conclusions.

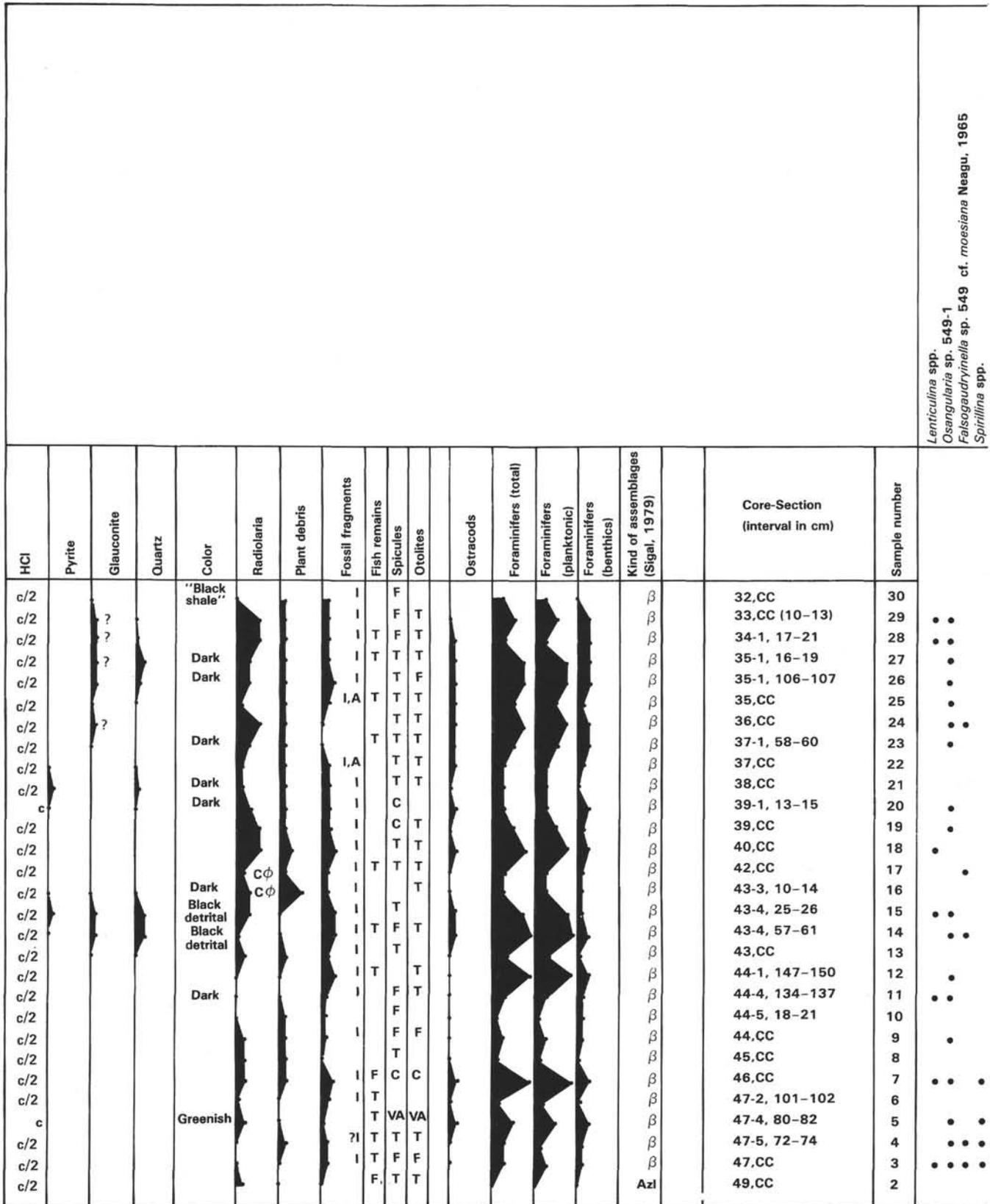
Plates 1 to 9 show the most representative taxa of the various paleoenvironments.

Also, because we had the opportunity, we attempted to locate the various samples at their correct positions on the lithological profile itself; hence we have included the γ -ray log and an interpretative lithological log of the Barremian on the left-hand side of Figure 1. The lithology was calculated from the geophysical logs taken on board ship. In an effort to attain the best possible accuracy, the probable position of the levels recovered in the cores has been indicated with a thickened vertical line to the left of the lithological log.

As will be seen, the progressive chronological "appearance" of the species indicated on the right-hand part of Figure 1 is primarily due to the fact that three successive facies (i.e., three significant ecological assemblages) are encountered from the base upward to the top. It is also true that this "stepped appearance" sometimes reflects an actual chronological succession that has a chronostratigraphic value. For instance, some first occurrences of *Falsogaudryinella* are probably significant, and this is also true for two succeeding subspecies of *Conorotolites bartensteini*. But it appears that for the majority of the recorded species, the dispersion through the successive samples, and consequently through time (particularly noticeable in Association 3), may be due to

¹ Graciansky, P. C. de, Poag, C. W., et al., *Init. Repts. DSDP*, 80: Washington (U.S. Govt. Printing Office).

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Lenticulina spp.
Osangularia sp. 549-1
Falsogaudyrynella sp. 549 cf. *moesiana* Neagu, 1965
Spirulina spp.

Figure 2. Ecological and chronostratigraphical chart of lower to basal middle Albian deposits at Site 549. Legend as in Fig. 1.

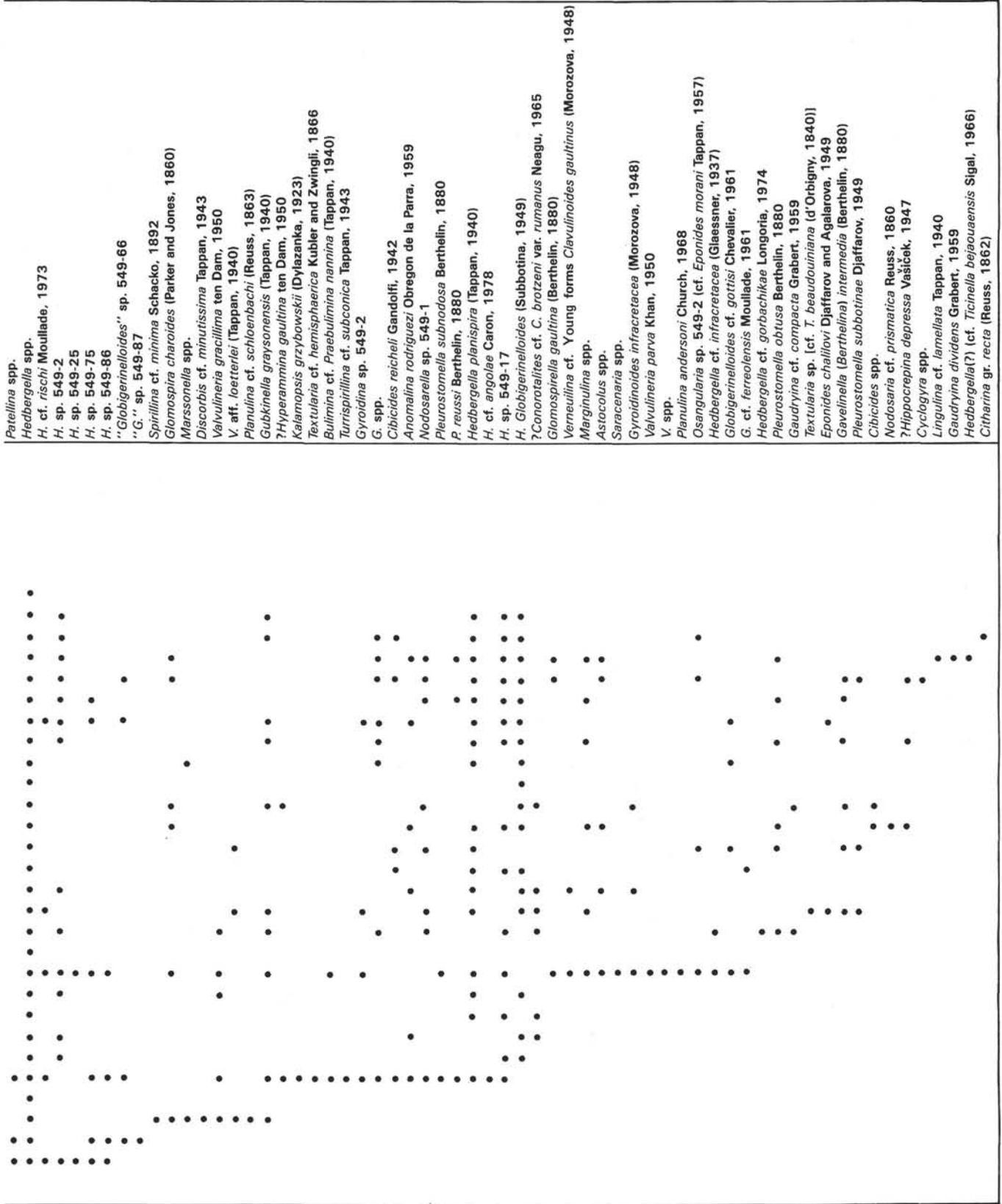


Figure 2. (Continued).

their own rarity, to the small quantity of sample material available, or to pure chance. Under better conditions (larger samples and more selective sorting), Figure 1 would probably be filled out more homogeneously, at least as long as the facies remains unchanged. This also applies to the Albian (Fig. 2), throughout which the "first occurrences" are fewer because the time lapse is shorter and the facies is more homogeneous.

In the thin sections, species identification was almost impossible because of common mediocre preservation (the shells are recrystallized), and because of the random orientation of the section planes. These thin sections generally are not very useful for accurate chronological work. However, taxonomic identification of the microfossils and their relationships with other elements in the sediment can provide information on environment, bathymetry, etc.

THE BARREMIAN STAGE

Figure 1 as well as Figures 3, 4, and 8 in Rat et al. (this volume) clearly show three successive, faunally exclusive units in the Barremian of Site 549 (Cores 93 through part of 52). This is particularly obvious in Figure 1, which documents the assemblages from the soft beds. These could be referred to as three "associations" closely linked to distinct sedimentary facies and paleoenvironments.

In describing the Barremian of Site 549, two biostratigraphic scales will be used concurrently. The first is the threefold subdivision of the German scale (Bettenstaedt, 1952; Bartenstein, 1978a and b, 1979), which is early Barremian or the *Strombecki* + *Rarocinctum* + *Fissicostatum* zones; middle Barremian or the *Elegans* + *Denckmanni* zones; and late Barremian or the *Sparisicosta*-*Stolleyi* + *Bidentatum*-*Scalare* zones. The second is the twofold subdivision of the planktonic zonation (Sigal, 1977), which is early Barremian or *Pulchella*-*Emerici* zone, and late Barremian or *Seranonis* zone.

Association 1 of *Choffatella* and Various Agglutinated Foraminifera

Throughout this interval (Cores 93?, 92?, and 91 through part of 78) the thin sections, as well as the washed residues, show that *Choffatella* and various other agglutinated forms (especially numerous species of *Haplophragmoides*) constitute the dominant faunal element. Foraminifera with hyaline calcareous tests are found less frequently. In the washed residues calcareous Foraminifera are more abundant within the carbonate-rich sediments. This was clearly seen in Cores 88, 87, and 81, and even more in Sample 85, CC, which was exceptionally rich in *Epistomina*. The thin sections showed that *Choffatella* is often more numerous, and the association more diversified, in the more bioclastic layers.

Both the thin sections and the washed residues show that all the Foraminifera, whether or not they are agglutinated, are rare if not absent in sediments which are rich in organic matter or pyrite or which are very clastic.

Other general trends can be seen in the data:

1. There is a great deal of fluctuation (presence/absence, abundance/rarity, diversity, etc.) linked with instability of the environment.

2. A more specialized population is found in the lowest beds (thin sections in Core 93) in which Foraminifera have been observed. It consists of some encrusting agglutinated forms probably belonging to *Acruliammina*.

3. In two intervals (Samples 549-91-1, 126-129 cm, and 549-84-1, 108-113 cm and 100-104 cm), a higher energy facies, sometimes with signs of reworking, contains (in thin section) more abundant and diversified small Foraminifera (Plate 7, Fig. 3), including miliolids (*Quinqueloculina* in particular), ataxophragmiids (*Dorothia*, *Marssonella*, etc.), and various other small Foraminifera which were difficult to identify (*Nezzazatinella*?, hyaline rotaliforms?, and polymorphinids?). *Trocholina* (up to 0.5 mm) were somewhat more frequent in these higher energy facies.

4. In addition to the normal agglutinated forms, an unusual assemblage of about 10 calcareous species, the most significant of which belongs to the genus *Epistomina*, has been found in Sample 549-85, CC. This indicates a "more marine" episode. The agglutinated forms present may have been transported.

5. Cores 80 to 78, for which there was poor recovery and which could be examined only with thin sections, contain a faunal assemblage transitional with the overlying association. It consists of small microgranular agglutinated forms, large *Haplophragmium* with calcareous walls, porcelaneous species, lagenids, and a few *Trocholina*. The latter are also found in the washed residues as deep as Core 91, although they are more dispersed and rare, probably occurring during carbonate-rich episodes.

Further Observations on the Sieved Residue

The following observations are based mainly on the washed residues, collected on a 63- μ m sieve; they are summarized in Figure 1. Similar observations made on the thin sections (and, thus, on another scale) are covered in Rat et al. (this volume).

There is a clearly marked alternation between carbonate-rich and carbonate-poor episodes; correlated with these (see above) are alternations between calcareous and agglutinated foraminiferal populations. The presence of pyrite is fairly frequent but irregular, and it decreases in abundance from Cores 82 to 81 upward (this may mark the boundary between lithologic Units E2 and E1). Pyrite appears to be correlated preferentially with the carbonate-poor episodes, where microfaunal elements tend to disappear. Pyrite sometimes owes its abundance to a large amount of pyritized plant remains. Glauconite is scarce and is apparently present in some carbonate-rich layers. Terrigenous material is generally abundant (especially quartz). Also present, often in abundance, are fragments of metamorphosed rock (up to Core 80). Radiolaria are absent, apart from two doubtful cases of pyritic spheres. Plant debris is consistently present up to Core 86. After that its presence becomes more irregular. It is sometimes abundant (especially in the lower cores), often of large size, and its anatomical structures are often well preserved.

Macrofossil fragments are frequently present. Bivalves are found as well as gastropods, occasional echinoids and *Inoceramus* (particularly toward the base of the section), and sporadic *Aptychus* and Bryozoa. Their abundance appears to correlate with the carbonate-rich episodes. Sponge spicules are rare. Ostracoda are usually

absent and rare where they do occur; they correlate positively with the carbonate-rich episodes.

Relationship of the Faunal Association to the Lithology

Faunal assemblages and lithology are associated in these series, which are dominantly terrigenous, although some bioclasts are present. This involves Units E1 to E4. At the base of the series, Unit E4 (Cores 93 to part of Core 91), which is made of alternating sandstone and siltstone beds, contains either the distinctive population of encrusting agglutinated forms described above, or on the contrary, no Foraminifera nor Ostracoda (although fragments of macrofossils, bivalves, and echinoids are sometimes abundant).

Units E3 and E2 (part of Core 91 to Core 84 and Core 83 to part of Core 80, respectively) cannot adequately be distinguished on the basis of their foraminiferal content. As we have seen, the populations are clearly sensitive to modifications of the facies, but only on the small scale of carbonate-rich banks or groups of banks. These units are composed of calcareous siltstone and bioclastic silty limestone beds. Unit E2 is poorer in fossils (at least in thin section) because of dilution by terrigenous material.

The transitional assemblage from part of Core 80 to Core 78 corresponds to Unit E1, which is distinguished by a fairly coarse clastic content and true bioclastic calcareous intercalations (in which the assemblage is more diversified than in units below). In thin section the appearance of the first ooliths and the presence of oncolites with *Girvanella* encrustations are noted. They are the first indications of the paleoenvironmental changes that lead to Unit D.

Composition of the Foraminiferal Association

A few genera, a moderate number of species, and generally few specimens (with the exception of *Epistomina* and sometimes *Choffatella*) characterize this first faunal association. Preservation of the isolated specimens is bad to mediocre; it is decidedly poor in thin section.

Acruliammina. These were observed only in thin sections taken from near the base of Unit E.

Glomospirella. One species was seen that can be related to *G. artica* Chamney, 1969 (Plate 1, Fig. 1); it was probably identified as *G. cf. gaultina* by various authors. It is found also in Association 3.

Haplophragmoides. Several species (at least 5 or 6) were encountered, but they are difficult to identify. One of these forms (in Samples 17 and 34) had a coarse wall and is probably related to *H. cf. barremicus* Mjatljuk, 1939 or to *H. arenatus* Crespin, 1963 (Plate 1, Fig. 2). Another form (in Sample 20) had a very flat, fine shell and may be related to *H. wilgunyaensis* Crespin, 1963.

Choffatella. Many specimens belonging to the group of *C. decipiens* Schlumberger, 1905 (Plate 1, Figs. 3–6) are found both in thin sections and washed residues. A clear morphological variation is noted: near the base they are small (usually less than 1 mm in diameter), but their size increases from Core 89 upward (approaching

or exceeding 3 mm). In thin sections subaxial section planes are most often observed (Plate 7, Fig. 1), with no preferential arrangement within the sediment. Thin, very flat forms (Plate 1, Fig. 5) are found alongside thick, umbilicate biconvex forms (Plate 1, Fig. 6)—a dimorphism (or even trimorphism) apparently linked to the life cycle (Sigal, 1959). The walls are often partially epigenized with pyrite, sometimes micritized, and the chambers are often filled with microsparite, sometimes pyrite, or in a few cases, glauconite (Cores 90 and 86). From Core 89 upward, much larger specimens are found, with a tendency toward fan-shaped chambers. *Choffatella* are also recorded farther up the section in Association 2.

Haplophragmium(?). Some large specimens (1.5–2 mm) observed in thin sections probably belong to this genus. Several species (?) follow successively, each differing in the extraneous elements of their walls: near the base they use grains of quartz, calcareous grains, and shell debris of bivalves (Sample 89-2) (Plate 7, Fig. 2), then coarse grains of quartz only (part of Core 89 to Core 87), and finally calcareous grains and shells of small Foraminifera (Cores 83–80).

Ammobaculites. There is a species in Sample 30 with a flattened and unlobated shell that can be compared to "*Ammobaculites*" *gomelensis* Akimetz, 1966, or *Ammobaculoides bellensis* Loeblich, 1946. It has also probably been identified as *Ammobaculites* sp. cf. *subcretaceus* Cushman and Alexander, 1930, or *A. humei* Nauss, 1947, in forms of specimens showing a tendency toward biserial growth when the shell begins to be rectilinear.

Trochammina. Two uncertainly determined species were found. One (in Sample 14) resembles *T. raggati* Crespin, 1944, or *T. lattai* Loeblich and Tappan, 1950; the other (in Sample 17) resembles *T. depressa* Lozo, 1944, or *T. mica* Akimetz, 1966.

Gaudryina. One species was found (in Sample 30) which has the morphology of *G. spissa* Berthelin, 1880, but with a more elevated aperture.

Miliolids. These are very sporadic in the thin sections.

Lenticulina. Several smooth-shelled species (at least 4 or 5) were found which are difficult to determine (and probably not of chronological interest). One form (in Samples 21, 23, and 59) belongs to the group *L. secans* (Reuss, 1860) as seen in its umbo and its slightly elevated sutures (see, e.g., the figures in Fuchs, 1971); another form (in Samples 50 and 59) belongs to the group *L. münsteri* (Roemer, 1839) or *L. caitarica* (Khalilov, 1951) as indicated by the great number of chambers. The absence of species with pustulated or ribbed shells should be emphasized.

Astacolus. A few (4 or 5) uncertainly determined species were found. One form (in Samples 15 and 20) may be compared to *A. chaltanica* (Agalarova, 1951) from the Barremian of Azerbaijan. Another form (in Samples 25 and 30) can be compared to *A. mutilatus* Espitalié and Sigal, 1963, from the late Neocomian of Madagascar or to *A. subgaultinus* (Bartenstein, 1962).

Saracenaria. One species found (in Sample 20) which cannot be determined.

Tristix. Three species found (in Sample 30) which cannot be determined.

Lingulina. Three species found, one of which (in Sample 30) can be ascribed to *L. nodosaria* Reuss, 1863.

Globulina. Three or four species found, one of which (in Samples 15, 30, and 51) belongs to *G. prisca* Reuss, 1863, and other (in Samples 24 and 48) to *G. exserta* (Berthelin, 1880).

Pseudonodosaria. One species found (in Sample 21) comparable to *P. cylindracea* (Reuss, 1845).

Epistomina. About 20 specimens were recovered (in Sample 30 in Core 85). Their occurrence gives this horizon an exceptional character compared to the lower Unit E (with Association 1). Their specific designation as *E. ex. group ornata* (Roemer, 1841) (Plate 1, Figs. 7–10), instead of *E. hechti* Bartenstein, Bettenstaedt, and Bolli, 1957, as was done on board the *Glomar Challenger*, still raises difficulties (H. Bartenstein, pers. comm., 1981). In fact, the morphology (in spite of a variable biconvexity), fine ornamentation, and small size (0.27–0.30 mm) on one hand, and the umbilical elevated ring (instead of convergent ventral sutures) on the other hand, could argue, respectively, for assigning these forms either to an atypically umbilicated *E. hechti* or to a young or possibly ecologically dwarfed *E. ornata*. (Forms with similar umbilicus, but normal sized [0.6–0.85 mm] *E. "hechti"* figured by P. Ascoli or E. Michael, from the Barremian could actually belong to *E. ornata*.) As explained below, this alternative identification has an effect on the age given to the sediments.

Trocholina. Some forms that generally cannot be assigned to a given species are encountered in the thin sections or in the washed residues. Some specimens which can be attributed to *T. aptiensis* Iovtcheva, 1962, are found, rare and dispersed, at several levels (in Samples 22, 54, and 63), as well as a variety (Variation 2 in Sample 30; see Association 2).

Paleoenvironmental Significance of Association 1

Generally the association of *Choffatella* and various agglutinated forms, characterized by a limited specific diversity and the predominance of a given species, indicates a distinctly littoral environment. This is probably more clearly marine, and with cleaner water, during the episodes in which the *Epistomina* and more numerous calcareous species become significant.

The sediments were most likely deposited in a shallow coastal marine environment where there was an influx of vast quantities of continental material, such as quartz and rock debris mixed with abundant plant remains (including *Charophyta*). The sedimentary context described by Rat et al. (this volume), i.e., the lithology and the sedimentary configuration and sequences, indicates a channeling, deltaic site of deposition.

Association 2 of Large *Trocholina* and Encrusting Foraminifera

Above the upper part of Core 78, except in one or two cases, Foraminifera are present in all samples, and the populations are consistently more prolific and more diversified than in Association 1. The problem posed at

the two ends of Association 2 (upper part of Core 78, Core 77, and Cores 66–62) will be considered later. In between (Cores 76–67), where the association is typically found, the faunal list includes two groups of species, one of which gives the name to the association, and another which is transitional between Associations 1 and 3.

Trocholina are the dominant faunal element and form rich and diversified populations. Their state of preservation is often poor: shells are often broken, corroded, and worn. Glauconitic internal molds are frequent. Their large size (up to 0.9–1 mm) distinguishes them from the less diverse *Trocholina* population found more sporadically in overlying Association 3.

Although the presence of *Trocholina* is a distinctive feature of Association 2, the genus is also observed in some horizons of the underlying Association 1 (sometimes with the same species). The link with Association 1 is strengthened (Plate 7, Fig. 4) by the number and frequency of specimens of *Choffatella*, although they are more sporadic and much less abundant than *Trocholina*. *Choffatella* are primarily observed in thin section (but also in washed residues) from the lowest level up to at least Core 72 (Core 71 was not recovered).

Some other species found in Association 2 also were encountered in the Association 1: these include *Lenticulina* (*L. secans* and *L. münsteri*) and probably some *Haplophragmoides*. Similarly, a few species which are abundant in overlying Association 3 are recorded here, but they are rare. These include *Astacolus crepidularis*, *Lenticulina* gr. *nodosa*, *Meandrospira djaffaensis*, and *Conorotalites bartensteini*. Possibly because of facies changes or because of chance in sampling or picking operations, these species are not found farther down in Association 1. For the same uncertain reasons, some other genera and species may not be confined to Association 2: for example, species such as *Epistomina colomi* and *Patellovalvulina patruliusi*, various indeterminate forms of *Lenticulina*, *Astacolus*, and *Spirillina*, and various microgranular agglutinated forms of *Valvulinidae*, *Verneuilinidae*, and *Textulariidae*.

Large and prolific *Trocholina* characterize this association, as do other characteristic Foraminifera observed in thin section, including miliolids (also present in washed residues), specifically encrusting Foraminifera found in carbonate-rich intervals (particularly in Cores 76–75 and 72–67), with chiefly agglutinated forms such as *Coscino-phragma*, then porcelaneous forms such as nubeculariids. Hyaline forms are rarely present.

Several sedimentological and paleobiological features are unique to faunal Association 2. As an example, there is the occasional presence (Plate 7, Fig. 7) of "calcitic eyes" (the origins of which are not clearly established) in the walls of the agglutinated Foraminifera (*Coscino-phragma*, *Haplophragmium*, and *Triplasia* [?]). They are observed principally in Cores 72, 69, and 67. Also, Foraminifera, especially worn *Trocholina*, frequently *Lenticulina*, and more rarely *Quinqueloculina* and *Marsionella*, serve as "nuclei" in the oolitic or oncolitic facies of Core 75 (Sections 2 and 3). Encrusting forms are sometimes oolitized or oncolitized and sometimes colo-

nized by newer generations of encrusting forms (Core 75, Section 3).

Further Observations on the Sieved Residue

These observations are summarized in Figure 1. The statements concerning Association 1 apply also to Association 2, with the addition of the remarks below.

The sediments are calcareous, and pyrite is practically absent. Glauconite is sometimes fairly abundant: it seems to be confined to the middle part of the interval concerned. It frequently takes the form of internal molds, particularly of *Trocholina*. The high clastic content seen in the sediments of Association 1 continues into the lower core (76) and then decreases and disappears upward. Metamorphic rock fragments have disappeared. There are sporadic occurrences of pseudo-oolitic horizons and a sandy dolomitic bed at the top of the section. Radiolaria are absent, as in Association 1. Plant remains and quartz grains vary similarly. The very diverse fragments of microfossils (sometimes of large size) are virtually always present and often abundant. By contrast, fish remains, spicules, and otoliths are sporadic. Ostracoda are present almost constantly but are usually rare.

Relationship of the Faunal Association to the Lithology

A correlation exists between the characteristics of the fossil association and the nature of the sediments in Units D1 and D2, where calcareous banks containing benthic organisms or bioclasts dominate. It is difficult to take this one step further and detect a distinct faunal correlation with these two units, although Unit D2 (Cores 76 to part of Core 72) does contain more terrigenous material than Unit D1: the faunal assemblage is homogeneous from the bottom to the top of the section. At best, a reduction in the number of individuals and species is observed where the facies is more detrital or quartz-rich (analogous to the situation seen in faunal Association 1). However, this is more sporadic than before. In general, the microfauna in upper Unit D1 seem to be a little less abundant; however, thin sections show that this impression is more apparent than actual and is linked to a high degree of micritization and dissolution and to the presence of coarse bioclasts (coral).

Actually upper Unit D1 has not been extensively analyzed because the only valid cores were 72 and 70; the remainder of the core barrels came up nearly or entirely empty. Nevertheless, thin sections from Core 67 and interpretation from the geophysical logs indicate that the lithology associated with the large *Trocholina* fauna extends through Cores 66 to 62.

At the base of lower Unit D2, lithological characteristics also indicate that sediments of Association 2 extend down to the level of Core 77 and part of Core 78.

Composition of the Foraminiferal Association

A small number of genera, a moderate number of species, and a small number of specimens (except for the characteristic genus *Trocholina*) are the typical features of this middle association. Preservation is gener-

ally poor and rarely good, probably because of the high-energy environment in which the fossils were deposited.

Agglutinated encrusting species are observed in thin section and belong to *Coscinophragma* (Plate 7, Fig. 7), *Acruliammina*, and *Placopsilina*.

Glomospira. An indeterminable species found rarely in thin sections.

Lituolids. These were found as sections of small, coiled forms (*Daxia* and *Mayncina*, in particular) and probably of large *Triplasia*.

Haplophragmoides. Very rare, isolated specimens were recovered, which are not determinable.

Haplophragmium(?). Sections of large specimens (Plate 7, Fig. 7) are present, usually calcareous-walled, rarely with incorporated quartz grains.

Choffatella. Those found still belong to the group *C. decipiens*, some of which are large (up to 3 mm), but they are mostly represented by thin, flat forms. In thin section (Plate 7, Fig. 7) the shells appear to be highly micritized. They are not found above Core 72.

Ataxophragmiidae. Fairly numerous forms, specifically indeterminable, were observed in thin sections. *Dorothia*, *Marssonella*, *Gaudryina*(?), *Tritaxia*, and *Belorusiella* have been recognized among them.

Gaudryina. A few rare specimens were found, which were not specifically determinable.

Falsogaudryinella. There are a few specimens (Sample 90), not specifically determinable. (This genus will be one of those characteristic of the following Association 3.) Sample 90 also contains several *Conorotalites bartensteini*, which are also important higher in the section. The presence of these taxa could indicate down-hole contamination. (Also, this clayey sample was recovered from a core barrel that was almost empty.) However, the presence of a few large *Trocholina* leads to the conclusion that this is not the case and that we are still within Association 2. Also, there are eight more cores of the same general facies (Unit D1) before the first record of overlying Association 3 (according to the logs mentioned previously).

Orbitolinids. Two very poor thin sections (Section 70-1), which Schroeder was to examine, were unfortunately lost. It is unlikely, however, that they would have given any precise chronostratigraphic information.

Porcelaneous encrusting species. Sections of forms belonging to the *Nubeculariidae* were found; the test walls are often partially dissolved.

Meandrosira. Observed only in thin section, these forms are probably *M. djaffaensis* Sigal, 1952, which is also found in washed residues from the first samples of Association 3.

Miliolids. Infrequent specimens (mostly *Quinqueloculina*) were observed in thin sections and a few specimens in the washed residues. The test walls are often partially dissolved.

Lenticulina. Unornamented species were present, which are of little interest, as in Association 1. Specimens belonging to the *L. secans* (Reuss, 1860) and to the *L. muensteri* (Roemer, 1839) or *L. caitarica* (Khalilov, 1951) groups continue up into this association (Samples 66-64). Among nodose or ornamented species, the first

forms belonging to the variable group *L. nodosa* (Reuss, 1863) (Samples 83 and 74) appear, as well as several specimens (Sample 74) comparable to *L. ataktos* Espitalié and Sigal, 1963 (Plate 1, Fig. 11), described from the late Neocomian of Madagascar, or comparable to *L. kugleri* Bartenstein, Bettenstaedt, and Bolli, 1957, described from the middle to late Barremian of Trinidad.

Astacolus. Two species are present, one of which could not be named, the other belonging to the variable species *Planularia crepidularis* (Roemer, 1842), which diversifies in faunal Association 3.

Hyaline encrusting species were observed in thin sections.

Spirillina. A few specimens, possibly comparable with *S. neocomiana* Moullade, 1961, were found.

Patellovalvulina. A few specimens (Sample 84) were recovered that can be related to *P. patrulei* Neagu, 1975, which is also found in faunal Association 3.

Trocholina. This genus gives the association its character. The most abundant specimens belong to the *T. aptiensis* group. The species itself was described by Iovcheva in 1962 and ranges through the Barremian and lower Aptian, and possibly into the upper part of the Hauterivian as well. The typical form of *T. aptiensis* (Plate 1, Figs. 12–13 and Plate 7, Fig. 5) occurs along with two varieties. Variety 2 has a generally more elevated cone and larger, more numerous and contiguous pillars (Plate 1, Figs. 14–15). Variation 7 is larger, with more numerous pillars, grooves, and scallops (Plate 2, Figs. 4–5). These forms dominate Association 2. It should be recalled that some specimens were observed occasionally in underlying Association 1. Other specimens were found in the overlying Association 3 and are discussed later. Numerous specimens occur, also present in overlying Association 3, which are similar to *T. burlini* Gorbačik, 1959, in their very pronounced flattening and irregular pillars (Plate 1, Figs. 16–17). Within this population of large *Trocholina* there are several other species that may be new: sp. 6 (pronounced conical shell, a few small pillars, with grooves and scallops) (Plate 2, Figs. 1–2); sp. 8 (almost hemispheric shell, many small pillars, with many grooves and scallops) (Plate 2, Fig. 3); sp. 15 (almost hemispheric shell, few large pillars, with grooves and scallops) (Plate 1, Figs. 18–19); and sp. 16 (relatively small shell, three to five large pillars, no grooves) (Plate 1, Figs. 20–21).

Epistomina. One specimen (Sample 67) recovered that belongs to *E. colomi* Sigal, 1949, which is also found in overlying Association 3.

Conorotalites. A few specimens were found that are related to *C. bartensteini bartensteini* (Bettenstaedt, 1952) in Sample 90, which was discussed above (see *Falsogaudryinella*).

Paleoenvironmental Significance of Association 2

The association of large *Trocholina* and encrusting Foraminifera suggests a shallow marine environment representing a carbonate-rich shelf, probably in the infralittoral stage. The greater abundance and diversity of the foraminiferal population in this association suggests that more favorable conditions, such as normal salinity and

sufficient oxygenation, existed than before. Several features suggest a similarity with the "Urgonian" facies: the age, general facies, and especially the main faunal elements, such as the macrofossils and bioclasts; the agglutinated foraminifers, especially those having calcareous walls; the porcelaneous species; nubeculariids; and *Trocholina*. But the cored sediments suggest a rather strong contamination with terrigenous material (particularly quartz), and many of the characteristic macrofossils (especially rudists) and microfossils (orbitolinids) of the Urgonian environments are missing. Thus it appears that any comparison would not be valid. Lastly, the unrecovered thick, overlying layers, thought to be much more calcareous, still remain a mystery.

Association 3 of *Hedbergella* and Small Benthic Calcareous Foraminifera

Every sample taken in the zone (Core 61 to part of Core 52) characterized by this association is fossiliferous. By comparison to Association 2 (and some genera are common to both of them), this is a typical "small Foraminifera association" (Plate 8, Fig. 1), in other words, their size is generally less than 1 mm: 0.2 to 0.5 mm for the benthic forms, except for some *Tritaxia* and less than 0.15 mm for the planktonic forms except in the highest beds. Even the *Trocholina* (admittedly not the same species as deeper in the section) are small.

Another obvious characteristic is the presence of planktonic forms, mainly *Hedbergella*, in the unindurated layers upward from Core 60 (Sample 103). In the thin sections (Plate 8, Figs. 16–17), *Hedbergella* species are present from the top of Core 61 (Section 61-1, 34–36 cm) upward, and they occur in more clay-rich beds. We have no explanation for the absence of planktonic Foraminifera in the lower horizons (Core 60 and part of Core 61), where they should be expected. Their absence may be due to a more abundant and coarser clastic input or to other unknown environmental factors, or it may be a matter of chance.

Another important characteristic of Association 3 is the far larger number of genera and species than in older units. The succession of first occurrences of species seen in Figure 1 does not necessarily constitute a succession of chronostratigraphic markers. Intrinsic rarity, the chance factor during picking processes, and the small volume of sediment processed can all explain this "stepped" succession. By contrast, however, it is well known that this is not the case for certain taxa, e.g., *Conorotalites bartensteini* has two variants which actually succeed one another at a certain level in the middle Barremian.

All major groups of smaller Foraminifera are represented in Association 3; quartz agglutinating forms, microgranular calcareous agglutinated forms, porcelaneous forms, and hyaline forms are always present. The benthic forms are almost always relatively abundant, but some genera are represented by only a few species (*Gyroldinoides*, *Conorotalites*, *Gaudryina*, and *Falsogaudryinella*), while other genera, especially among the Lagenidae, are represented by many species but only a few individuals. Planktonic forms are never abundant, often

being absent (Assemblage β') in the lower half of the section (Cores 61–57) but rarely absent in the upper half, with the exception of the highest beds (Cores 54 and 52) where they are often missing again.

Associated with the "normal" species that one expects to find at that level in this facies (e.g., the *Gavelinella*, some *Gaudryina/Spiroplectinata*, *Lenticulina*, and *Marginulinopsis*) some unusual forms are found in Association 3 (at least by comparison with Mesogean microfaunas or with microfaunas of the Paris Basin). The genus *Falsogaudryinella*, for example, is highly diversified and sometimes abundant and could even be said to characterize this association (albeit at a secondary level).

The lowest core (61) is distinguished by the presence of a few large *Trocholina* and some *Choffatella* (except at its top, as just discussed, with regard to the *Hedbergella*). This core is thus related to the underlying layers, and it is possible that these fossils were transported during the deposition of the sediment, which is more clastic and biotrital (containing fragments of *Madreporaria*) than in the higher part of the section.

Core 61 could almost be distinguished as a "lower subzone" with numerous Ataxophragmiidae and without *Hedbergella*, which is most clearly noticeable in thin sections. Along with the genera already mentioned, numerous *Dorothia*, *Marssonella*, *Falsogaudryinella*, and *Gaudryina*(?) are also present. Added to these are various other forms such as *Spiroplectamina/Textularia*, fairly common porcelaneous species (such as *Quinqueloculina*), rare *Meandrosira*, a few *Lenticulina*, *Lingulina*, and *Pseudonodosaria*, small but typical *Conorotalites*, and a few hyaline rotaliforms.

If Core 61 would be distinguished as a lower subzone, the rest of the section would then correspond to an "upper subzone," which is more readily characterized by Association 3. The remains of Association 2, present in the lower subzone, have disappeared. The microfauna is relatively rich in the soft sediment and varies in detail with the lithology. In thin sections lower cores (61 and 60) have the richest and most highly diversified foraminiferal assemblages. Middle cores (59 to 55) are poorer and the test walls are micritized; the top of Core 55 and all of Core 54 again show a more abundant assemblage particularly attributable to a proliferation of the genus *Hedbergella*.

Further Observations on the Sieved Residue

These observations are summarized in Figure 1. The statements made about Association 1 apply also to Association 3, with the addition of the remarks below.

The sediments are rich in carbonate throughout. Pyrite is virtually absent. Glauconite is present, sometimes abundant, at the base of the section (Core 61 to part of Core 58, and especially Core 60); above this it becomes sporadic. It frequently appears as internal infilling of fossils. The amount of terrigenous material follows the glauconite curve of the bottom of the section but then progressively disappears about two-thirds of the way through the section, at the level of Cores 56 and 55.

Radiolaria are absent. Plant remains are almost constantly present, except in the upper third of the section

(part of Core 55 to Core 52), where they are often absent. They are never abundant. Macrofossil fragments are constantly present and often fairly abundant. *Inoceramus* fragments are prominent, along with the usual remains of bivalves, gastropods, echinoids, and more rarely, bryozoa, brachiopods, sponges, *Madreporaria*, worm tubes, and algae. Fish remains are frequent but always rare; nevertheless they are absent in lower Cores 61 and 60 and in upper Cores 54 and 52. Spicules occur sporadically. Ostracoda are always present (except at the very top) but rarely abundant.

Relationship of the Faunal Association to the Lithology

The entire section containing the association of *Hedbergella* and small calcareous benthic Foraminifera corresponds to a single lithological unit (C). This facies is considered to be homogeneous (as indicated by the geophysical logs): it is a clayey carbonate-rich deposit dominated by fine terrigenous material (calcareous silt or claystone). Thin sections and washed residues suggest that the terrigenous material becomes finer and less abundant from the bottom toward the top.

The lithological homogeneity is not reflected by the various organic components: planktonic and benthic Foraminifera, among others, evolve independently throughout the section. Moreover, the abundance of Foraminifera and even the generic or specific composition differ in washed residues versus thin sections. All of these variations indicate that the sediments of Association 3 are somewhat heterogeneous, as most likely were the conditions under which they were deposited. These conditions doubtless evolved toward a "more marine" environment, which is a general trend seen in the Barremian section so far described. It is difficult, however, to find evidence in foraminiferal Association 3 to confirm this upward evolution, except for the proliferation of planktonic forms in the upper cores (seen in thin sections) coinciding with the upward fining of the sediment. Certain Foraminifera, quartz grains, and glauconite present at the base of the section were apparently inherited from Association 2, but it is not possible to determine which elements are the result of redeposition (distant reworking) of pre-existing sediments and which are a result of the persistence of old conditions in a new environment.

Lastly, it is possible that internal dynamic factors, such as currents, might have led to sedimentary deposits (such as pseudosequences and contourites) which could differ slightly in their biological characteristics (e.g., abundance, size, and possibly specific composition) as well as lithological characteristics (e.g., grain size, sorting, and induration).

Composition of the Foraminiferal Association

The characteristics of this association have been given above; there are many genera and many species represented by few individuals (especially among the lagenids). The preservation of both isolated specimens and those in thin section varies but is usually about average.

Glomospira. A few forms were present that probably belong to *G. subartica* Chamney, 1969, described from

the Barremian of Canada, and to *G. gordialis* (Jones and Parker, 1860) or *G. tortuosa* Eicher, 1960.

Glomospirella. A few forms were found that probably belong to *G. elongata* Chamney, 1969, described from the Barremian of Canada and sometimes named *G. multivoluta* Romanova, 1955. *G. artica* Chamney, 1969, is also found at this level.

Spiroplectamina/Textularia. Along with a few individuals that approach *S. dorni* Zedler, 1961 (Sample 108), this group is well represented throughout the section by abundant *S. schultzei* (Reuss, 1863) (Plate 2, Fig. 6) and more rarely by *T. bernardi* Chevalier, 1961 (Plate 2, Figure 7) (Samples 98 and 120). One last, rather variable, rare form (Samples 129 and 141) belongs to the genus *Textularia* and might be compared to *S. cushmani* Crespin, 1944.

Trochammina. There were a few specimens (Sample 148) present that probably belong to *T. globigeriniformis* (Parker and Jones, 1865).

Verneuilina/Gaudryina/Tritaxia. A number of forms (sp. 4) (Plate 2, Figs. 8–10) can be assigned to these "genera." They resemble *V. angularis* Gorbačik, 1971 fairly closely and seem to be present only in the upper levels of the section. In the lower levels, another group of forms (sp. 6) belonging to the same spectrum of genera probably corresponds to a new species, with a distinctly angular triserial stage (Plate 2, Figs. 11–12).

Gaudryina/Spiroplectinata. This generic group is sometimes abundantly and frequently represented. Two species are dominant. *G. praedivida* Neagu, 1975 (Plate 2, Figs. 13–16), is described from the early Barremian of Rumania and ranges through the Hauterivian and Barremian, according to Bartenstein (1979). This may be synonymous with *G. intercedens* Fuchs, 1971, described from the middle Barremian of Austria. The other species (*G. sp. 5*) (Plate 2, Figs. 17–20) (probably a new one) has a fairly coarse, arenaceous test wall with an enlarged, flat biserial stage. It differs from the two species between which it is stratigraphically found (*G. chettabaensis* Sigal, 1952 [Valanginian] and *G. lata* Grabert, 1959 [lower Albian]) both in the greater size of its triserial stage and in the design and obliquity of its biserial chambers. These two species show specimens which correspond to a *Spiroplectinata* stage. Thus, we have here typical morphologic spectra displaying "generic" diversity within a single species, as described by several authors (*S. dividens* according to Grabert, 1959, and Sigal, 1966; *S. carinata* according to Moullade, 1966; and *S. robusta* according to Moullade, 1966).

Along with these two species (*G. praedivida* and sp. 5), several other more sporadically occurring forms are found, one of which (Samples 98 and 110) resembles *G. richteri* Grabert, 1969, described from the late Hauterivian–Barremian of Germany. Another (Sample 110) resembles *G. (?) spassensis* Mjatljuk, 1970, or *G. tappa-nae* Chamney, 1969, both described from the Barremian. The latter form (in Sample 110) is probably linked to a species like *Verneuilinoides subfiliformis* Bartenstein, 1952, which is also Barremian to early Aptian in age.

Palaeogaudryina(?). A few specimens (Sample 127) were recovered which can be compared to *Belorussiella textularioides* (Reuss, 1863) (Plate 8, Fig. 6).

Tritaxia. The genus is represented throughout the section by *T. pyramidata* (Reuss, 1863) (Plate 8, Figs. 2–3).

Falsogaudryinella (sometimes ascribed to the genus *Uvigerinamina*). The strong development of this genus (to which the Mesogean micropaleontologists and those working in the Paris Basin are little accustomed) constitutes one of the characteristics of Association 3 (although some specimens appeared immediately before the association). A fairly large variability and an evident dimorphism of generations (A and B) are responsible for the large number of described species. Yet it will be shown that the material of Site 549 suggests the introduction of a new species. *Falsogaudryinella* are also encountered in thin sections (Plate 8, Figs. 7–8).

The two main species, which are present throughout the series and which are sometimes abundant, correspond to *F. hannoverana hannoverana* (Bartenstein and Brand, 1951) (Plate 2, Figs. 21–24) and *F. hannoverana tealbyensis* (Bartenstein, 1956) (Pl. 2, Figs. 25–26). Both are known from the late Valanginian–Barremian. Some forms of the latter resemble *Pseudopolymorphina(?) gureviensis* Mjatljuk, 1973, which is described from the late Aptian. Obviously they are not subspecies in the biological sense of the word. It has been suggested in the literature that they represent micro- and macrospheric forms of the same species. This is not certain, however, and they are probably only two distinct varieties.

A third form (*F. sp. 7*) (Plate 3, Figs. 1–3) with a voluminous *proloculus*, probably belongs to the preceding group (possibly an A1–A2 dimorphism?). It resembles certain examples given by Neagu (1975) for *F. hannoverana* and for *F. sp.* Damotte and Magniez, 1973, which is now *F. alta* Magniez, 1975, of the early Aptian (at the Aube Department, France).

A fourth form (*F. sp. 5*) (Plate 3, Figs. 4–6) resembles *F. moesiana* (Neagu, 1965), described from the Rumanian middle Albian, from which it retains the angular and twisted shell (even more angular and twisted than the type specimens). The fifth and last form (*F. sp. 4*) (Plate 3, Figs. 7–10) is apparently new, if we consider the particular morphology resulting from its angular, almost winged shell, extended at the base by a series of short spines.

Dorothia. There are several forms present which are difficult to determine. Some almost certainly belong to *D. hechti* Dieni and Massari, 1966, a somewhat variable species. Others (Sample 115) might be young forms of *D. praeoxycona* Moullade, 1966, and a third may be compared with *D. grandis* Crespin, 1963, or to a slender variety of *D. hauteriviana* Moullade, 1961. The first is present throughout the association, and the latter in the upper half. They are frequent in thin sections (Plate 8, Fig. 5).

Pseudoclavulina. This genus occurs rarely; one form (Sample 100) is probably close to *P. almadensis* Cushman and Todd, 1948.

Discorinopsis. Rare specimens which resemble *D. primitivus* Neagu, 1975, described from the Barremian of Rumania.

Cyclogyra. Some undeterminable sections probably belong to this genus.

Meandrospira. Specimens are found in several layers, but they are rare. (Some specimens also occurred in Association 2.) They correspond to *M. djaffaensis* Sigal, 1952, which extends from the upper Hauterivian to the lower Aptian.

Miliolidae. There are several forms present, but their specific identification was not undertaken because they are always rare (six or so) in the few samples that contained them. They are observed (*Quinqueloculina*) in particular in the thin sections (Plate 8, Figs. 9–10) of the lower subzone (Core 61).

Lenticulina. This genus is frequently represented by numerous species, among which the following are worthy of note: *L. nodosa* (Reuss, 1863), which was also present within Association 2; *L. deilmanni* Kemper, 1963 (Plate 3, Figs. 14–15) (syn. *L. pseudoatheria* Fuchs, 1971); *L. ouachensis* (Sigal, 1952) (Plate 3, Fig. 17); *L. collignoni* Espitalié and Sigal, 1963 (Plate 3, Fig. 16); and *L. barremica* (Agalarova, 1961). This group of forms is centered on the Barremian, but may survive it.

Astacolus. The forms encountered are numerous (at least 40), but they are infrequent and not very abundant, owing to their natural rarity and the small quantity of material processed; most are consequently of little use. One exception is the highly variable species *A. crepidularis* (Roemer, 1842), which is abundantly found almost everywhere (it has also been noted within Association 2).

Vaginulina. These are relatively frequent. The “*Citharina*” *recta* group is present with its diverse “species” (*C. recta* Reuss, 1863; *C. robusta* Chapman, 1894; *C. arguta* Reuss, 1860; and *V. kochii* Roemer, 1841). This group was examined in detail several years ago (Albers, 1952) with reference to the Barremian stage (to which it is not limited). Some other forms may possibly be related to species already described or cited in the literature. However, there is the continuing problem of the variable concept of species by different authors with forms whose original descriptions date far back (as in the case of *V. striatula* Roemer, 1842, and *V. incurvatus* [Reuss, 1863]).

Marginulina/*Marginulinopsis*. A few forms were present which were rare and difficult to identify. *M. djaffaensis* Sigal, 1952 (Plate 3, Fig. 18), a Barremian and Hauterivian species, and *M. robusta* (Reuss, 1863) have been recognized.

Saracenaria. Many forms (at least 10) were present but they were infrequent, rare, and not identifiable.

Palmula. One specimen (Sample 148) was found but it was unidentified.

Nodosaria and *Dentalina*. Very few forms were found and they were rare, infrequent, and unidentifiable.

Tristix. There were fairly numerous forms (about 10), but they were rare, infrequent, and unidentifiable.

Lingulina. Numerous forms (about 20) were recovered but they were rare, infrequent, and unidentifiable

(Plate 8, Fig. 19), except two that resemble *L. loryi* (Berthelin, 1880) (Sample 130) and *L. trilobitomorpha* Patey, 1968 (Samples 134, 138, and 141).

Lagena. Very few forms were found and they were rare, infrequent, and unidentifiable.

Pseudonodosaria. Fairly numerous forms were recovered but they were rare, infrequent, and unidentifiable, except for the highly variable species *P. mutabilis* (Reuss, 1863) (Samples 99, 102, 112, 115, 116, and 121) and *P. obscura* (Reuss, 1845) (Sample 144).

Neobulimina. There were very few forms, rare and infrequent, which can be compared to *N. egojani* Antonova, 1964, and to *N. boliviniiformis* Antonova and Kalugina, 1964 (Plate 3, Fig. 19).

Patellina. Several forms were relatively common and fairly frequent but difficult to recognize or determine because of their poor preservation. Note *P. subcretacea* Cushman and Alexander, 1930.

Pseudopatellinella. A few specimens were found in mold state that can be compared to *P. rumana* Neagu, 1975.

Spirillina. There were fairly numerous forms (Plate 8, Fig. 18) sometimes relatively frequent and abundant but difficult to identify principally because of poor preservation. Some have oval shells that resemble those of *Ammodiscus siliceus* (Terquem, 1862) (e.g., shown by Neagu, 1975). Others by their massive coiling resemble *Ammodiscus rotalarius* Loeblich and Tappan, 1949, or *A. translucens* Subbotina, 1949. Some very rare and poorly preserved specimens resemble *S. neocomiana* Moullade, 1961.

Globospirillina. Specimens (Pl. 3, Figs. 12–13) are found throughout the association and are sometimes fairly numerous. They are referable to *G. bulloides* (Agalarova, 1951). The ontogenetic stages of the shell, and sometimes its subsequent partial removal, result in a multitude of morphologies. This led to the description of several “species” of *Globospirillina* by Antonova (1964), which are generally considered to be synonymous.

Turrspirillina. Very rare specimens appear similar to *T. simplex* Antonova, 1964, or *T. subconica* Tappan, 1943 (which are probably synonymous).

Trocholina. Aside from a few specimens encountered at the extreme base (Sections 549-61-2, 3, and 4) belonging to the species of Association 2, the population here is composed of very small representatives, which are more sporadic and much less numerous than below. They are related to the following species: *T. infragranulata* Noth, 1952 (Plate 3, Figs. 20–21); *T. paucigranulata* Moullade, 1960 (Plate 4, Fig. 1); and *T. cf. acuta* Antonova, 1964 (Plate 3, Fig. 22). There are also a few undeterminable forms.

Conorotalites. Many specimens in a great number of samples have made it possible to recognize two of the variants described by Bettenstaedt (1952): *C. bartensteini bartensteini* (Plate 4, Fig. 2 and Plate 8, Fig. 11) and *C. bartensteini intercedens* (Plate 4, Fig. 3 and Plate 8, Fig. 12). The one succeeds the other at Cores 58 to 60, which indicates that this level is about at the middle part of the middle Barremian (according to the German

scale) or at the upper part of the lower Barremian (according to planktonic zonation). Present upward from the base (the lower subzone of Core 61), they are still sporadic and of moderate size (0.25 mm). Specimens with rectangular profiles typical of the *C. bartensteini bartensteini* variety predominate. Some specimens in Cores 55 and 54 show an evolution that relates them to the third variant *C. bartensteini aptiensis*, which should theoretically indicate that we are nearing the upper part of the upper Barremian.

Gyroidinoides. Except for several undeterminable specimens, the majority of the forms recorded belong to *G. sokolovae* Mjatljuk, 1953 (Plate 4, Figs. 6–8).

Gavelinella. Many and frequent specimens represent several species. Among them can be recognized *G. barremiana* Bettenstaedt, 1952 (Plate 4, Figs. 4–5 and Plate 8, Figs. 13–14) (syn. *Discorbis djaffaensis* Sigal, 1952), as well as a form resembling *G. brielensis* Malapris-Bizouard, 1974. A third species, *G. (Lingulogavelinella) sigmoicosta* (ten Dam, 1948), is represented by a few doubtful specimens (Sample 140).

Planktonic Foraminifera. The first specimens appear in Section 61-1 in thin section and in Section 60-5 in washed residues. They are present in varying quantities through the sediment section and are generally abundant and more frequent in the upper half of the sediment section (as mentioned above). Preservation is often poor making specific determination difficult. The genus *Hedbergella* is clearly dominant. Many forms are unidentifiable, and some could have been tentatively related by the authors to *H. infracretacea* or *H. planispira*, two widely interpreted taxa. Some classical species, however, are recognizable at this level: *H. (Caucasella) hauerivica* (Subbotina, 1953); *H. kugleri* (Bolli, 1959); *H. cf. tuschepsensis* Antonova, 1964; *H. triangulata* (Antonova, 1964); *H. sigali* Moullade, 1966; *H. cf. beegumensis* Marianos and Zingula, 1966; *H. sp. A* Marianos and Zingula, 1966; *H. ventriosa* Fuchs, 1971; and *H. eocretacea* Neagu, 1975.

There are probably several populations, as suggested by the main size of their components, which perhaps differ taxonomically. From Core 55 upward, a population of very small specimens is observed in which some forms from the Barremian type locality are recognized (Guillaume and Sigal, 1966). Also present is a population of fairly large, more massive forms with specimens comparable to those described by Fuchs (1971) from the Barremian.

Some *Globigerinelloides* are recorded which also resemble various forms from the Barremian type locality or whose morphology resembles that of more recent species, such as *G. blowi* Bolli, 1959. This affinity with the early Aptian is confirmed by the presence at the top of the section of forms of *Hedbergella* comparable to late Barremian to early Aptian species, such as *G. aptica* Agalarova, 1951, or *G. aptiana* Bartenstein, 1965.

Paleoenvironmental Significance of Association 3

The association of *Hedbergella* and small calcareous benthic Foraminifera suggests a fairly open marine environment corresponding to an outer platform (outer lit-

toral zone) in the circalittoral stage. The frequency of bioclasts of highly diverse macrofossil fragments observed in thin sections and washed residues should also be noted.

The base of the section (Cores 60–61) coinciding with a more detrital (quartz) facies is fairly rich in microfauna, probably as a result of greater water turbulence and a higher degree of oxygenation. The relative impoverishment of Foraminifera and shell fragments in intermediate Core 59 to part of Core 55 may be linked to less favorable conditions (greater turbidity, less oxygenation, and grain-size sorting). But this impoverishment is more apparent in thin section from indurated rocks than in washed residues from soft material. Thus it could also partially be the result of recrystallization causing highly micritized tests, sometimes as ghosts, pyritic infillings, and so forth.

Conclusions on Environment and Age, with Comparisons

The conclusions reached on board the Glomar Challenger concerning age and environment have been confirmed by the detailed analysis on shore. In addition, S. Crittenden (personal communication) studied the Foraminifera of some samples rich in Ostracoda submitted to M. B. Hart and kindly informed us of his observations, which agree with our own results.

Environment

The Barremian deposits represent an orderly evolution of the environment. This evolution does not appear to be truly progressive, but rather reflects the shift of the depositional environment through three successive biotopes, whose succession records a trend toward a more open marine setting.

The first sedimentary unit (E) on the Hercynian basement is predominantly terrigenous and indicates an unstable environment. The carbonate content is significant but variable, and there is thus the option of dividing it into subunits. The environment was marine, probably of variable salinity. The fossils reflect these various sedimentary conditions through fluctuations in abundance and frequency of plant remains, bioclasts, marine macrofossil fragments, and microfauna characteristic of an inner littoral environment. Although Unit E is markedly different from the overlying sedimentary unit, its upper part shows some transitional characteristics in terms of the paleoenvironment.

The middle sedimentary unit (D) is predominantly calcareous but does contain a good deal of terrigenous detritus in the lower subunit. Its greater homogeneity is reflected in a fossil population which is itself more homogeneous and less sporadically distributed than in Unit E. Comparison with the underlying sedimentary unit shows a change in depositional setting. The environment of Unit D is shallow water, but it corresponds to a carbonate-rich platform in the infralittoral stage.

The upper sedimentary unit (C) is again predominantly terrigenous but is fine grained and fairly homogeneous. Its homogeneity is confirmed by the fossil population, particularly the Foraminifera. However, one can

again detect an evolution between the succeeding Units D and C. Unit C still represents a relatively shallow-water environment but on an external platform (outer littoral zone) open to pelagic influences and in the circalittoral stage.

Thus on the scale of the whole section (all three units), we observe a deepening and a shifting of the environment at Site 549 toward the open ocean. This specific paleogeographic evolution of the site itself must be viewed in the broader context of the genesis of the European continental margin during the rifting phase.

Age

It is now clear that this sedimentary series is mainly Barremian in age. Its lower and upper limits, however, cannot be dated using the Foraminifera since a large part of the microfauna is controlled by the facies (this is particularly true of sedimentary Units E and D). Also some particularly useful biostratigraphic markers are absent (mainly for the upper Unit C).

The most reliable biochronostratigraphic data have been obtained in the middle part of the section. The presence of the taxon *Conorotalites* with its "subspecies" indicates that Cores 60 through 58 represent the middle part of the middle Barremian (*Denckmanni* zone) on the German chronologic scale (Bettenstaedt, 1952), or the upper part of the lower Barremian (*Pulchella-Emerici* zone) according to chronostratigraphic zonation based on planktonic Foraminifera (Sigal, 1977). The presence of *Gavelinella barremiana* is worthy of note. If its first occurrence here is "real" (not controlled by the facies), then it places Core 60 in the middle Barremian (using the German scale) or toward the early/late Barremian boundary if the planktonic scale (MCi 13/MCi 14) is used. We are thus assured of a "middle" Barremian age in the middle part of the section, or more precisely, this age applies to the base of that part of the section which corresponds to Association 3 of *Hedbergella* and small calcareous benthic Foraminifera.

Below this dated interval, the assemblages are controlled by the sedimentary facies. The species encountered, although confirming Barremian age, do not exclude the possibility that sedimentary deposition on the Hercynian basement began in the late Hauterivian. Both *Choffatella decipiens* and *Trocholina aptiensis* existed at that time. Moreover (as mentioned above), the alternative specific assignment of the *Epistomina* has influence on the age assigned to Core 85 and, consequently, on the age of the lower part of the series: *E. ornata* is known since the late Valanginian, but *E. hechti* appears in the later part of the early Barremian (*Fissicostatum* zone) on the German scale (Bartenstein and Kovatcheva, 1970). Thus, although the sedimentation rate for these nearshore deposits was probably quite rapid (so the section does not represent a very long span of time), the Foraminifera suggest that the sediments of Cores 93 to about 60 might have been partly deposited during Hauterivian time.

The uppermost part of the section belongs to the Barremian stage. Although many species observed in both Associations 2 and 3 can be found in the Barremian and in

the lower Aptian, there are no taxa present that decisively indicate an Aptian age for these sediments. Calcareous nannofossils (Müller, this volume) support this conclusion. In these sediments there are species of Foraminifera, such as *Marginulina djaffaensis*, *Astacolus crepidularis*, *Epistomina ornata*, *E. hechti*, and *Conorotalites bartensteini intercedens*, which as far as we know, did not survive the Barremian. The observation of forms resembling the third variety *C. bartensteini aptiensis* suggests that the youngest date for the top of the section would be the latter part of the late Barremian (*Bidentatum* zone) on the basis of the German scale and the planktonic scale (MCi 15).

Therefore, the whole deposit (including the lateral complementary beds inferred from the seismic profiles) might still be Barremian and perhaps may extend into the (lower?) Aptian. Studies at Site 549 (e.g., Borkowski and Mazzullo, this volume) and other DSDP sites in the North Atlantic indicate that sedimentation was interrupted between the synrift and postrift phases during the Aptian, very likely the late Aptian. The sedimentation then resumed during the early Albian or, at the earliest, the latest Aptian (or Clansayesian).

Comparisons

The Scotian Shelf and the Grand Banks of eastern Canada were fairly close to Site 549 during the Early Cretaceous prior to sea-floor spreading, which resulted in the opening of the Goban Spur segment of the North Atlantic.

In Canada, Foraminifera in the upper part of the Mississauga formation show marked similarities to those in parts of the Site 549 section, indicating littoral to inner neritic environments, with some outer neritic marine phases (Ascoli, 1976). This sedimentary unit encompasses the end of the Jurassic and Berriasian to the early Aptian; a marine transgression apparently occurred during the Aptian. There is thus an important age difference between the Canadian sequence of events and the record at Site 549.

In these Canadian strata, several zonations are used which are based on Foraminifera (planktonics, calcareous benthics, agglutinated benthics, and *Trocholina*) and on ostracods, depending on the sediments encountered in the various wells (Ascoli, 1976). These zones at the Barremian level correspond to three of the assemblages observed at Site 549: the *Caucasella hauterivica* zone (with *Hedbergella ventriosa*); the *Epistomina hechti*, *E. ornata*, and *E. caracolla* zone; and the *Choffatella decipiens*, *Trocholina* gr. *infragranulata*, and *Marssonella* gr. *oxycona* zone. Thus there are some faunal similarities between parts of the Mississauga and Site 549 sections, which are now separated by several thousand kilometers of ocean. Moreover, the biosedimentary units of Site 549 are assembled in one single well in chronological order; this unique quality makes them much easier to study and interpret. Other important foraminiferal components in the Canadian offshore sediments are also found at Site 549, but they have a broad distribution and are found in many other geographical locations. These more cosmopolitan species make it possible to compare

Site 549 sedimentary deposits with such distant areas as southern Russia, Rumania, Bulgaria, Austria, southern France, North Africa, and Trinidad. In addition, R. Ascoli (1976) has drawn attention to the "Afro-European affinities" of these species as opposed to the expected American affinities (central Canadian and southeastern United States).

The geologic history of Site 549 during the Barremian, from a nearshore to an open marine environment, suggests that a "Weald" facies developed somewhere in the vicinity of the site. This brings to mind the history of the basins of southeastern England and northern Europe, the classic geologic terminology of which is well known (the Rjazanian transgression in Russia, the Serpulitan beds of Poland and northern Germany, the Grieselle sands of the Paris Basin, the Speeton Clay of Yorkshire, etc.). However, one fundamental difference between these other basins and Site 549 is that these basins include marine strata older than the Barremian, even when they are developed with the Purbeckian facies, as in the English Southern Basin (Dorset and Sussex). This latter basin separates the Atlantic regions (Irish Sea and Western Approaches Basin) from the Lincolnshire/Norfolk regions (the Spilsby series) and Yorkshire (Speeton Clay). Thus, the development of a marine environment is much later at Site 549, and no Rjazanian, no Berriasian, no Valanginian, and no Hauterivian microfauna are to be found there.

Once an open marine environment was established at Site 549 (during the middle and late Barremian), microfaunas developed numerous common species coevally with the basins of Yorkshire (part of the Speeton beds, as noted in Fletcher, 1973), with the basins of Germany, with the Vocontian Basin of southeastern France, and even with areas much more distant, such as Rumania and southern Russia. Even though the microfaunas were similar, however, the environments may have been different (e.g., the Vocontian Basin was deeper), and some of the important taxa (such as the *Conorotalites*) may have been sparse or missing. Also, although relatively close to Site 549, a quite different facies represented by a part of the Weald Clay (which terminates the Weald Group), also belongs to the Barremian.

It would seem likely that analogies would be found between sections (upper Barremian?, Aptian?) which are largely missing at Site 549 itself, but which are present laterally (according to the seismic profiles), where an impoverishment of genera and species might be observed due to a deterioration in the environment. (This has been noted in the upper layers of the Speeton Clay and the coeval series in Germany and the Paris Basin.) However, the entirely different paleogeographic situation of Site 549 during Barremian and Aptian time suggests that a peculiar evolution took place through the remaining Barremian and possible early Aptian, which probably makes any eventual comparison impossible.

The sites drilled during Leg 48 (Dupeuble, 1979) that are not far from Site 549 do not readily lend themselves to comparison with Leg 80. The basal sediments at Site 400A are younger (middle late Aptian) and mark the base of a sequence of nearly homogeneous deposits. The ear-

ly Albian portion of these are comparable to the Albian (i.e., postrift) deposits of Site 549. Below a few centimeters of chalk dated as the base of the late Aptian, shallow-water, calcareous, bioclastic, *Trocholina*-bearing limestones are present at Site 401, which might be similar in part to middle Unit C of Site 549. Nevertheless, these limestones at Site 401 are believed to be Valanginian or Neocomian in age, and they could be older than the limestone unit of Site 549. On the other hand, the clayey limestones dated as Aptian in Hole 402A might be similar to the synrift deposits which seismic profiles suggest are present laterally from Site 549; these limestones would be younger than the Barremian dated at Site 549. However, there are two reasons to doubt this: (1) a relatively great difference in age could exist because the sediments of Hole 402A are late Bedoulian; and (2) the whole section at Hole 402A consists of this one facies, making it possible that these deposits are not representative of the first steps of postrift sedimentation at Site 402A.

Calcareous bioclastic fragments dredged at the boundary between the continental shelf and slope (Auffret et al., 1979) in the vicinity of Leg 48 (Meriadzek and Shamrock escarpments) and Leg 80 (King Arthur and Pen-dragon escarpments) have been assigned to the Barremian or Barremian-Aptian (among others). Among them, *Choffatella* and *Trocholina* have been observed in thin sections and resemble the median Association 2 of Site 549. However, rudists and *Orbitolina* are often found together in the dredgings, and their presence would suggest a different environment.

Coeval Vrigonian facies are compared by Rat et al. (this volume).

THE ALBIAN STAGE

Figure 2 of this article and Figures 3 and 8 in Rat et al. (this volume) clearly indicate that a single homogeneous formation and fauna constitute the entire Albian section drilled. As in the third assemblage of the Barremian, the sporadic presence (and the "stepped" nature of the first occurrences of species) could result from actual fossil rarity, but could also result from insufficient sampling and pure chance in collecting the samples and picking the specimens. Each Albian sample (except the first washed residue) contained Foraminifera.

The foraminiferal population is relatively diverse overall, with numerous genera and species. Nevertheless, the benthos is much less diversified than the benthic assemblages that are usually encountered at this stratigraphic level in Mesogean Parisian or oceanic sediments. In the indurated sediments studied in thin section, benthic forms appear to be rare. They are represented by various small rotaliforms that are difficult to identify; a few microgranular forms such as *Ataxophragmiidae* and *Textularia*; a few porcelaneous forms such as *Quinqueloculina*(?) found especially at the base; a few *Lagenidae*; a few *Praebulimina* and/or *Neobulimina*; and some rare *Pleurostomella*, *Spirillina*, and *Patellina*. All of these forms also occur variably in the washed residues. In contrast, planktonic populations are the same as those observed

at Mesogean and Atlantic sites. They are composed of numerous small *Hedbergella* which vary so greatly that they defy all attempts to systematically classify them.

The numbers of benthic and planktonic Foraminifera vary in a parallel manner and also vary in proportion to the amount of macrofossil debris present.

Further Observations on the Sieved Residue

These observations are summarized in Figure 2. The statements concerning Association 1 of the Barremian Stage also apply to the Albian Stage, with the addition of the remarks below.

The sediments are calcareous and clayey throughout. Pyrite and glauconite are virtually absent. The terrigenous material is localized; it is even absent at the base. *Radiolaria* are consistently present and more abundant in the upper two-thirds of the section. Plant remains are present throughout but are usually not abundant. Macrofossil fragments (mainly *Inoceramus*) are constant but vary in quantity from one bed to another. Fish remains occur sporadically, except at the base; spicules and otoliths are consistently present. Ostracoda are virtually constant, especially in the upper two-thirds of the section.

Relationship of the Faunal Association to the Lithology

The samples taken on board the *Glomar Challenger* do not make it possible to establish a detailed small-scale correspondence between the variations in abundance of Foraminifera and other organisms and variations in the lithological facies.

Generally, a slight difference is noted between the two groups of Cores 49 through 44 and 43 through 32, with the higher, more clayey group being richer in radiolaria and higher in clastic material. In thin sections the *Hedbergella* are less numerous when the facies is rich in sponge spicules or rich in recrystallized *Radiolaria* (calcite); this was also observed in the washed residues of Cores 43 through 42 (Samples 16 and 17).

A subsequent, more systematic sampling made on the basis of sedimentologic studies and logging might explain the quantitative variations observed.

Composition of the Foraminiferal Association

The general characteristics of the association have been detailed above. In summary, there are numerous genera, relatively few species, and relatively few specimens except for the planktonic species and a few benthic species. The preservation varies from generally average (most commonly) to good (occasionally).

Hippocrepina(?). A few forms were recovered that resemble *H. depressa* Vasiček, 1947.

Hyperammia(?). There were a few forms that resemble *H. gaultina* ten Dam, 1950.

Glomospira. A few sporadic specimens of *G. charoides* (Parker and Jones, 1860) or *G. corona* Tappan, 1962 (Plate 4, Fig. 9) were found which are generally large (diameter 0.5 mm). Frequent sections from Core 45 upward showing fine-grained quartzose walls are probably attributable to this species.

Glomospirella. A few specimens of *G. gaultina* (Berthelin, 1880) were found (Plate 4, Fig. 11).

Kalamopsis(?). A few rare forms are related to *K. grybowski* (Dylazanka, 1923).

Spiroplectammina/Textularia: Some rare forms found are similar to *S. baudouiniana* (d'Orbigny, 1840) already noted in the early Albian (see, e.g., Bach, 1965, in Germany). *S. baudouiniana* is actually a Senonian species and has a thicker shell. Others resemble *T. hemisphaerica* Kuebler and Zwingli, 1866. Because of the poor preservation of the shells, it cannot be excluded that they are close to *Bimonilina textulariaeformis* Akimetz, 1966.

Verneuilina. A few unidentifiable forms were found which may be juvenile specimens of *Clavulinoides gaultinus* (Morozova, 1948).

Gaudryina. Some of the rare forms present can be ascribed to *G. dividens* Grabert, 1959 (Plate 4, Fig. 10), but they are distinguished by their marked biserial chambers and the first occurrence of uniserial chambers. The other forms resemble *G. compacta* Grabert, 1959.

Tritaxia. A few specimens correspond to a form described by H. Tappan (1943) from the Duck Creek Formation and are called *Gaudryina alexanderi* Cushman, 1936 (Pl. 4, Figs. 12-13).

Falsogaudryinella. These are represented by a few specimens (Plate 4, Fig. 14) which differ widely from those that are characteristic of the underlying Barremian. It is difficult to choose from the various species cited at the Albian level because of the large morphological variation; the most comparable appear to be *F. moesiana* Neagu, 1965, and *F. triangula* Fuchs, 1967.

Marssonella. These are represented by very rare, specifically undeterminable forms.

Cyclogyra. These are represented by very rare, specifically undeterminable forms.

Lenticulina. This genus is rather sparsely represented, and no specific determination is possible.

Marginulina. There are a few rare forms, one of which (Sample 19) is related to *Marginulinopsis chandlerensis* Tappan, 1960.

Saracenaria: These are represented by very rare, specifically undeterminable forms.

Vaginulina (Citharina). Very rare forms are present, some belonging to the *V. recta* Reuss, 1863 group.

Lingulina. Very rare forms are present, which may be related to *L. lamellata* Tappan, 1940.

"*Bulimina*". There are a few forms (sp. 1, Plate 4, Fig. 15 and sp. 2, Plate 4, Fig. 16), some probably belonging to the variable species *Praebulimina nannina* (Tappan, 1940) and to *P. hergottensis* Ludbrook, 1966.

Discorbis. Very rare forms present are comparable to *D. minutissima* Tappan, 1943.

Valvulineria. These are represented by at least four species, sometimes abundant, some of which belong to *V. gracillima* ten Dam, 1950 (Plate 4, Figs. 18-19), *V. aff. loetterlei* (Tappan, 1940), and *V. parva* Khan, 1950 (Plate 4, Fig. 17).

Spirillina. There are a few rare forms, some of which resemble *S. minima* Schacko, 1892.

Patellina: These are represented by a few rare, specifically undeterminable forms.

Turrispirillina: A few rare forms are present, of which some resemble *T. subconica* Tappan, 1943.

Eponides. There are relatively numerous forms present, some belonging to *E. chalilovi* Djaffarov and Agalárova, 1949 (Plate 4, Fig. 20 and Plate 5, Fig. 1).

Anomalina. Fairly frequent and abundant specimens belong to *A. rodriguezii* Obregón de la Parra, 1959 (Plate 5, Figs. 2-3).

Planulina. Very rare specimens are present, some of which belong to *P. andersoni* Church, 1968, although these may be better placed in the genus *Gavelinella* (Plate 5, Fig. 4). Others probably belong to *P. schloenbachi* (Reuss, 1863).

Cibicides. Fairly frequent and abundant specimens belong to *C. reicheli* Gandolfi, 1942 (Plate 5, Figs. 5-6).

Pleurostomella. Fairly frequent and abundant specimens belong to *P. reussi* Berthelin, 1880 (Plate 5, Fig. 7); *P. subnodosa* Berthelin, 1880; *P. obtusa* Berthelin, 1880; and *P. subbotinae* Djaffarov, 1949 (Plate 5, Fig. 8).

Nodosarella. Fairly frequent and abundant forms are present but they are not specifically determinable.

Bolivina. A few broken specimens were recovered which may be related to *B. subcretacea* Khan, 1950.

Gyroidina. Relatively numerous forms are present, some of which belong to *Gyroidinoides infracretaceus* (Morozova, 1948) (Plate 5, Figs. 9-11), while others are not specifically determinable. Of the latter, *G.* sp. 2 (Samples 7, 12, 18, and 24) (Plate 5, Figs. 12-14) is remarkable for its truncated, cone-shaped, lateral profile and the hump on each chamber on the spiral face. It probably belongs to a new species, although it bears a certain morphological resemblance to *G. quadratus* var. *martini* Sliter, 1968, described from the Campanian stage of California.

Osangularia. These are represented by two fairly abundant, specifically undeterminable forms. One of them, *O.* sp. 2 (Plate 5, Figs. 18-19), has characteristics of *Eponides morani* Tappan, 1957, but the aperture is different from that typical of the genus. The other, *O.* species 1 (Plate 5, Figs. 15-17), which is more frequent, is remarkable for its umbo and the slightly elevated sutures. It is interesting to note that species usually found in Atlantic DSDP sites, such as the group of *O. utaturensis*, are absent at Site 549.

Conorotalites. A few rare specimens are present that can be related to *C. rumanus* Neagu, 1965.

Gavelinella. Fairly frequent and numerous forms present that belong to *G. (Berthelina) intermedia* (Berthelin, 1880).

Gubkinella. These are fairly frequent, with a few forms belonging to *G. graysonensis* (Tappan, 1940).

Hedbergella. The impressive development of this genus, at least with regard to the number of specimens, has previously been emphasized. It appears as a rich, sometimes prolific population of small forms which have been encountered many times in outcrops and Atlantic DSDP sections at the base of the lower Albian, below the first occurrence of the larger *Hedbergella* and *Ticinella* of the middle Albian. In the sediments of Site 549 they have a range between 80 and 250 μm , attaining 300 μm in some beds (e.g., Sample 549-45-3, 41-44 cm, in thin sections). Preservation is generally good in both

thin sections and washed residues, although the tests are often not entirely free from recrystallization. The chambers are usually empty, except for the lowest ones, which are sometimes filled with pyrite.

These *Hedbergella* are particularly striking in their morphological diversity, which can be described using some simple criteria; (1) the degree of asymmetry or subsymmetry of the coiling of the shell; (2) whether the "normal" chambers are equidimensional or elongated in the direction of the spire; (3) whether the outline is strongly or weakly lobate; (4) whether the spire is flat or elevated; (5) the ratio of shell diameter to thickness (high or low); (6) the rapidity of growth of the chambers; and (7) above all, the number of chambers in the last whorl. According to the number of chambers in the last whorl, the forms have been divided into "Type 3" and "Type 4," through the "intermediate" types (e.g., 4.5, 5-5.5, or 6-6.5), to the many-chambered shell (e.g., Type 7 and higher). The morphology and external shape of the shell depends largely on this highly variable number of chambers.

The double (or multiple) entry grids that can be established on the basis of these criteria define a certain number of positions. Specimens of such prolific and variable populations can easily fill a good many of these positions. A given position in the grids will thus correspond to the holotype of a given species. The difficulty lies, however, in knowing where to draw the line between the different parts of the populations that truly define the species (holotype plus variations). This is a particular difficulty for some groups of Foraminifera (notably the globigerinids) and, in this case, for the genus *Hedbergella*. It might be said that this plethora of forms is a characteristic of the group at this level of the lower Albian.

In the Albian of Site 549 a range from four to eight chambers in the last whorl is observed. According to the other criteria, the species *H. planispira* (Tappan, 1940) (Plate 6, Figs. 1-3) and *H. globigerinelloides* (Subbotina, 1949) (Plate 6, Figs. 4-5) have been identified. These two are the most easily recognizable forms and the most widely noted by authors. An equally recognizable species also widespread in the literature, that should probably be separated as a new species, is *H.* species 17 (Plate 6, Figs. 6-11), which is morphologically similar to *H. globigerinelloides* but generally smaller. It has clearly oblique sutures on the spiral side and may have more chambers in the last whorl (up to eight). It sometimes shows a tendency toward subsymmetrical coiling. Other *Hedbergella* forms have been related to described species such as *H. infracretacea* (Glaessner, 1937) (Plate 6, Figs. 12-13), although it is difficult to get a true picture of the taxon (and its holotype) because of the innumerable morphological types that have been used under this name; *H. rischi* Moullade, 1973 (Plate 6, Figs. 14-15); *H. angolae* Caron, 1978 (Plate 6, Fig. 16); *H. gorbachikae* Longoria, 1974 (Plate 6, Fig. 17); and *H. (?)* cf. *Ticinella bejaouaensis* Sigal, 1966 (Plate 6, Fig. 18) (or *H. trochoidea* in Tsirekidze, 1975, or *H. trochoidea* var. 2, Kuhry et al., 1977). There remain many morphological types (located in the various grid positions based on the

criteria discussed above) which probably correspond to many specific variable units and which constitute much of the population found at Site 549.

Globigerinelloides. A few rare forms are observed which belong morphologically to Gargasian species (although they are smaller): *G. ferreolensis* Moullade, 1961 (Plate 6, Fig. 20), and *G. gottisi* Chevalier, 1961 (Plate 6, Fig. 19). This may be the reason why these species have sometimes been observed as high as the base of the Albian. Such forms have already been found at this level at other sites and have been noted by other authors (e.g., Miles and Orr, 1980; *G. caseyi*, in Michael, 1972).

Paleoenvironmental Significance of the Association

The abundance of *Hedbergella* (and radiolaria) indicates open marine conditions with a large community of epipelagic microfaunas. The predominance of planktonic forms and the composition of the benthos (which is apparently homogeneous) indicate that the sediments may have been deposited on the middle to lower part of the slope (middle to lower bathyal).

Conclusions on Environment and Age, with Comparisons

This Albian benthic association is relatively impoverished and is thus difficult to compare with contemporary microfaunas from continental deposits. Also, the absence of certain forms (e.g., various species of *Osangu-laria* and *Buliminidae*) makes it difficult to compare it with other DSDP sites in the North Atlantic. It was stated above that the *Hedbergella* population is regularly found at the base of the Albian in Mesogean or Tethyan regions, chronologically following the characteristic species of the Gargasian and Clansayes zone and before the appearance of *Hedbergella* and *Ticinella* in middle Albian. Thus, we are led to assign an early Albian to earliest middle Albian age to this section (in Mesogean planktonic zonation, Zones MCi 23 and/or MCi 24). This determination agrees with the conclusion drawn from the calcareous nannofossils, which is middle Albian (*Cretacea* zone) and perhaps, at the level of Core 52, early Albian (*Angustus* zone) (see Müller, this volume).

The bathyal character of the benthic association excludes any comparison with eastern Canadian regions such as the Scotian Shelf or the Grand Banks. At this level the North American deposits belong to two types which are observed from the upper Barremian through the Albian. As described by Ascoli (1976), "These are either shales with minor sandstone and carbonate beds from an inner neritic environment (Naskapi Member) or predominantly sandstone sequences consisting of alternating sandstone, siltstone, and shales from a continental to margin and shallow-marine neritic environment (Logan Canyon Formation)". In Canada, the section between the upper Gargasian and the middle Albian is well defined by planktonic and benthic Foraminifera and Ostracoda, and the lower Albian is poorly characterized. Early Albian zonal forms (e.g., *Epistomina cretosa* and *E. carpenteri*) and many accompanying species that de-

veloped in the environment of the Canadian deposits have no equivalent at Site 549.

Albian deposits have been recovered at two of the sites that were cored during Leg 48 located at the juncture of the Atlantic Ocean and the English Channel. The sediments from Hole 402A, particularly at the level of the lower Albian, correspond to a continental shelf deposit and consequently contain a different foraminiferal assemblage (although there are populations of small *Hedbergella* present). Sediments from Hole 400A, however, particularly at the lower Albian level, contain deep-sea sediments (lower bathyal or abyssal). Where they have escaped dissolution, planktonic and benthic assemblages carried down by turbidites have some similarities to their equivalents at Site 549.

Drilling undertaken near the coast in the Western Approaches Basin (Evans et al., 1981) recovered 40 to 50 m of shallow-marine limestone and carbonaceous sands and clays containing abundant terrigenous detritus. Ostracoda and miospores indicate that these sediments are partly of early Albian age. The same report states that a Barremian to lower Cenomanian section has been observed at nearby continental outcrops, which had at the base an early Weald-type fluvial-lacustrine facies (carbonaceous sand and clay), succeeded by marine sandstone containing bioclastic debris or by sandy carbonaceous clay containing marine bioclastic limestone deposited in brackish water. The latter has been compared to the Hole 402A deposits. All of these deposits contrast markedly with the facies of Site 549.

Several formations have been defined for the upper part of the lower Greensand Formation in southern and southwestern England (Southern Basin) which are time equivalents of the Albian of Site 549 (Hart, 1973). They are the Sandrock Formation and the Carstone Formation on the Isle of Wight and the Folkestone beds in Kent (the part which spans the *Tardefurcata* and *Mammillatum* zones). Sometimes they locally represent the transition to the Gault Clay facies since the lower Greensand/Gault Clay contact is diachronous (ranging from the *Jacobi* to the *Mammillatum* zone). Descriptions of these beds by Casey (1961) as sand and calcareous sandstone with glauconite, phosphate nodules, and condensed sequences indicate a succession of shallow basin deposits quite different from that represented by Site 549. The lowest zone of planktonic Foraminifera in the Gault facies (Carter and Hart, 1977), that is the *Hedbergella delrioensis* and *H. infracretacea* zone of middle and late Albian, might appear to be an outgrowth of, or be related to, Association 3 of Site 549. But Carter and Hart (1977) are of the opinion that the zone extends up to the Albian/Cenomanian boundary, owing to the absence of other markers (such as *Planomalina* or *Ticinella*) that would permit a more precise zonation. Finally if Site 549 is compared with the lowest zone of Gault benthic Foraminifera, which is of middle Albian age, it becomes clear that the assemblage of Site 549 cannot be considered as an impoverished Gault fauna. Sediments at Site 549 were deposited at a different bathymetric level, even if they were laid down until middle Albian time.

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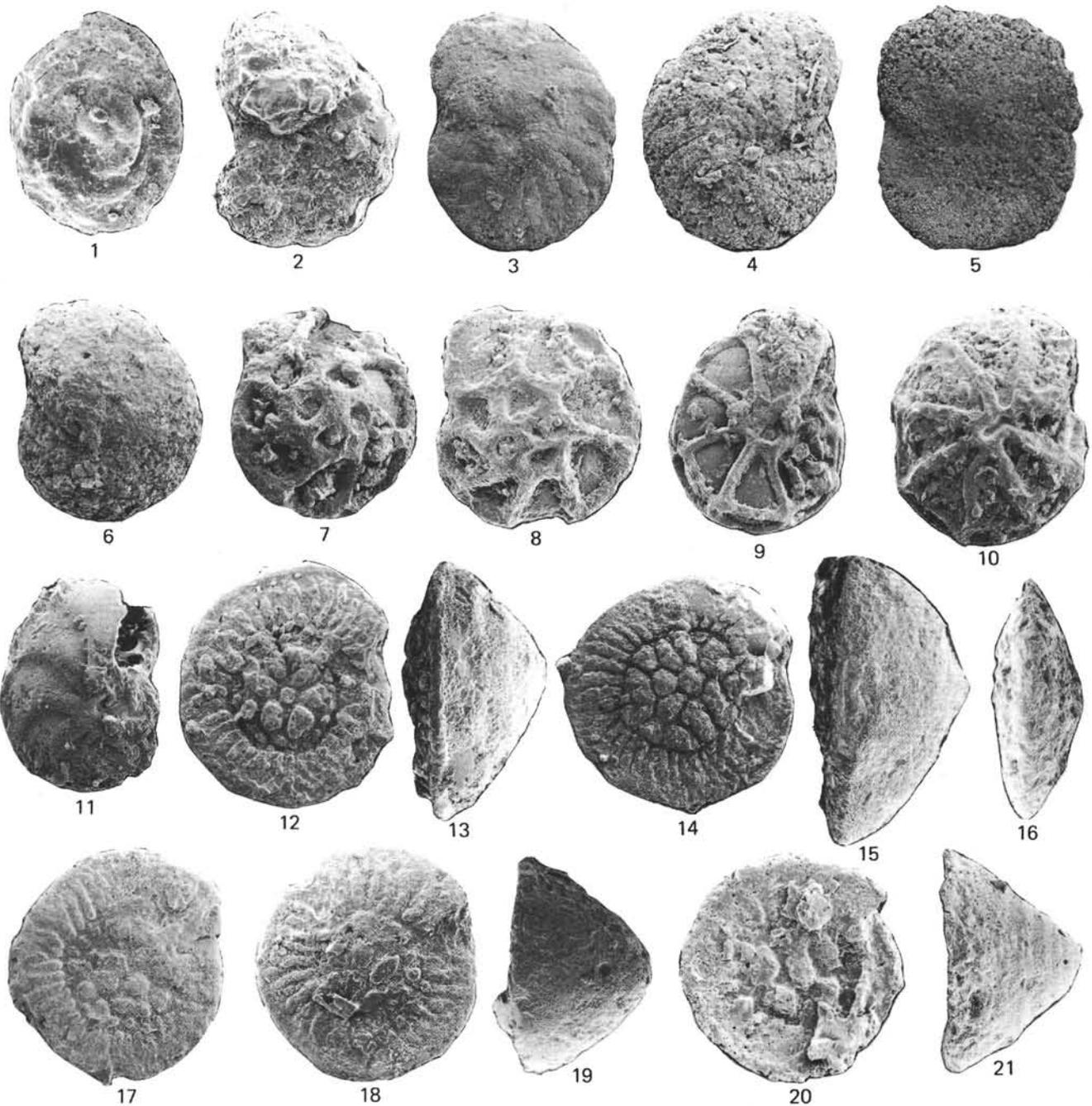


Plate 1. Barremian Foraminifera: 1-10, Association 1, and 11-21, Association 2. 1. *Glomospirella arctica* Chamney, 1969, $\times 120$, Sample 549-87,CC. 2. *Haplophragmoides* cf. *barremicus* Mjatljuk, 1939, $\times 110$, Sample 549-85-1, 124-126 cm. 3-6. *Choffatella decipiens* group Schlumberger, 1905, (3-4) A1 macrospheric, $\times 27$, Samples 549-81-2, 8-10 cm and 549-85,CC (5) B microspheric, $\times 42.5$, Sample 549-80-2, 109-113 cm, (6) A2 macrospheric, $\times 85$, Sample 549-85,CC. 7-10. *Epistomina* group *ornata* (Roemer, 1841), Sample 549-85,CC, (7) $\times 80$, (8) $\times 110$, (9) $\times 80$, (10) $\times 65$. 11. *Lenticulina ataktos* Espitalié and Sigal, 1963, $\times 80$, Sample 549-74-3, 87-90 cm. 12-13. *Trocholina aptiensis* Iovcheva, 1962, Sample 549-72,CC, (12) $\times 70$, (13) $\times 80$. 14-15. *Trocholina aptiensis* var. 2, Sample 549-72-2, 33-35 cm, (14) $\times 50$, (15) $\times 70$. 16-17. *Trocholina* cf. *burlini* Gorbačik, 1959, Sample 549-75-3, 21-23 cm (16) $\times 65$, (17) $\times 55$. 18-19. *Trocholina* sp. 15, $\times 65$, (18) Sample 549-75-2, fragments, (19) Sample 549-72,CC. 20-21. *Trocholina* sp. 16, $\times 100$, Sample 549-72,CC.

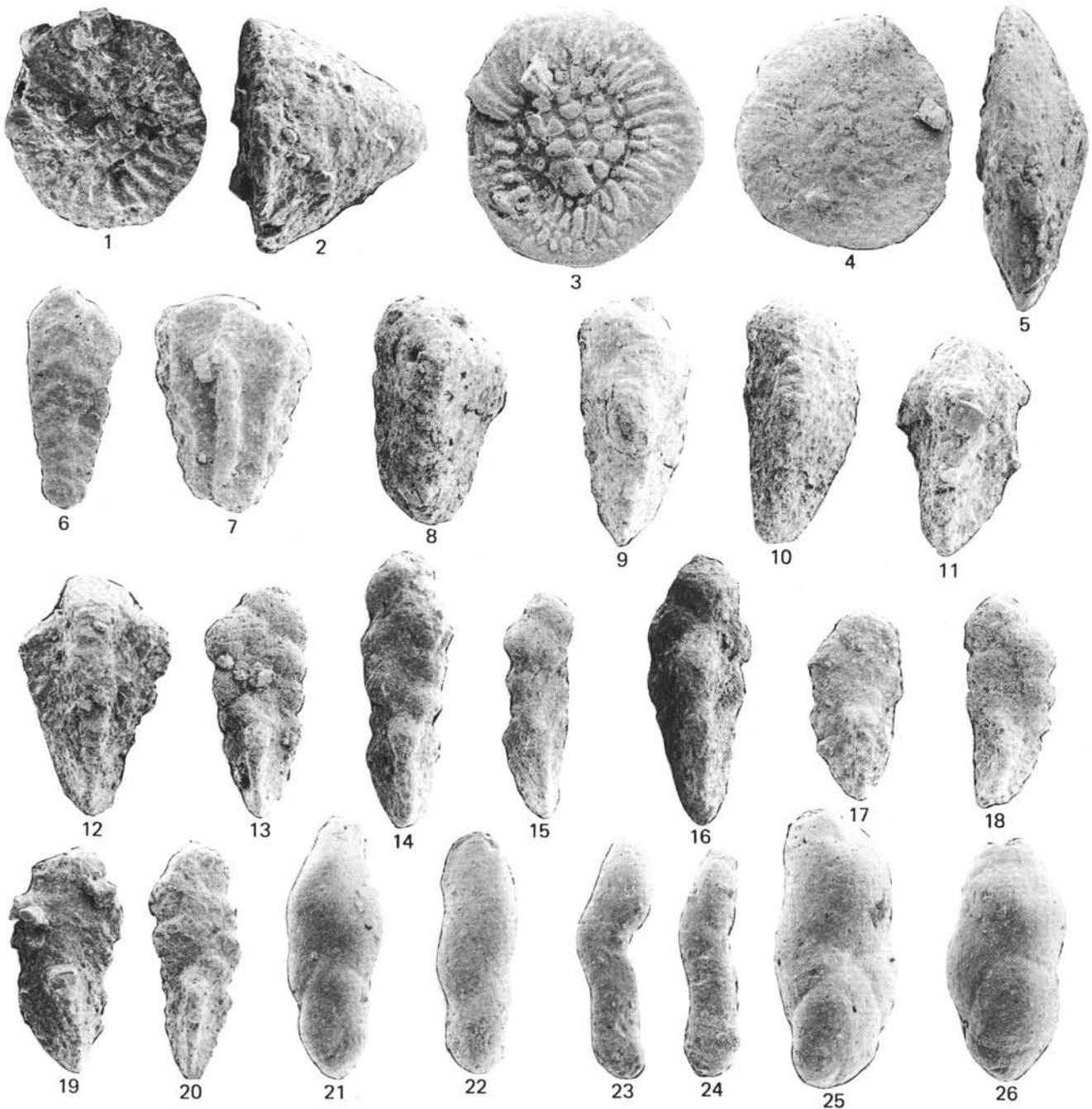


Plate 2. Barremian Foraminifera: 1-5, Association 2, and 6-26, Association 3. 1-2. *Trocholina* sp. 6, $\times 65$, Sample 549-75-3, 21-22 cm. 3. *Trocholina* sp. 8, $\times 50$, Sample 549-73-1, 31-33 cm. 4-5. *Trocholina aptiensis* var. 7, $\times 50$, Sample 549-75-2, fragments. 6. *Spiroplectammina schultzei* (Reuss, 1863), $\times 100$, Sample 549-59-1, 108-110 cm. 7. *Textularia bernardi* Chevalier, 1961, $\times 175$, Sample 549-58-2, 37-40 cm. 8-10. *Verneuilina/Gaudryina/Tritaxia* spectrum-4, (8) $\times 65$, morphogenus *Verneuilina*, Sample 549-54, CC, (9) $\times 55$, morphogenus *Gaudryina*, Sample 549-54-3, 140-143 cm, (10) $\times 55$, morphogenus *Tritaxia*, same sample. 11-12. *Verneuilina/Gaudryina/Tritaxia* spectrum-6, (11) $\times 80$, morphogenus *Gaudryina*, Sample 549-58-3, 79-81 cm, (12) $\times 70$, morphogenus *Tritaxia*, same sample. 13-16. *Gaudryina/Spiroplectinata* spectrum-*praedividens* Neagu, 1975, (13) $\times 70$, morphogenus *Gaudryina*, Sample 549-55, CC, (14) $\times 70$, morphogenus *Spiroplectinata*, Sample 549-56-3, 89-93 cm, (15) $\times 55$, idem, Sample 549-55-2, 108-111 cm, (16) $\times 70$, idem, Sample 549-56-4, 32-35 cm. 17-20. *Gaudryina/Spiroplectinata* spectrum-5, $\times 55$, (17) morphogenus *Gaudryina*, Sample 549-56, CC, (18-20) morphogenus *Spiroplectinata*, Samples 549-56-2, 68-70 cm, 549-56-4, 32-35 cm, and 549-55, CC, respectively. 21-24. *Falsogaudryinella hannoverana hannoverana* (Bartenstein and Brand, 1951), (21) $\times 80$, Sample 549-56-4, 32-35 cm, (22) $\times 100$, Sample 549-56-2, 68-72 cm, (23) $\times 80$, Sample 549-58-3, 79-81 cm, (24) $\times 90$, Sample 549-58-6, 86-89 cm. 25-26. *Falsogaudryinella hannoverana tealbyensis* (Bartenstein, 1956), $\times 100$, (25) Sample 549-58, CC, (26) Sample 549-58-5, 85-87 cm.

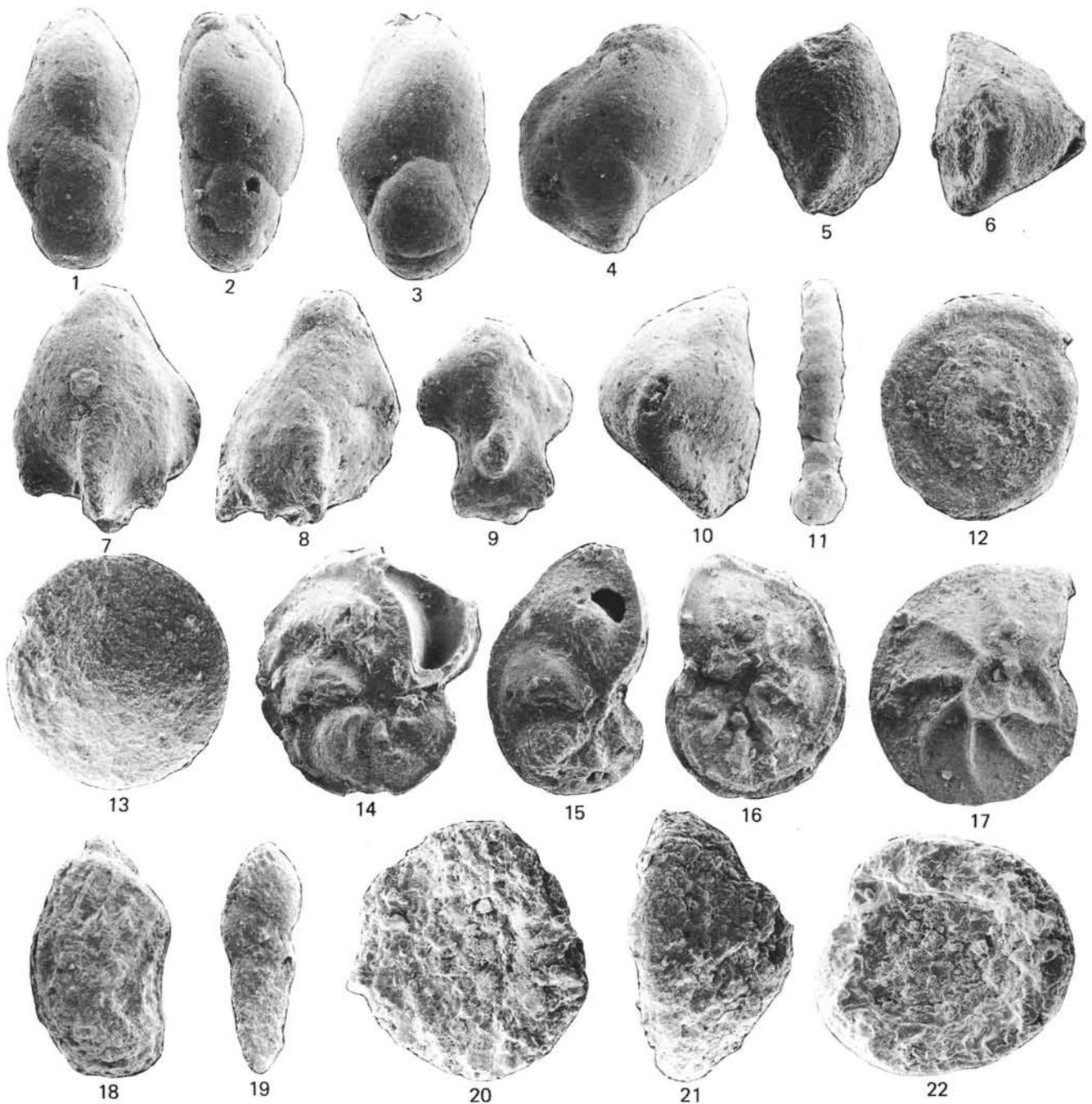


Plate 3. Barremian Foraminifera, Association 3. 1-3. *Falsogaudryinella* sp. 7, (1) $\times 110$, Sample 549-56-3, 89-93 cm, (2) $\times 80$, Sample 549-55, CC, (3) $\times 100$, Sample 549-54-3, 7-9 cm. 4-6. *Falsogaudryinella* sp. 5, $\times 120$, (4-5) Sample 549-58-2, 37-40 cm, (6) Sample 549-54-3, 140-143 cm. 7-10. *Falsogaudryinella* sp. 4, (7) $\times 195$, Sample 549-58-2, 37-40 cm, (8) $\times 165$, Sample 549-58, CC, (9) $\times 120$, Sample 549-59-1, 108-110 cm, (10) $\times 220$, Sample 549-55, CC. 11. *Meandrospira djaffaensis* Sigal, 1952, $\times 65$, Sample 549-58-4, 51-54 cm. 12-13. *Globospirillina bulloides* (Agalarova, 1951), (12) $\times 90$, Sample 549-58-1, 29-31 cm, (13) $\times 70$, Sample 549-54-3, 140-143 cm. 14-15. *Lenticulina deilmanni* Kemper, 1963, (14) $\times 70$, Sample 549-61, CC, (15) $\times 140$, Sample 549-55, CC. 16. *Lenticulina collignoni* Espitalié and Sigal, 1963, $\times 50$, Sample 549-57-3, 84-86 cm. 17. *Lenticulina ouachensis* Sigal, 1952, $\times 42.5$, Sample 549-54-2, 91-93 cm. 18. *Marginulinopsis djaffaensis* Sigal, 1952, $\times 80$, Sample 549-54-3, 140-143 cm. 19. *Neobulimina* cf. *boliviniiformis* Antonova and Kalugina, 1964, $\times 140$, Sample 549-54-3, 140-143 cm. 20-21. *Trocholina infragranulata* Noth, 1952, $\times 140$, Sample 549-55, CC. 22. *Trocholina acuta* Antonova, 1964, $\times 225$, Sample 549-59, CC.

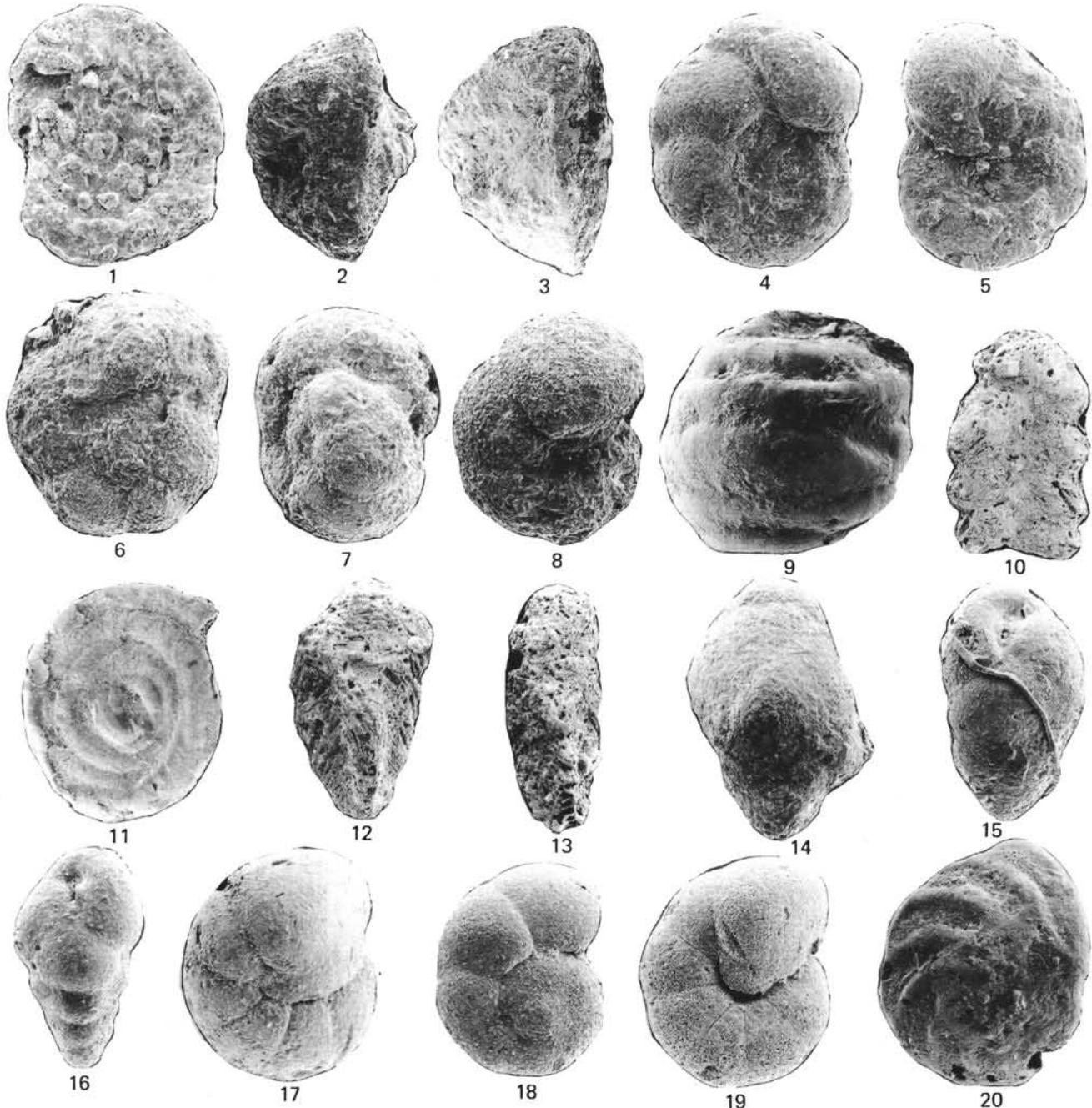


Plate 4. Barremian (1-8, Association 3) and Albian (9-20) Foraminifera. 1. *Trocholina paucigranulata* Moullade, 1960, $\times 165$, Sample 549-58-1, 29-31 cm. 2. *Conorotalites bartensteini bartensteini* (Bettenstaedt, 1952), $\times 130$, Sample 549-60-6, 105-107 cm. 3. *Conorotalites bartensteini intercedens* (Bettenstaedt, 1952), $\times 100$, Sample 549-57-1, 53-55 cm. 4-5. *Gavelinella barremiana* Bettenstaedt, 1952, (4) $\times 110$, Sample 549-58, CC, (5) $\times 130$, Sample 549-57-5, 26-29 cm. 6-8. *Gyroidinoides sokolovae* Mjatljuk, 1953, Sample 549-54-2, 91-93 cm, (6-7) $\times 195$, (8) $\times 175$. 9. *Glomospira charoides* (Parker and Jones, 1860), $\times 120$, Sample 549-47-4, 80-82 cm. 10. *Gaudryina dividens* Grabert, 1959, fragment of biserial part of the shell, $\times 42.5$, Sample 549-35-1, 16-19 cm. 11. *Glomospirella gaultina* (Berthelin, 1880), $\times 80$, Sample 549-35-1, 106-107 cm. 12-13. *Gaudryina/Tritaxia spectrum-alexanderi* Cushman, 1936, Sample 549-35-1, 16-19 cm, (12) $\times 80$, (13) $\times 38$. 14. *Falsogaudryinella* cf. *moesiana* Neagu, 1965, $\times 165$, Sample 549-47-5, 72-74. 15. "*Bulimina*" sp. 1, $\times 240$, Sample 549-46, CC. 16. "*Bulimina*" sp. 2, $\times 240$, same sample. 17. *Valvulineria parva* Khan, 1950, $\times 195$, Sample 549-44-1, 147-150 cm. 18-19. *Valvulineria gracillima* ten Dam, 1950, $\times 195$, Sample 549-46, CC. 20. *Eponides chalilovi* Djaffarov and Agalarova, 1949, $\times 175$, Sample 549-36, CC.

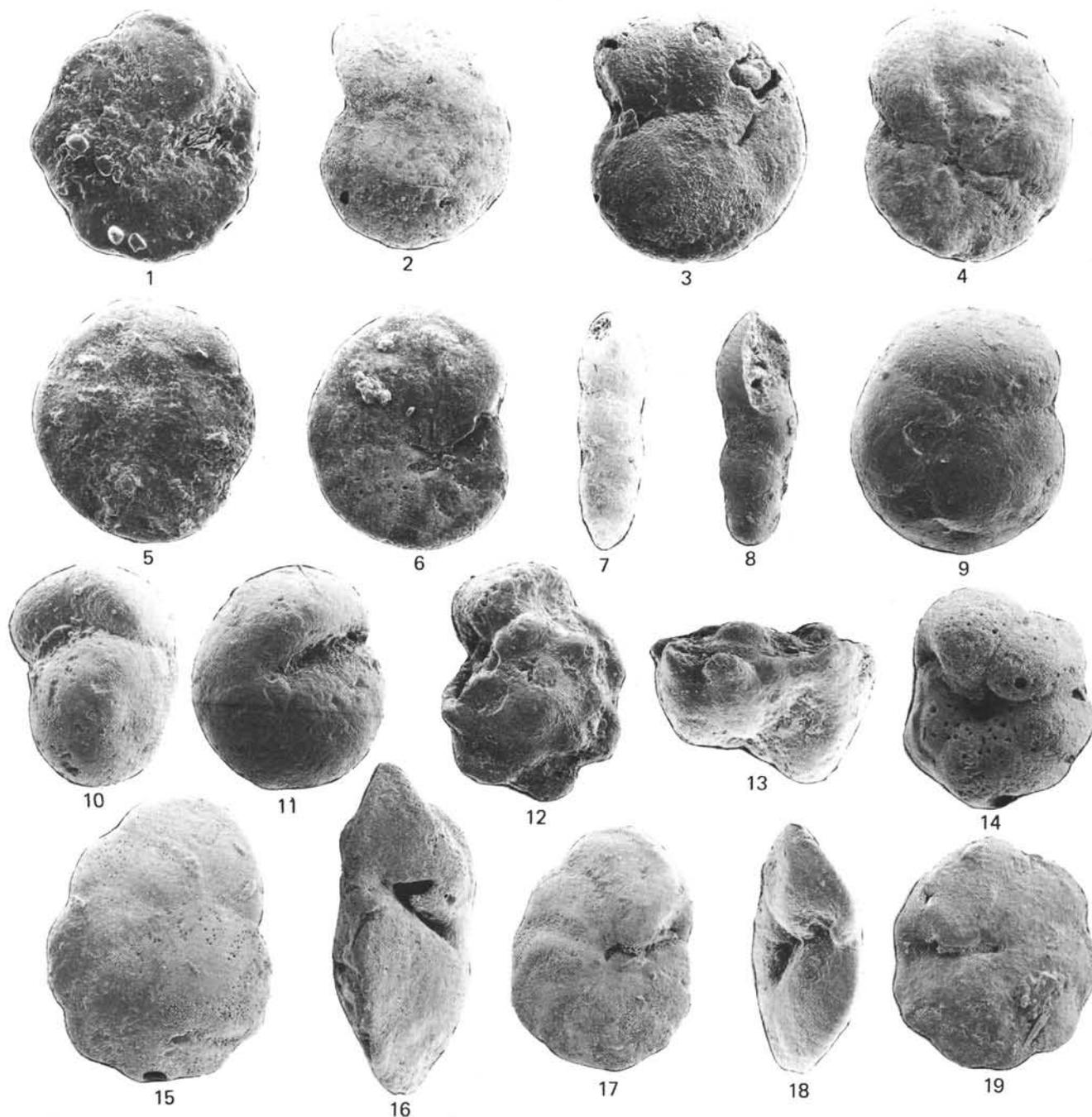


Plate 5. Albian Foraminifera. 1. *Eponides chalilovi* Djaffarov and Agalarova, 1949, $\times 175$, Sample 549-43-4, 25-26 cm. 2-3. *Anomalina rodriguezii* Obregón de la Parra, 1959, (2) $\times 165$, Sample 549-46, CC, (3) $\times 240$, Sample 549-35-1, 16-19 cm. 4. "*Planulina*" *andersoni* Church, 1968, $\times 110$, Sample 549-44-1, 147-150 cm. 5-6. *Cibicides reicheli* Gandolfi, 1942, (5) $\times 165$, Sample 549-40, CC, (6) $\times 220$, Sample 549-35-1, 106-107 cm. 7. *Pleurostomella reussi* Berthelin, 1880, $\times 130$, Sample 549-35, CC. 8. *Pleurostomella subbotinae* Djaffarov, 1949, $\times 38$, Sample 549-43-3, 10-14 cm. 9-11. *Gyroidinoides infracretaceus* (Morozova, 1948), $\times 175$, Sample 549-44-1, 147-150 cm. 12-14. *Gyroidina*(?) sp. 2, (12-13) $\times 220$, Sample 549-44-1, 147-150 cm, (14) $\times 260$, Sample 549-46, CC. 15-17. *Osangularia* sp. 1, (15) $\times 130$, Sample 549-35-1, 16-19 cm, (16) $\times 195$, Sample 549-46, CC, (17) $\times 110$, Sample 549-35-1, 16-19 cm. 18-19. *Osangularia* sp. 2, $\times 165$, (18) Sample 549-34-1, 17-21 cm, (19) Sample 549-44-1, 147-150 cm.

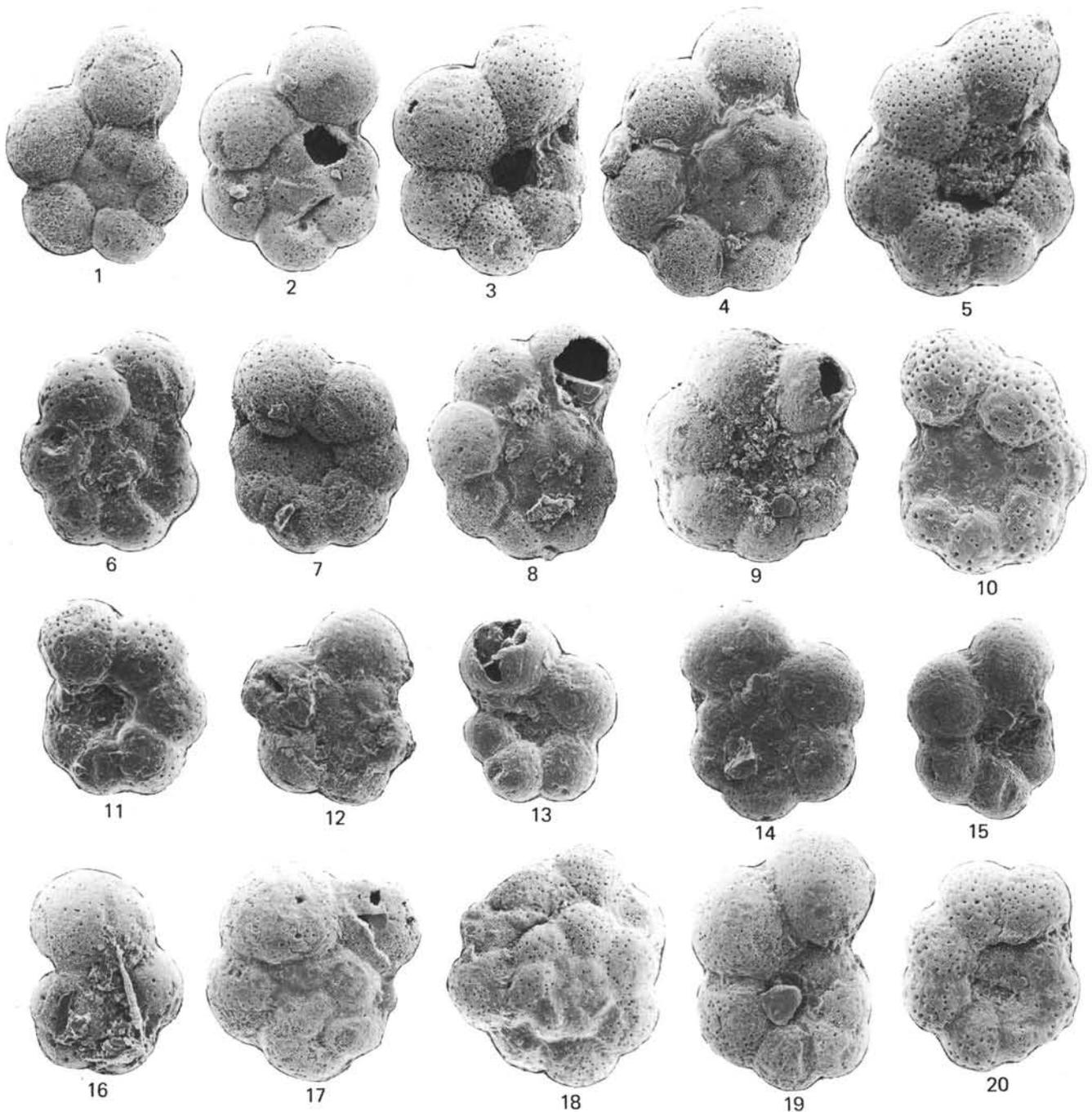


Plate 6. Albian planktonic Foraminifera. 1-3. *Hedbergella planispira* (Tappan, 1940), $\times 195$, Sample 549-46, CC. 4-5. *Hedbergella globigerinelloides* (Subbotina, 1949), $\times 195$, (4) Sample 549-39, CC, (5) Sample 549-36, CC. 6-11. *Hedbergella* sp. 17, $\times 240$, (6) Sample 549-44-1, 147-150 cm, (7) Sample 549-46, CC, (8-9) Sample 549-39, CC, (10-11) subsymmetrical tendency of coiling, Sample 549-44-1, 147-150 cm. 12-13. *Hedbergella infracretacea* (Glaessner, 1937), $\times 240$, Sample 549-44-1, 147-150 cm. 14-15. *Hedbergella rischi* Moullade, 1973, $\times 175$, Sample 549-44-1, 147-150 cm. 16. *Hedbergella angolae* Caron, 1978, $\times 260$, Sample 549-34-1, 17-21 cm. 17. *Hedbergella gorbačikae* Longoria, 1974, $\times 240$, Sample 549-43-4, 57-60 cm. 18. *Hedbergella*(?) cf. *Ticinella bejaouaensis* Sigal, 1966, $\times 165$, Sample 549-35-1, 16-19 cm. 19. *Globigerinelloides* cf. *gottisi* Chevalier, 1961, $\times 195$, Sample 549-44-1, 147-150 cm. 20. *Globigerinelloides* cf. *ferreolensis* Moullade, 1961, $\times 220$, Sample 549-44-1, 147-150 cm.

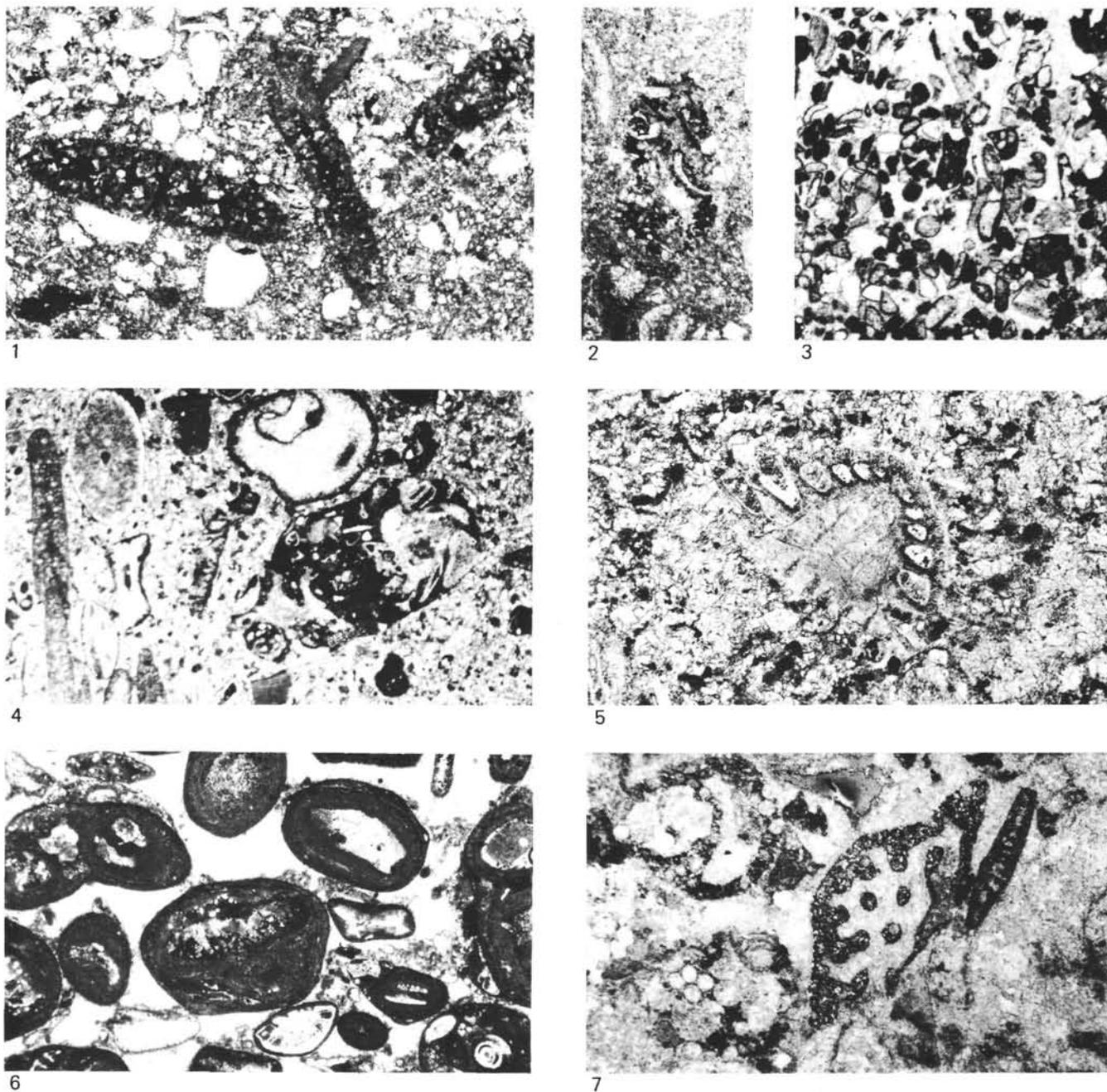


Plate 7. An association of *Choffatella* and various agglutinated Foraminifera, Barremian age (Figs. 1-3) and an association of large *Trocholina* and encrusting Foraminifera, Barremian age (Figs. 4-7). 1. *Choffatella decipiens* Schlumberger, 1905, $\times 55$, subaxial sections, Sample 549-88-3, 5-7 cm. 2. *Haplophragmium*(?), $\times 20$, wall composed of carbonate granules, fragments of bivalve shells and rare quartz grains, Sample 549-89-2, 31-34 cm. 3. Silty packstone with small *Ataxophragmiidae*, *Miliolidae*, and *Trocholina*, $\times 20$, Sample 549-91-1, 126-129 cm. 4. Bioclastic siltstone with *Choffatella*, *Trocholina*, and *Haplophragmium*(?), $\times 20$, Sample 549-76-2, 118-121 cm. 5. *Trocholina aptiensis* Iovcheva, 1962, $\times 55$, axial section, Sample 549-74-3, 92-95 cm. 6. Oncolitic grainstone with *Trocholina* and encrusting Foraminifera, $\times 20$, Sample 549-75-3, 49-51 cm. 7. *Haplophragmium*(?) with carbonate test including "calcite eyes," *Coscinophragma cribrosa* (Reuss), transverse section, *Choffatella decipiens* Schlumberger, 1905, subaxial section, $\times 20$, Sample 549-72-1, 30-31 cm.

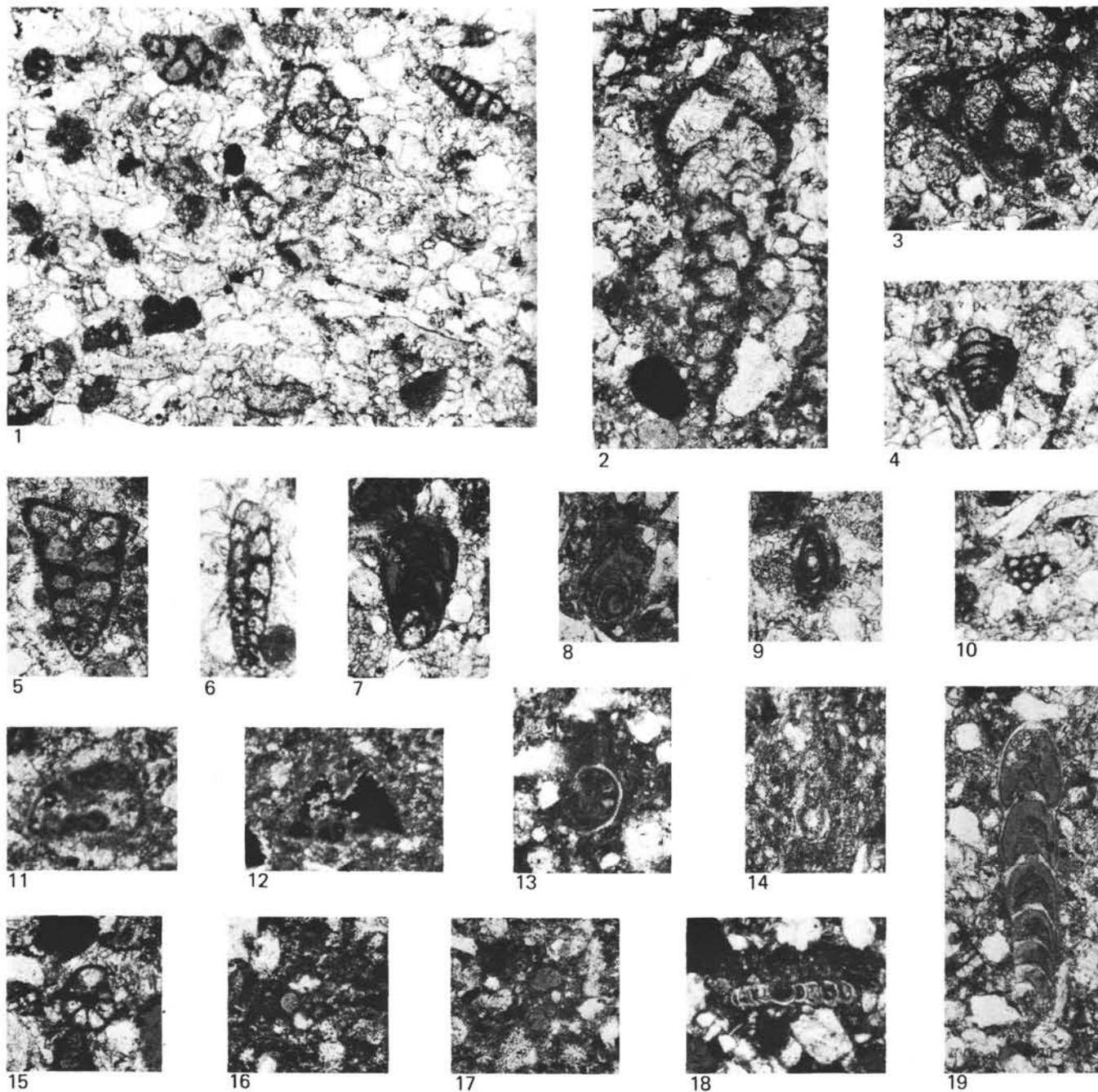


Plate 8. Association of *Hedbergella* and small benthic calcareous Foraminifera, Barremian age ($\times 80$, except Figs. 16–17 which are $\times 125$). 1. Sandy siltstone with small benthic Foraminifera, mainly Ataxophragmiidae, Sample 549-61-4, 28–31 cm. 2–3. *Tritaxia pyramidata* Reuss, (2) oblique longitudinal section, Sample 549-60-5, 122–124 cm, (3) oblique transverse section, Sample 549-61-3, 110–112 cm. 4. *Textularia*, subaxial section, Sample 549-61-3, 110–112 cm. 5. *Dorothia*, axial section, Sample 549-61-2, 140–150 cm. 6. *Belorussiella*(?), subaxial section, Sample 549-61-3, 110–112 cm. 7–8. *Falsogaudryinella*, longitudinal sections, (7) Sample 549-61-2, 94–96 cm, (8) Sample 549-60-5, 1–5 cm. 9–10. *Quinqueloculina*, (9) longitudinal section, Sample 549-61-3, 14–16 cm, (10) transverse section, Sample 549-61-3, 110–112 cm. 11. *Conorotalites bartensteini bartensteini* (Bettenstaedt, 1952), axial section, Sample 549-61-2, 140–150 cm. 12. *Conorotalites bartensteini intercedens* (Bettenstaedt, 1952), axial section, Sample 549-58-3, 149–150 cm. 13–14. *Gavelinella barremiana* Bettenstaedt, 1952, (13) oblique horizontal section, Sample 549-60-6, 68–70 cm, (14) axial section, Sample 549-54-3, 119–123 cm. 15. *Valvulineria*(?), equatorial section, Sample 549-61-2, 94–96 cm. 16–17. *Hedbergella*, (16) equatorial section, (17) axial section, Sample 549-58, CC. 18. *Spirillina*, axial section, Sample 549-60-5, 122–124 cm. 19. *Lingulina*, oblique longitudinal section, Sample 549-61-3, 14–16 cm.

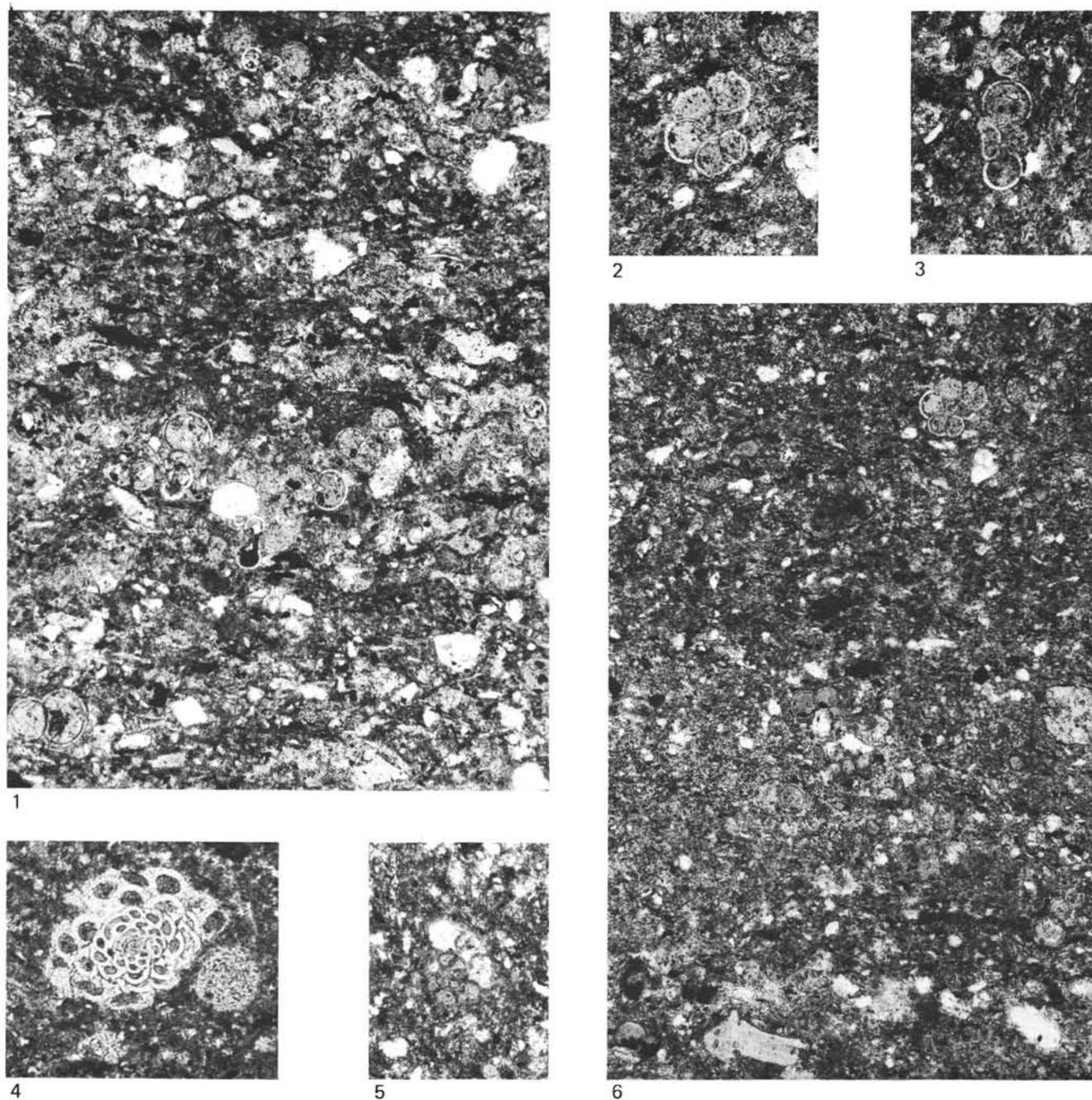


Plate 9. Association of numerous *Hedbergella*, Albian age ($\times 80$, except Figs. 2-3 which are $\times 125$). 1. Silty mudstone with numerous *Hedbergella*, Sample 549-49-2, 83-85 cm. 2-3. *Hedbergella*, (2) equatorial section, enlarged specimen from Fig. 6, (3) axial section, Sample 549-46-1, 18-20 cm. 4. *Glomospira* sp., Sample 549-45-2, 75-78 cm. 5. *Gyroidinoides*(?), equatorial section, Sample 549-40-1, 3-6 cm. 6. Silty mudstone with small *Hedbergella*, Sample 549-41-6, 18-20 cm.