39. PALYNOSTRATIGRAPHY OF THE LOWER CRETACEOUS SECTION AT DEEP SEA DRILLING PROJECT SITE 391, BLAKE-BAHAMA BASIN, AND ITS CORRELATION IN THE NORTH ATLANTIC

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ABSTRACT

Dinoflagellate and sporomorph zonations are presented for the Lower Cretaceous section recovered from the Blake-Bahama Basin in the western North Atlantic, at Hole 391C. The palyniferous interval ranges from Berriasian (stratigraphic level of Core 38) through late Albian (Core 6), on the basis of precise correlation of the Hole 391C section with the independently dated palynomorph reference zones at Site 105.

The following dinoflagellate zones are distinguished, in ascending stratigraphic order: *Biorbifera johnewingii*, *Druggidium apicopaucicum*, *D. deflandrei*, *D. rhabdoreticulatum*, *Odontochitina operculata*, *Deflandrea vestita*. The following sporomorph zones are distinguished: *Ephedripites multicostatus*, *Clavatipollenites*, *Retitricolpites georgensis* (*Psilatricolporites* Subzone).

Ceratioid dinoflagellate fossils in *Phoberocysta neocomica* (Gocht), *Pseudoceratium pelliferum* Gocht, and *Muderongia* sp. cf. *M. simplex* Alberti are reported for the first time from the western North Atlantic. The stratigraphic disappearance of *P. neocomica* within the *Odontochitina operculata* Zone at Hole 391C divides it into a lower *Phoberocysta neocomica* Subzone and a higher *Subtilisphaera perlucida* Subzone.

INTRODUCTION

In this study palynostratigraphic zonations are proposed for the Lower Cretaceous section recovered at Site 391 (Hole 391C) in the western North Atlantic, and compared with the zonations at Site 101 (Hole 101A) and the reference section at Site 105 (Figure 1).

Hole 391C was drilled near the center of the Blake-Bahama Basin (Benson, Sheridan, et al., 1976), at 29°13.61′N latitude and 75°37.00′W longitude; it represents the westernmost abyssal plains in the North Atlantic. Drilling penetrated to 1412 meters below the sea floor, in relatively flat-lying sedimentary strata (Dillon, et al., 1976, p. 462, fig. 4). A relatively thick Mesozoic section was recovered, extending into the Upper Jurassic. The Cretaceous section is approximately 608 meters thick, and extends from 558 meters sub bottom (Core 3) to 1266 meters sub bottom (Core 38). The palyniferous interval extends from Core 6 to Core 38 (Figure 2) and is approximately 579 meters thick. It is dated upper Albian to Berriasian, respectively, on the basis of its correlation with the independently dated palynomorph zones at Site 105 (Habib, 1977).

Ninety samples, collected from 35 cores representing the Mesozoic section, were studied (Table 1). Most samples contain rich assemblages of dinoflagellate cysts, sporomorphs, and small acritarchs. However, 15 samples were barren or only poorly fossiliferous. These samples include all those obtained from Core 9, most of those from Core 34, and those immediately below Core 38 (Cores 40, 41, 42, 43, 44) and above Core 6 (Cores 4 and 5).

The Neocomian part of the section was cored continuously and core recovery was good. The Aptian-Albian part is not as well represented, because of the larger stratigraphic spacing between cores (Figure 2).

Benson, Sheridan, et al. (Site 391, this volume) have defined a lithostratigraphic classification for the sediments recovered at Hole 391C. That part which pertains to this study is summarized below.

Lithostratigraphic unit 3 consists of dark-colored carbonaceous claystone and shale which grade downward into calcareous mudstone and limestone (Figure 2). The calcareous mudstone is carbonaceous as well. The transition from carbonaceous clay lithology to limestone lithology divides unit 3 into a higher sub-unit (3a) and a lower sub-unit (3b).

Lithostratigraphic unit 4 consists of a variety of limestone lithologies composed mostly of calcareous nannoplankton ooze. Four sub-units are distinguished, three of which pertain to this report. Sub-unit 4a consists of limestone and mudstone containing quartz sand and silt. Cross-laminated mudstone and limestone intervals suggest deposition by turbidites. Sub-unit 4b consists mainly of thinly laminated calcilutite, in

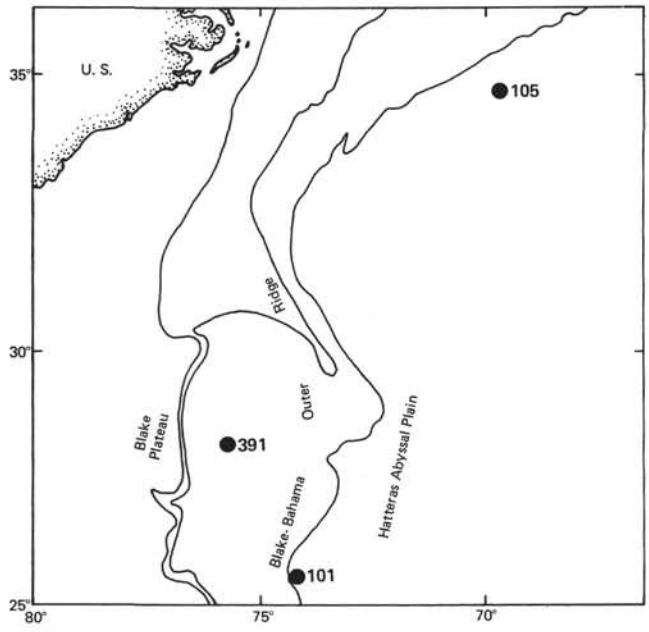

Figure 1. *Location of Holes 101A, 391C, and 105 in the the western North Atlantic.*

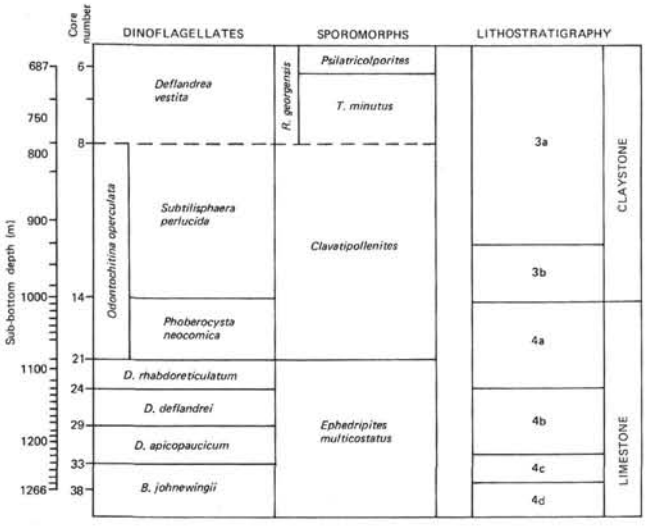

Figure 2. *Palynostratigraphic zonations at Hole 391C. Major lithostratigraphic units shown for comparison.*

addition to bioturbated and massive calcilutite, and dark gray shale. Sub-unit 4c consists primarily of bioturbated calcilutite.

STRATIGRAPHIC PALYNOLOGY

The Lower Cretaceous section at Hole 391C contains various proportions of dinoflagellates, sporomorphs, and small acritarchs. The stratigraphy of dinoflagellates and sporomorphs was studied in order to prepare a stratigraphic zonation for each of these two groups of palynomorphs. The third group of palynomorphs, small acritarchs, is currently under investigation.

The stratigraphic ranges of 62 taxa, 47 dinoflagellate and 15 sporomorph, are shown in Figure 3. Although more species are present in the investigated section, these 62 species were selected for their continuous stratigraphic ranges and chronostratigraphic potential.

Six dinoflagellate zones (two new subzones) and three sporomorph zones (two subzones) are distinguished at Hole 391C, on the basis of stratigraphic or phylogenetic appearance of species defining the lower boundary of its nominative zone (Figure 2).

The palynomorph stratigraphy at Hole 391C is well documented, and provides precise correlation with the reference section at Hole 105 adding significantly to the palynostratigraphy of the western North Atlantic for the following reasons:

1) The Lower Cretaceous is more than twice as thick at Hole 391 than at Hole 105, and equally palyniferous. The same zonation is evident and correlatable such that dinoflagellate subzones described by Habib (1976) can now be elevated to the status of zones. The good

TABLE 1
Samples Studied From Hole 391C

4-1, 123-125 cm*	26-4, 34-32 cm
5-1, 124-126 cm*	27-1, 12-14 cm
6-1, 102-104 cm	27-2, 130-132 cm
6-2, 122-124 cm	27-3, 92-94 cm
6-4, 67-69 cm	27-4, 44-46 cm
6-5, 80-82 cm	28-2, 102-104 cm
6-6, 80-82 cm	28-3, 134-136 cm
7-2, 44-45 cm	28-4, 112-114 cm
8-2, 19-20 cm	29-1, 138-139 cm
9-1, 50-52 cm*	29-2, 37-38 cm
9-2, 66-68 cm*	29-3, 148-150 cm
10-1, 105-107 cm	29-4, 127-128 cm
10-2, 83-85 cm*	29-5, 82-84 cm
10-3, 53-55 cm*	30-2, 8-10 cm*
11-1, 128-129 cm	30-3, 63-65 cm
11-2, 45-47 cm	30-4, 106-108 cm*
11-3, 45-46 cm	31-2, 52-54 cm
12-1, 75-76 cm	31-3, 20-22 cm
12-2, 86-88 cm	31-4, 148-145 cm
12-3, 72-74 cm	31-5, 108-109 cm
12-6, 83-84 cm	31-6, 142-144 cm
14-1, 117-118 cm	32-2, 141-143 cm
14-2, 127-129 cm	32-3, 109-111 cm
14-3, 103-105 cm	32-4, 102-104 cm
15-1, 42-44 cm	33-2, 76-78 cm
15-2, 69-70 cm	34-4, 119-121 cm*
15-2, 83-85 cm	35-1, 2-4 cm
16-2, 77-79 cm	35-2, 33-35 cm
16-3, 83-85 cm	35-3, 73-75 cm
16-4, 61-63 cm	35-4, 70-72 cm
17-2, 33-35 cm	36-1, 68-70 cm
18-1, 124-126 cm	36-3, 115-116 cm
21-4, 93-95 cm	36-5, 60-62 cm
24-1, 114-116 cm	37-2, 74-75 cm
24-2, 145-147 cm	38-1, 73-75 cm
24-3, 43-45 cm	38-2, 130-132 cm
24-4, 102-104 cm*	38-4, 137-138 cm
24-5, 116-118 cm	40-3, 37-39 cm*
24-6, 122-124 cm	41-2, 74-76 cm*
25-1, 124-126 cm	41-4, 24-25 cm*
25-2, 79-81 cm	42-5, 129-131 cm*
25-3, 79-81 cm	43-4, 101-103 cm*
26-1, 108-110 cm	44-2, 23-25 cm*
26-2, 77-79 cm	44-3, 78-80 cm*
26-3, 65-66 cm	44-4, 89-91 cm

Note: Numbers marked with an asterisk represent barren or poorly fossiliferous samples.

Figure 3. *Stratigraphic range chart, Hole 391C.*

recovery of cores at Hole 391C and the relatively close stratigraphic spacing between investigated samples permits this precise zonation.

2) A number of dinoflagellate and sporomorph taxa occur in the section at Hole 391C, which were not found in previous studies of Sites 99, 100, and101 (Habib, 1976, p. 382). Important among these are the dinoflagellates *Phoberocysta neocomica* (Gocht) (Plate 1, Figures 2, 3) and *Pseudoceratium pelliferum* Gocht (Plate 1, Figure 5) which are considered valuable guide species and which occur in the corresponding chronostratotype sections of western Europe (Millioud, 1969, 1975). Other species which were found for the first time at Hole 391C, for example, the dinoflagellate *Muderongia* sp. cf. *M. simplex* Alberti (Plate 1, Figure 4), are stratigraphically useful because of their stratigraphic ranges.

Other dinoflagellate species which are stratigraphically useful because of their distribution at Hole 105 also occur at Hole 391C. These include *Amphorula metaelliptica* Dodekova, *Biorbifera johnewingii* Habib, *Diacanthum hollisteri* Habib, and *Polysphaeridium warrenii* Habib, as well as the other species used for zonation. However, a dinoflagellate guide species which occurs at Sites 99, 100, 101, and 105, *Pyxidinopsis challengerensis* Habib, was not found at Hole 391C.

Although a larger number of sporomorph species was found than at Hole 105, the overall aspect is the same. The flora is characterized by numerous pollen taxa, particularly species of *Classopollis* and bisaccates (*Pinuspollenites*, *Alisporites*), which are long ranging in the Lower and Middle Cretaceous. *Classopollis torosus* (Reissinger) is the most abundant palynomorph species in the Neocomian-Aptian interval. Reticulate triaperturate angiosperm pollen first occur in the Albian and are the most abundant morphotype, replacing *C. torosus*, in the younger sediments.

The palynostratigraphic zonations at Hole 391C are determined on the basis of those recognized for reference section at Hole 105 (Habib, 1976, 1977). The dinoflagellate and sporomorph zonations at Hole 105 are illustrated in Figure 4. The zonations at Hole 105 are useful for correlation with other sites in the western North Atlantic for the following reasons. First, the section extends from Berriasian to Cenomanian and is most complete for this chronostratigraphic interval. Moreover, there is good core recovery (Hollister, Ewing, et al., 1972) and the stratigraphic spacing between samples is close (Habib, 1973). Second, the section at Hole 105 has been dated on the basis of a number of fossil groups, including foraminifers (Luterbacher, 1972), nannofossils (Wilcoxon, 1972; Bukry, 1972; Thierstein, 1976), ammonite aptychi (Renz, 1972), and tintinnids (Lehmann, 1972). The recent study of the Site 105 nannofossils by Thierstein (1976) provides evidence for the Cretaceous-Jurassic boundary, and age-determination for the Berriasian-Hauterivian (or early Barremian) interval. Luterbacher (1972) dated the latest Albian (Vraconian) there, on the basis of planktonic foraminifers, including *Rotalipora apenninica apennica* (Renz) and *Planomalina buxtorfi* (Gandolfi). The investigations by Thierstein (1976) and

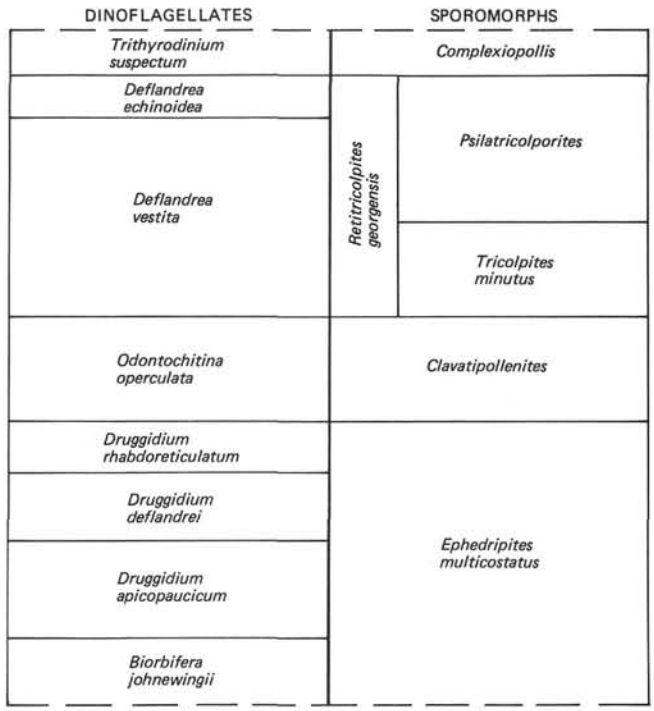

Figure 4. *Dinoflagellate and sporomorph zonations of the reference section at Hole 105. After Habib (in press).*

Luterbacher (1972) are significant as they allow the direct comparison of the Neocomian and Albian palynomorph zones at Site 105 with the geochronological scale recently published by van Hinte (1976) (Figure 5).

The palynomorph zonations at Hole 391C range from Berriasian to late Albian, as determined by correlation with Site 105. These correspond to the *Biorbifera johnewingii-Deflandrea vestita* dinoflagellate zones and *Ephedripites multicostatus-Retitricolpites georgensis* (*Psilatricolporites* Subzone) sporomorph zones. The dinoflagellate *Oligosphaeridium complex* Zone described by Habib (1976) is replaced by elevating its two subzones to zones (Habib, 1977). These are the *Druggidium rhabdoreticulatum* and *Odontochitina operculata* zones. On the basis of the stratigraphic range of *Phoberocysta neocomica* at Hole 391C, the *Odontochitina operculata* Zone is divided into a lower *Phoberocysta neocomica* Subzone and a higher *Subtilisphaera perlucida* Subzone at this site.

The sporomorph zonation is defined by the successive stratigraphic appearances of *Ephedripites multicostatus* Brenner, *Clavatipollenites* spp., and *Retitricolpites georgensis* Brenner. The *Retitricolpites georgensis* Zone is divided into a lower *Tricolpites minutus* Subzone and a higher *Psilatricolporites* Subzone.

Dinoflagellate Zones

Biorbifera johnewingii Zone

The *Biorbifera johnewingii* Zone was defined by Habib (1976) as the interval from the first stratigraphic appearance of the nominative species up to, but not

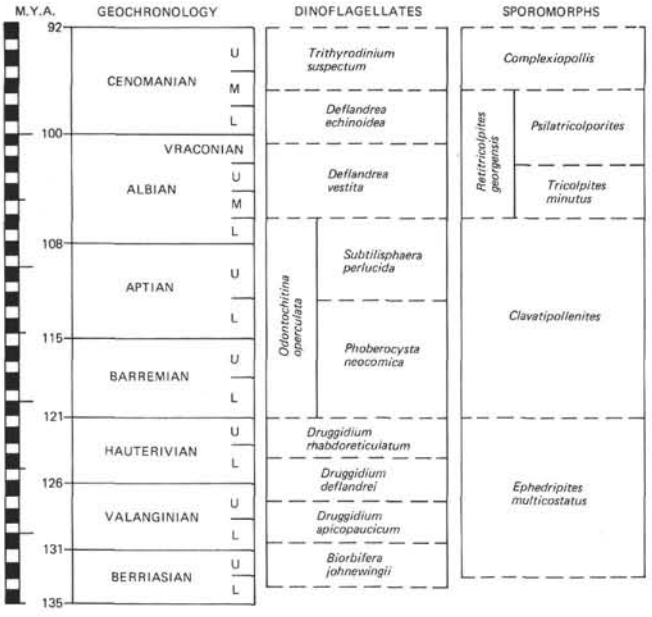

Figure 5. *Geochronologically dated palynostratigraphic zonations of the western North Atlantic. Geochronological scale (part) after van Hinte (1976). After Habib (1977).*

including, the first appearance of *Druggidium apicopaucicum* (Figure 3). The zone ranges from Berriasian to lower Valanginian (Habib, 1977). At Hole 391C, the *Biorbifera johnewingii* Zone comprises the stratigraphic interval between Sample 391C-38-4, 137-138 cm, up to Core 33 (Table 1).

The stratigraphically lowest samples of the *Biorbifera johnewingii* Zone contain a number of species which are useful for distinguishing Cretaceous near the Cretaceous/Jurassic boundary. These include *Polysphaeridium warrenii* and *Diacanthum hollisteri*, as well as *B. johnewingii*. Other species which are useful for distinguishing the Cretaceous/Jurassic boundary, and which occur in the zone at Hole 391C, are *Ctenidodinium elegantulum* Millioud, *Phoberocysta neocomica*, and *Pseudoceratium pelliferum* (Jenkins et al., 1974; Williams, 1975; Millioud, 1975). *Muderongia* sp. cf. *M. simplex* and the Upper Jurassic species *Amphorula metaelliptica* are restricted to the lower two-thirds of this zone.

At Hole 391C, *Cyclonephelium distinctum* Deflandre and Cookson, *Gonyaulacysta helicoidea* (Eisenack and Cookson, *Surculosphaeridium* sp., *Dingodinium, cerviculum* Cookson and Eisenack, and *Scriniodinium attadalense* Cookson and Eisenack occur in the *Biorbifera johnewingii* Zone as well.

Druggidium apicopaucicum Zone

The *Druggidium apicopaucicum* Zone is the interval from the first appearance of the nominative species up to the phylogenetic appearance of *Druggidium deflandrei* (Millioud). It is Valanginian in age. At Hole 391C it is represented in the stratigraphic interval from Samples 391C-33-2, 76-76 cm through 391C-29-5, 82-84 cm (Figure 3).

Druggidium deflandrei Zone

The *Druggidium deflandrei* Phylozone is the interval from the phylogenetic appearance of *D. deflandrei* up to the phylogenetic appearance of *D. rhabdoreticulatum* Habib (Habib, 1976).

The zone is represented at Hole 391C as the interval of Samples 391C-29-4, 127-128 cm through 391C-24-6, 112-124 cm (Table 1). It ranges from late Valanginian to Hauterivian (Habib, 1977).

Surculosphaeridium sp. and the Neocomian guide dinoflagellates *Biorbifera johnewingii* and *Diacanthum hollisteri* disappear stratigraphically within the *Druggidium deflandrei* Zone. *Gonyaulacysta episoma* Sargeant, *Hystrichodinium voigtii* (Alberti), and *Oligosphaeridium complex* (White) first occur near the upper boundary.

Druggidium rhabdoreticulatum Zone

The *Druggidium rhabdoreticulatum* Zone is the interval from the first phylogenetic appearance of *D. rhabdoreticulatum* up to (but not including) the first stratigraphic occurrence of *Odontochitina operculata* (Wetzel). Habib (1976) described this zone originally as the lower of two subzones primarily because of its small thickness at Site 105 in the *Oligosphaeridium complex* Zone It is raised to rank of zone (Habib, 1977) because it is correlatable in the western North Atlantic, despite its small thickness. Also, at Hole 391C, *O. complex* first occurs approximately nine meters below the phylogenetic appearance of *D. rhabdoreticulatum*. At Hole 105, these species occur at the same stratigraphic level.

At Hole 391C the *Druggidium rhabdoreticulatum* Zone comprises the stratigraphic level from sample 391C-24-5, 116-118 cm, up to Core 21. It is of Hauterivian or Barremian age.

Odontochitina operculata Zone

The *Odontochitina operculata* Zone is defined as the stratigraphic interval from the first appearance of *O. operculata* up to the appearance of *Deflandrea vestita* (Brideaux). At Hole 391C, the zone ranges from the stratigraphic level of Sample 391C-21-4, 93-95 cm up to Core 8. It is from upper Hauterivian or Barremian to lower or middle Albian (Habib, 1977). The *Odontochitina operculata* Zone was originally described as a subzone by Habib (1976) and is now elevated to the rank of zone because of its wide geographic range in the western North Atlantic. The *Druggidium rhabdoreticulatum* and *Odontochitina operculata* zones replace the *Oligosphaeridium complex* Zone described originally by Habib (1976).

Two new subzones are proposed for the *Odontochitina operculata* Zone at Hole 391C on the basis of the stratigraphic disappearance of *Phoberocysta neocomica*. The lower subzone, the *Phoberocysta neocomica* Subzone, is defined as the interval from the appearance of *O. operculata* through the highest occurrence of *P. neocomica*; from the stratigraphic level of Sample 391C-21-4, 93-95 cm through that of Sample 391C-14-2, 127-129 cm. On the basis of the stratigraphic ranges of *O. operculata* and *P.*

neocomica in chronostratotype sections studied by Millioud (1969), the *Phoberocysta neocomica* Subzone is upper Hauterivian or Barremian to lower Aptian. The higher new subzone, the *Subtilisphaera perlucida* Subzone, is defined as the interval from immediately above the highest occurrence of *P. neocomica* up to, but not including, the stratigraphic appearance of *Deflandrea vestita*. At Hole 391C, the stratigraphic range of *Subtilisphaera perlucida* (Alberti) approximates the thickness of the *Subtilisphaera perlucida* Subzone. However, the species appears in the highest parts of the *Phoberocysta neocomica* Subzone (Core 15) and disappears in the lowest part of the *Deflandrea vestita* Zone (Core 8). The *Subtilisphaera perlucida* Subzone is considered to be Aptian to lower or middle Albian.

A relatively large number of species disappear or appear stratigraphically within the *Odontochitina operculata* Zone in the western North Atlantic. At Hole 391C, species which disappear in the *Phoberocysta neocomica* Subzone include *Ctenidodinium elegantulum*, *Polysphaeridium warrenii*, and *Druggidium apicopaucicum*; those which disappear stratigraphically in the *Subtilisphaera perlucida* Subzone include *Pseudoceratium pelliferum*, *Dingodinium cerviculum*, *Meiourogonyaulax stoveri* Millioud, *Gonyaulacysta helicoidea*, *Wallodinium krutzschii*, *Druggidium deflandrei*, and *Gonyaulacysta episoma*.

Dinoflagellate species which appear stratigraphically in the *Phoberocysta neocomica* Subzone are *Spiniferites ramosus* (Ehrenberg), *Callaiosphaeridium asymmetricum* (Deflandre and Courteville), *Cribroperidinium muderongensis* (Cookson and Eisenack), and *Hystrichosphaerdium cooksonii* Singh. *Spiniferites cingulatus* (Wetzel) first appears in the *Subtilisphaera perlucida* Subzone.

Deflandrea vestita Zone

The *Deflandrea vestita* Zone, defined by Habib (1977), is the interval from the first stratigraphic appearance of the nominative species at the lower boundary up to the phylogenetic appearance of its descendant species *Deflandrea echinoidea* Cookson and Eisenack. At Hole 391C, the *Deflandrea vestita* Zone ranges from Sample 391C-8-2, 19-20 cm through the top of the palyniferous interval (Sample 391C-6-1, 102-104 cm). The upper boundary is not known, due to the stratigraphic occurrence of *D. vestita* (Brideaux) and the absence of *D. echinoidea*. According to verdlove and Habib (1974), *D. vestita* became phyletically extinct during the Vraconian Albian, on the basis of their studies of Site 105 (cf. Figure 4) samples.

Core 9 at Hole 391C is barren. Consequently, the lower boundary of the *Deflandrea vestita* Zone is not well established.

Hystrichosphaeridium arundum Eisenack and Cookson, *Achomosphaera ramulifera* (Deflandre), *Palaeohystrichophora infusorioides* Deflandre, *Cyclonephelium vannophorum* Davey, *Phoberocysta ceratioides* (Deflandre), and *Litosphaeridium siphoniphorum* (Cookson and Eisenack) appear in the *Deflandrea vestita* Zone.

Sporomorph Zones

Ephedripites multicostatus Zone

The *Ephedripites multicostatus* Zone is the interval from the first appearance of *Ephedripites multicostatus* up to, but not including, the first tectate, monosulcate, angiospermous pollen grains assigned to *Clavatipollenites*. At Hole 391C, the zone ranges from Sample 391C-38-1, 73-75 cm through Sample 391C-24-1, 114-116 cm. It ranges from Berriasian to upper Hauterivian or Barremian.

The *Ephedripites multicostatus* Zone is relatively thick, and corresponds to the *Biorbifera johnewingii-Druggidium rhabdoreticulatum* dinoflagellate zones. A number of species of cicatricose spores occur in the zone which are considered to be useful for stratigraphic zonation in the Neocomian (Dorhofer and Norris, 1975); however, they are not stratigraphically persistent (cf. Norris, 1969) at Hole 391C and consequently are of little value for this section.

Clavatipollenites Zone

The *Clavatipollenites* Zone is defined by the interval from the stratigraphic appearance of *Clavatipollenites* up to the first occurrence of *Retitricolpites georgensis*. The *Clavatipollenites* Zone at Hole 391C ranges from Sample 391C-21-4, 93-95 cm through Sample 391C-10-1, 105-107 cm.

Clavatipollenites sp. (Plate 1, Figure 7) occurs in the lowest samples, and is rare. It is common in the upper half of the zone, in Core 12, where it occurs together with *Clavatipollenites hughesii* Couper and *C. tenellis* Paden-Phillips and Felix. *Clavatipollenites* sp. is distinguished by its continuous tectum layer, as determined by light microscopy. It is retained in the genus *Clavatipollenites* because of its tectate exine, which displays both the tectum and columella layers well.

The *Clavatipollenites* Zone correponds to the *Odontochitina operculata* dinoflagellate zone at Hole 391C and elsewhere in the western North Atlantic, and is dated as ranging from upper Hauterivian or Barremian to lower or middle Albian.

Retitricolpites georgensis Zone

The *Retitricolpites georgensis* Zone is defined at Site 105 as the interval from the first occurrence of the nominative species up to, but not including, the first occurrence of oblate triaperturate pollen of the Normapolles group, e.g., *Complexiopollis*. At Hole 391C, this zone extends from Sample 391C-8-2, 19-20 cm up to the top of the palyniferous interval, represented by Sample 391C-6-1, 102-104 cm.

A number of tricolpate and tricolporoidate angiosperm species are present at or very near the base of the *Retitricolpites georgenis* Zone. At Hole 391C, these include *Tricolpites minutus* (Brenner), *T. auritus* (Bolkhovitina), *Retitricolpites sphaeroides* Pierce, and *R. magnificus* Habib, as well as *R. georgensis*.

Two subzones have been described for the *Retitricolpites georgensis* Zone; a lower *Tricolpites minutus* subzone and a higher *Psilatricolporites* Subzone (Habib, 1977). The *Tricolpites minutus*

Subzone ranges from the first stratigraphic occurrence of *T. minutus* up to the first stratigraphic occurrence of *Psilatricolporites* sp.The higher subzone is distinguished as the interval from the first occurrence of *Psilatricolporites* sp. (Plate 1, Figure 8) up to the first occurrence of *Complexiopollis*. The *Tricolpites minutus* Subzone is considered to be of Albian age, and corresponds to the lower half of the *Deflandrea vestita* dinoflagellate zone (Figure 4). The *Psilatricolporites* Subzone may be of upper Albian or lower Cenomanian. It corresponds to the upper half of the *Deflandrea vestita* and the entire *Deflandrea echinoidea dinoflagellate zones (Habib, 1977) in the western* North Atlantic. At Hole 391C, the *Tricolpites minutus* subzone extends from Sample 391C-8-2, 19-20 cm through Sample 391C-6-6, 80-82 cm; the *Psilatricolporites* Subzone from Sample 391C-6-5, 80-82 cm to the top of the palyniferous interval, for example, Sample 391C-6-1, 102-104 cm.

DISCUSSION

The palynostratigraphic zonations at Hole 391C compare favorably, and can be correlated, with other sites in the western North Atlantic (cf. Habib, 1976, text-fig. 4). Figure 6 compares the zonations of Hole 391C with those at Hole 101A, drilled at the southern end of the Blake-Bahama Outer Ridge, and at Hole 105 to the north, drilled in the lower Continental Rise hills east of Cape Hatteras (Figure 1; Hollister, Ewing, et al., 1972). Of the three sites illustrated in Figure 6, the section at Hole 391C is thickest. It is more than twice as thick as the reference section at Hole 105, although it does not extend as high as the upperAlbian-Cenomanian zones there, for example, the *Deflandrea echinoidea* and *Trithyrodinium suspectum/Complexiopollis* zones. The Neocomian and Albian zones appear to be proportionately thicker at Hole 391C. However, the *Odontochitina operculata/Clavatipollenites* palynomorph zones are disproportionately thicker, which suggests that the rate of sedimentary accumulation in this area for the corresponding interval of time was much higher. Because of the poorly fossiliferous assemblages from Core 9 and the large stratigraphic spacing between Cores 8 and 10, the upper boundary of the *Odontochitina operculata/Clavatipollenites* zones at Hole 391C is not well established, and consequently its thickness is not known precisely. Nevertheless, a minimum thickness of the zones at Hole 391C is at least five times that at Hole 105, and maximum thickness (Figure 6) is at least seven times as thick. It is within the *Odontochitina operculata/Clavatipollenites* zones in the western North Atlantic that the major change in lithofacies occurs from predominantly calcareous nannofossil ooze below to predominantly carbonaceous clay above. Thus, the disporportionate thicknesses between the two sites may be explained alternatively in terms of an unconformity at the facies

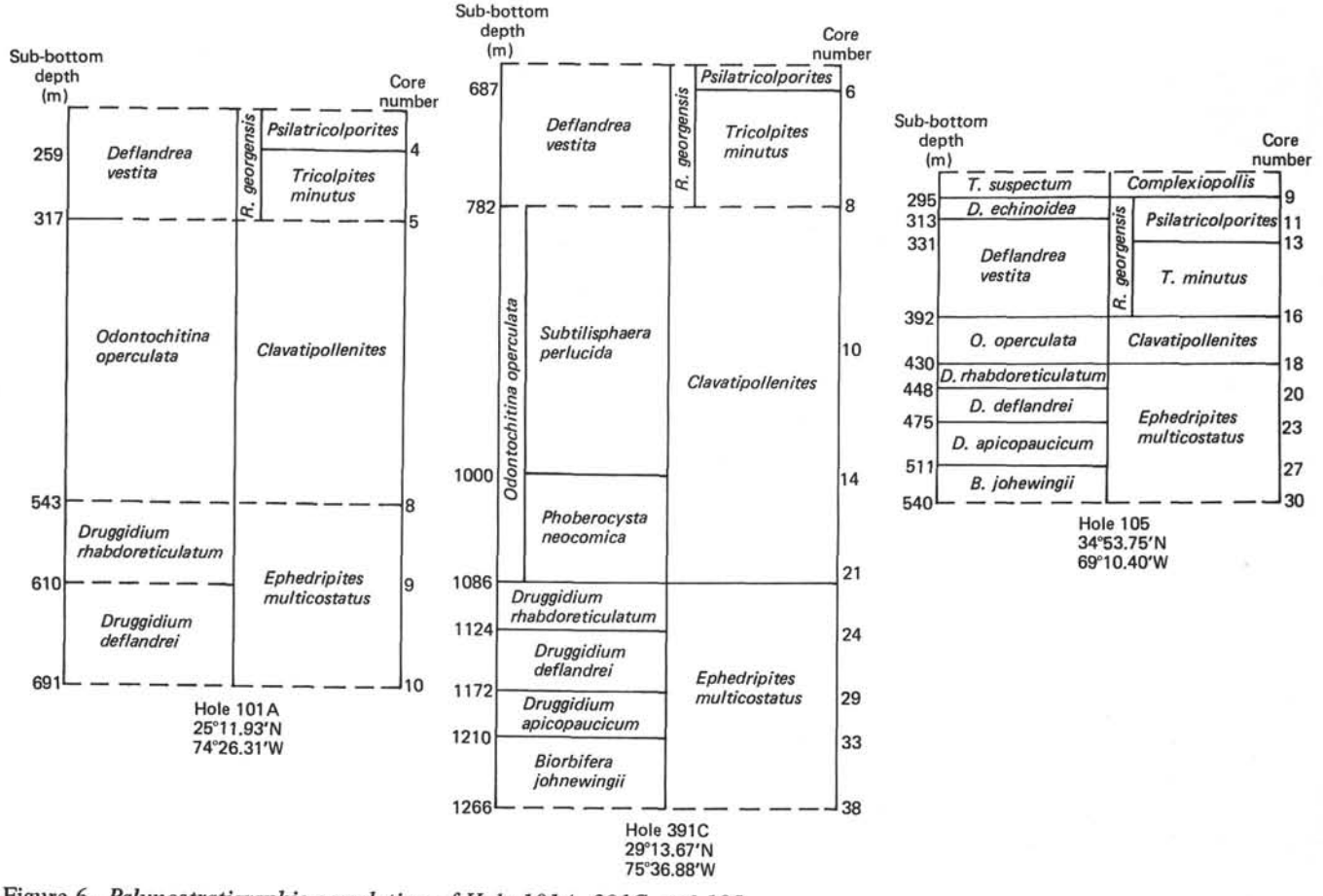

Figure 6. *Palynostratigraphic correlation of Hole 101A, 391C, and 105.*

change, with the larger hiatus represented at Hole 105.

At Hole 101A, the zonations range from *Druggidium deflandrei/Ephedripites multicostatus* zones to the *Deflandrea vestita/Retitricolpites georgensis* (*Psilatricolporites*) zones (Figure 6). The stratigraphic positioning of boundaries between all the zones at this site is approximate, because of the large stratigraphic intervals between collected cores (e.g., Hollister, Ewing, et al., 1972, p. 111, fig. 3). However, the relative thicknesses of the zones appear to be of the same order of magnitude as they are at Hole 391C.

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PLATE 1

Magnifications not to scale.

Figure 1 — *Subtilisphaera perlucida* (Alberti).
Sample 391C-10-1, 105-107 cm. 68 μm.

Figure 2,3 — *Phoberocysta neocomica* (Gocht).
2. Sample 391C-14-2, 127-129 cm. Specimen with operculum in place, showing apical horn. 107 μm.
3. Sample 391C-33-2, 76-78 cm. Apical archeopyle evident. 88 μm.

Figure 4 — *Muderongia* sp.
Sample 391C-36-3, 115-116 cm.
This species resembles *Muderongia simplex* Alberti, but differs by possessing five well-developed horns. The fifth (apical)horn is missing in this specimen, by virtue of the presence of the archeopyle. 127 μm.

Figure 5 — *Pseudoceratium pelliferum* Gocht.
Sample 391C-29-5, 82-84 cm. 115 μm.

Figure 6 — *Odontochitina operculata* (Wetzel).
Sample 391C-8-2, 19-20 cm. 159 μm.

Figure 7 — *Clavatipollenites* sp.
Sample 391C-12-6, 83-84 cm. 26 μm.
7a. Focus on exine stratification, optical section. Note columella below tectum layer.
7b. Focus on distal surface. A faint reticulate pattern is evident.

Figure 8 — *Psilatricolporites* sp.
Sample 391C-6-1, 102-104 cm. Oblate grains; triangular in polar view with gentle concave to convex interradial margins. Psilate. Tricolporate, with long slender colpi and circular pores. Tectate, with developed columella layer. 14 μm.

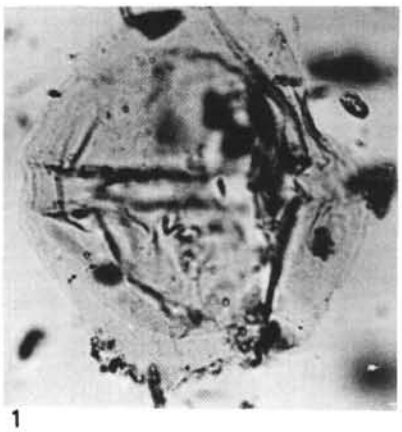
Figure 9 — *Biorbifera johnewingii* Habib.
Sample 391C-35-3, 73-75 cm. 32 μm.

Figure 10 — *Druggidium apicopaucicum* Habib.
Sample 391C-32-3, 109-111 cm. 37 μm.

Figure 11 — *Druggidium deflandrei* (Millioud).
Sample 391C-27-3, 92-94 cm. 38 μm.

Figure 12 — *Druggidium rhabdoreticulatum* Habib.
Sample 391C-12-2, 86-88 cm. 34 μm.

PLATE 1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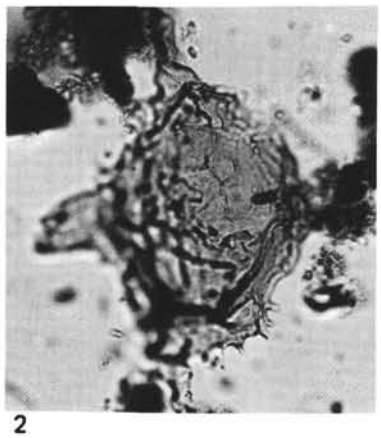
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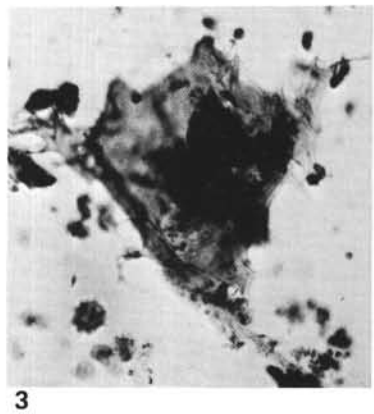
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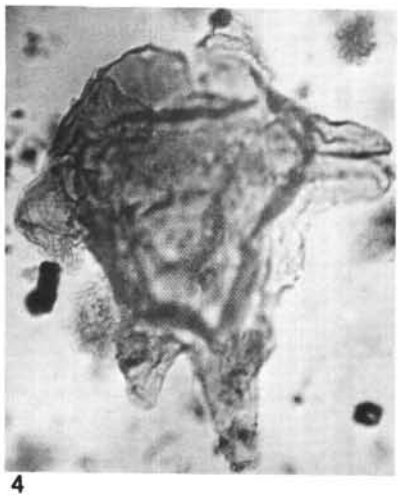
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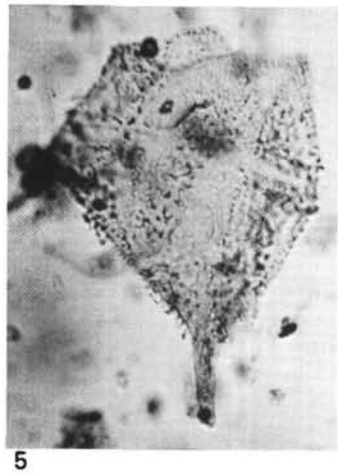
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7a


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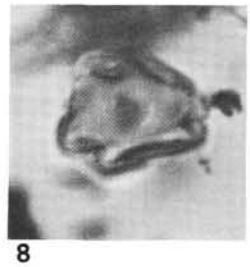
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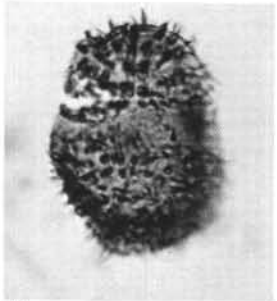
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