

## 19. BIOSTRATIGRAPHIC AND PALEONTOLOGIC SYNTHESIS: DEEP SEA DRILLING PROJECT LEG 71, FALKLAND PLATEAU AND ARGENTINE BASIN<sup>1</sup>

I. A. Basov,<sup>2</sup> P. F. Ciesielski,<sup>3</sup> V. A. Krasheninnikov,<sup>4</sup> F. M. Weaver,<sup>5</sup> and S. W. Wise, Jr.<sup>6</sup>

### ABSTRACT

An integrated correlation scheme constructed for all microfossil and megafossil groups recovered in four DSDP holes from Leg 71 in the southwest Atlantic provides a basis for comparing Jurassic to Holocene sediment sequences in this region with others from throughout the world. The 11 fossil groups in the graphic correlation charts are benthic and planktonic foraminifers, benthic and pelagic mollusks, calcareous nannofossils, diatoms, silicoflagellates, radiolarians, dinoflagellates, pollen and spores, and sponge spicules. The use of all groups allows correlation within the province as well as with lower-latitude zonal schemes. The impoverishment and ecologic restriction of various faunas and floras and the incompleteness of some sections, however, leave many stratigraphic problems to be resolved through the study of additional high- and mid-latitude sections.

### INTRODUCTION

Four sites were drilled by Deep Sea Drilling Project Leg 71 in the southwestern Atlantic Ocean (Fig. 1). Two sites are located on the Falkland Plateau (Site 511, water depth 2589 m, and Site 512, water depth 1846 m) and the other two were drilled in the Argentine Basin on the western flank of the Mid-Atlantic ridge (Site 513, water depth 4373 m, and Site 514, water depth 4318 m). Sediments penetrated by these holes represent a variety of lithologic facies and incorporate various groups of fauna and flora: benthic calcareous and agglutinated foraminifers, planktonic foraminifers, radiolaria, pelecypods, ammonites, belemnites, sponges, nannoplankton, diatoms, silicoflagellates, dinoflagellates, calcisphaerulids, spores, and pollen.

Ludwig et al. (1980) stated:

The broad objectives of Leg 71 were to study the history of sedimentation at the eastern end of the Falkland Plateau, to assess the effect of the Plateau as a barrier between water masses during the early opening of the South Atlantic, and to determine the evolution of the Antarctic convergence in the vicinity of the lower western flank of the Mid-Atlantic Ridge. The particular objectives were fourfold: (1) to extend the geological history of the Falkland Plateau on the basis of sediment cores and to determine its influence on oceanic circulation during the Cenozoic. Changes in oceanic circulation are thought to have occurred during this period in response to the initial opening and enlargement of the South Atlantic, the development of deep-water passage-ways through the ridges and fracture zones in the vicinity of the Falkland Plateau, the opening of Drake Passage, and the climatic evolution of Antarctica and the Southern Ocean; (2) to study the history of bottom-current flow through the region during the Cenozoic on the basis of its erosional, transportational, and depositional consequences; of calcium carbonate dissolution; and of the oxygen isotopic record; (3) to provide Cenozoic biostratigraphic sequences for the South Atlantic; and (4) to provide, given the successful coring, the Mesozoic sedimentary sequences needed to define the paleoceanographic conditions existing during the early opening and development of the Atlantic Ocean.

graphic conditions existing during the early opening and development of the Atlantic Ocean.

The acquisition of relatively complete sequences of Mesozoic and Cenozoic sediments during Leg 71 (Fig. 2) has presented an opportunity to approach, in addition to regional geological tasks, general stratigraphic problems such as the creation of a correlated biostratigraphy based on different groups of macro- and microfossils for the high latitudes. Correlating the stratigraphies of these diverse groups with each other and with the appropriate tropical-subtropical schemes is the main purpose of this paper.

To expand on the immediate problem, we can state that one of the most important problems of modern biostratigraphy is the delineation of biostratigraphic schemes and the limits of their application (global and regional). In recent years biostratigraphic scales based on calcareous and siliceous microorganisms have been worked out for the high latitudes of the Southern Hemisphere. Jenkins (1971) suggested a zonation for the New Zealand Cenozoic sediments based on planktonic foraminiferal distributions. An analogous scheme was proposed by Edwards (1971) using calcareous nannoplankton. Subdivision of high-latitude Neogene siliceous sediments in various regions has been achieved using radiolarian (Chen, 1975; Weaver, 1976), diatom (McCollum, 1975; Schrader, 1976; Gombos, 1977; Weaver and Gombos, 1981) and silicoflagellate (Ciesielski, 1975; Perch-Nielsen, 1975; Bukry, 1975; Busen and Wise, 1977) zonations. The question arises as to how all these regional scales relate to each other and to well-established, low-latitude zonations. Are they strictly local in character, or can they be applied to stratigraphic investigations everywhere in the high latitudes of the Southern Hemisphere? Is it possible to correlate them directly with tropical-subtropical zonations or may Cenozoic sediments at different latitudes be correlated only through new, intermediate, biostratigraphic schemes? Are the changes in different microfossil groups synchronous or asynchronous, and how do the boundaries of stratigraphic subdivisions drawn up by these means relate to

<sup>1</sup> Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 41 (U.S. Govt. Printing Office).

<sup>2</sup> Institute of the Lithosphere, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R.

<sup>3</sup> University of Georgia, Athens, Georgia.

<sup>4</sup> Geological Institute, U.S.S.R. Academy of Sciences, Moscow, U.S.S.R.

<sup>5</sup> Exxon Production Research Co., Houston, Texas.

<sup>6</sup> Florida State University, Tallahassee, Florida.

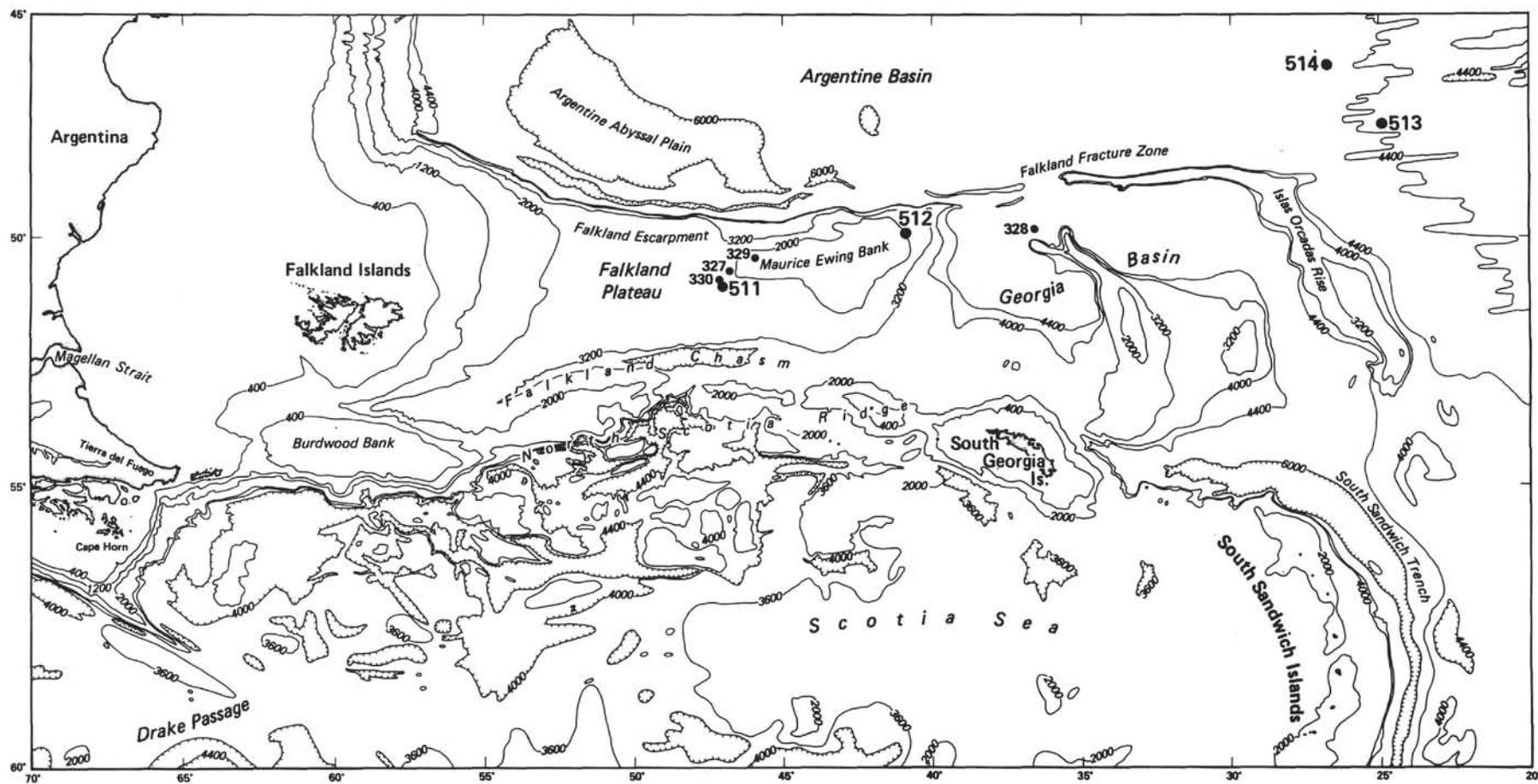


Figure 1. Location of DSDP Leg 71 sites.

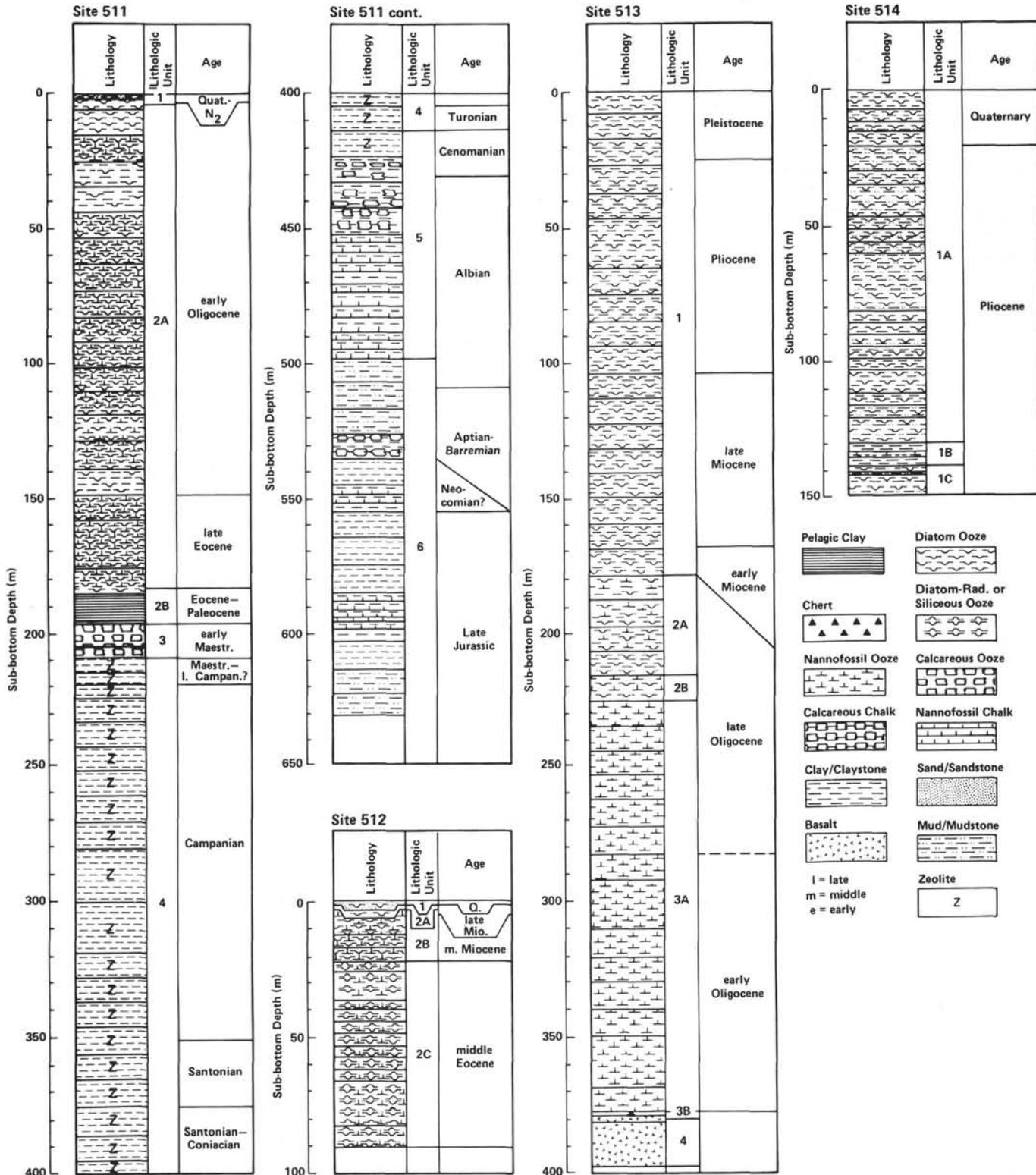


Figure 2. Lithologic columnar sections, DSDP Leg 71 sites.

each other? These and other questions were to be answered by Leg 71 drilling. The geological and biostratigraphic objectives that faced the shipboard scientists called for continuous coring in all sites. Sites 512 and 514 were hydraulic piston cored to correlate biostratigraphy and magnetostratigraphy.

Practically all groups of fauna and flora in the Leg 71 materials underwent shore-based investigation which allowed us to subdivide stratigraphically the sediments recovered and correlate the major Mesozoic and Cenozoic events in the southwestern Atlantic. Benthic and planktonic foraminifers of the Mesozoic and Cenozoic and

Mesozoic calcisphaerulids were studied by V. Krashennikov and I. Basov, radiolarians by F. Weaver, Mesozoic pelecypods, ammonites, and belemnites by J. Jeletzky, nannoplankton by S. Wise and F. Wind, diatoms by P. Ciesielski and A. Gombos, silicoflagellates by P. Ciesielski and C. Shaw, dinoflagellates by D. Goodman, M. Millioud, and L. Ford, Mesozoic pollen and spores by I. Kotova, Paleogene pollen and spores by G. Bratzeva, and Paleogene sponge spicules by M. Ivanik. In addition, correlative stable isotope studies were carried out by J. Muza, D. Williams, and S. Wise and paleomagnetic measurements were made by M. Ledbetter, J. Bloemendal, and J. Salloway. The results of these investigations are published in this volume. These investigations provide a description of the most complete sequence of the Mesozoic and Cenozoic fossils yet available for study in the high latitudes of the Southern Hemisphere. All data concerning the age of sediments, their lithology, stratigraphies of the various groups of fauna and flora and their relation to lithologic stratigraphic subdivisions are given in Figures 3 to 6. A more detailed description follows.

### MESOZOIC

Mesozoic sediments were penetrated at Site 511 off the western edge of the Maurice Ewing Bank. Upper Jurassic, Lower Cretaceous, and Upper Cretaceous sediments are delineated within the Mesozoic sequence. Each of these three subdivisions is further subdivided, but according to rather different criteria, since the sediments are characterized by groups of fossils which are often different and have different stratigraphic resolutions.

The Upper Jurassic portion of the section contains palynological assemblages which allow an approximate age determination only. This is complicated by the absence of precise ages for similar palynoassemblages from the continents fringing the South Atlantic, that is, from South America and Africa. The macrofossils, which occur rather consistently but often as fragments throughout the Upper Jurassic sequence, also do not yield precise age assignments. The Lower Cretaceous sediments contain impoverished assemblages of cool-water planktonic foraminifers and calcareous nannofossils which permit more certain definition, but their stratigraphic resolution remains low. Subdivision of the Upper Cretaceous sediments was based on rather diverse assemblages of planktonic foraminifers and coccoliths. Planktonic foraminiferal assemblages include globotruncanids, which make it possible to subdivide the Upper Cretaceous into stages. The nannofossil stratigraphy includes both universal and local provincial datums.

#### Upper Jurassic

Black shales of Late Jurassic age, which probably accumulated in a semiclosed basin under anoxic conditions, were recovered in the interval from Cores 63 to 70. Benthic and planktonic foraminifers and siliceous microfossils are missing. Fragments and poorly preserved specimens of ammonites, belemnites, and pelecypods are common throughout the section, restricting the age of the sediments (according to Jeletzky) to the ?Ox-

fordian to middle late Tithonian. This age determination is supported by palynological data, which underscore the similarity of palynoassemblages in Cores 63–70 with those from the Vaca Muerta Formation (Argentina) of Tithonian age and the Kirkwood Formation (the Uitenhage group, Algoa Basin, South Africa) which is supposedly of Late Jurassic/Early Cretaceous age. By palynological data, therefore, the age tentatively attributed is the Tithonian. It should also be noted that the same assemblage of pollen and spores was found in black shales of the neighboring Site 330; underlying layers of black shales at Site 330 are older but most of the sequence is still Upper Jurassic, judging by palynoassemblages (Harris, 1977; Hedlund and Beju, 1977; Kotova, this volume).

Nannoplankton are generally sparse but the presence of *Stephanolithion bigoti* supports a late Jurassic age for these cores. In Core 70, however, *S. hexum* suggests a Callovian to early Oxfordian age, a determination supported by dinoflagellates (Goodman and Millioud; see Site 511).

#### Barremian–Aptian, Neocomian?

The stratigraphic interval from 511-57,CC to 511-62,CC is represented by dark gray and black thinly laminated mudstones (black shales) and nannofossil claystones with a high content of organic matter. In addition there are thin interbeds of zeolitic clays, hard muddy calcarenites, and clayey detrital limestones consisting of prisms of *Inoceramus* and fragments of other pelecypods. Benthic foraminifers are very sparse and poorly preserved. The presence of very impoverished assemblages of planktonic foraminifers makes it possible to attribute the sediments to the Barremian–Aptian. Coccoliths from Cores 58 to 60 restrict the age of these sediments to the Barremian–early Albian, including the interval of the *Rhagodiscus angustus* Zone. Some disagreement exists about the age of Cores 61 and 62; the presence of rare hedbergellids among the foraminifers suggests that they should be Barremian or younger. Mollusks are essentially absent in this interval. Pollen and spores suggest an Earliest Cretaceous age, whereas dinoflagellates suggest a Late Jurassic (late Oxfordian to early Kimmeridgian) age (Goodman and Millioud; see Site 511 site chapter, this volume; these workers did not examine Core 60). Coccoliths include a Cretaceous species (*Cretarhabdus conicus*) along with a number of forms that transcend the Jurassic/Cretaceous boundary.

In view of the above, three possibilities exist. First, the hedbergellid forams could have been reworked down-hole during coring. Second, the Jurassic dinoflagellates may have been reworked upsection during an extensive depositional hiatus thought to have occurred somewhere within this part of the sequence. Third, our necessarily long range correlations may be at fault because there are no well-dated land sequences in this part of the world with which comparisons can be made. At present there are two leading choices for the placement of the Jurassic/Cretaceous boundary: (1) at a lithologic change from a shallow-water molluscan limestone above to a

fine, largely barren clay below, occurring at 511-60-5, 82 cm; (2) in the interval between the measured sections of Cores 62 and 63. In any event, there is a hiatus of up to 20 m.y. in the section at or around Cores 61 and 62.

### Albian

Albian sediments have been identified in the interval between Sample 511-49-5, 120–122 cm and Sample 511-57-6, 11–13 cm. They contain rather diverse assemblages of benthic and planktonic foraminifers and nannoplankton. Pelecypods are rather abundant throughout the section. Solitary corals are present in Cores 49–50. Nannoplankton restrict the age of Cores 56 and 57 to the *Rhagodiscus angustus* Zone and that of the interval from Section 511-50-2 to Core 55 to the early/middle Albian *Prediscosphaera cretacea* Zone. Planktonic foraminifers allow us to distinguish the lower Albian (*Ticinella roberti* Zone, from Sample 511-55-6, 34–36 cm to Sample 511-57-6, 11–13 cm), the upper Albian (Sample 511-49-5, 120–122 cm), and an undifferentiated Albian interval from Sample 511-49-6, 14–16 cm to Sample 511-55-3, 34–36 cm. Judging by benthic foraminifers, the lower part of the Albian section in the interval of Cores 55–57 tentatively belongs to the lower–middle Albian and the upper part of the section up to Sample 511-49-6, 120–122 cm is assigned to the middle–upper Albian. Nannofossils place the upper middle Albian boundary between Sections 511-50-1 and 511-50-2, based on the first appearance datum (FAD) of *Eiffellithus turriseiffeli*, but allow no boundary to be drawn between the Albian and the Cenomanian. Macrofossil evidence also makes it possible to attribute the sediments to the Albian.

The uppermost Albian in this site was probably destroyed by subsequent erosion, because layers of this age with the planktonic foraminiferal species *Praeglobotruncana delrioensis* recovered in the neighboring Hole 330A are missing here. Pollen and spores are absent in the well-oxidized Albian sediments. Only the lower layers (Cores 55 and 57), rich in organic matter, contain palynoassemblages similar to those from the tentatively Aptian–Albian sediments of Site 361, Leg 40, South African coast (McLachan and Pieterse, 1978) and from the Albian of neighboring Site 327, Leg 36, Falkland Plateau (Hedlund and Beju, 1977). Although palynoassemblages incorporated in these sediments differ distinctly from those of the Barremian–Aptian and Upper Jurassic, the absence of precise age determinations for similar assemblages in other regions again prevents their attribution to a limited stratigraphic interval. Siliceous fossils are almost absent. Cores 56 and 57 contain sparse recrystallized casts of unidentified radiolarians.

### Upper Cenomanian

Upper Cenomanian deposits are identified in the interval from Sample 511-48-1, 70–72 cm to Sample 511-49-5, 102–104 cm and are represented by variegated claystones and nannofossil claystones. They contain an impoverished assemblage of long-ranging, benthic, agglutinated foraminifers. Planktonic foraminifers date the sediments as late Cenomanian. Fragments of *Inocera-*

*mus* (presumably redeposited), indeterminable pelecypods, and solitary corals are present throughout this interval. Pollen and spores are sporadic whereas calcisphaerulids are rather common. Siliceous microfossils are absent. The boundary between the Lower and Upper Cretaceous, though not manifested lithologically, is very distinctly evident from the incorporated microfossils, which at this level mark a hiatus that seems to be regional in character, although its duration varies at different sites on the Falkland Plateau (Site 511 and 327).

### Turonian

Turonian sediments composed of claystones and zeolitic claystones were distinguished in the interval from Sample 511-47-3, 44–46 cm to Sample 511-48-1, 35–37 cm. They form a continuous sequence with underlying and overlying deposits. The age determination is based on planktonic foraminifers, which are used to subdivide the Turonian into early and late divisions. An early Turonian age is assigned to sediments in the interval from Sample 511-47,CC to Sample 511-48-1, 35–37 cm because many *Praeglobotruncana* specimens are present, whereas double-keeled *Globotruncana* are absent. The appearance of *G. pseudolinneiana* marks the lower/upper Turonian boundary just below Sample 511-47-6, 44–46 cm. Benthic foraminifers are more diverse in the Turonian interval and are represented by long-ranging, deep-water, agglutinated and resistant calcareous species.

Nannoplankton are few to common and are moderately well preserved in cores from Section 511-46-4 to Section 511-48-1; below that level they are absent. They date the sediment as late Turonian (*Kamptnerius magnificus* Zone of Roth, 1978) in a two-part scheme rather than the three-division scheme used for planktonic foraminifers.

*Inoceramus* debris is common in Core 48. Pollen and spores are scarce and siliceous microfossils were not found.

### Coniacian–Santonian

An undifferentiated Coniacian–Santonian sequence was recovered from Sample 511-44-1, 44–46 cm to Sample 511-46,CC. Claystones of this age contain poorly preserved, impoverished assemblages of planktonic foraminifers which testify to the post-Turonian age of sediments but prevent a more precise age determination. Nannoplankton also place the sediments within the Coniacian–Santonian interval only. Layers with mixed bathyal agglutinated and resistant calcareous benthic foraminifers alternate with layers of abyssal, exclusively agglutinated benthic forms. These do not provide an age definition but serve as ecologic indicators. *Inoceramus* fragments (prisms), most probably displaced from submerged heights, are rather common throughout this sequence.

### Santonian

Claystones attributed to the Santonian were penetrated in the interval from Sample 511-41,CC to Sample 511-43,CC. The Santonian age is established by double-

|  | Cored Interval (m) | Lithology | Age                           | Benthic Foraminifers   | Planktonic Foraminifers   | Nannoplankton                         | Radiolarians   | Diatoms                              | Silicoflagellates  | Dino-flagellates   | Macrofauna   | Sponge Spicules   | Palynology  | Calcisphaerulids  |
|--|--------------------|-----------|-------------------------------|--|---|---------------------------------------|--|--------------------------------------|--|--|--|---|---|-------------------|
|  | 0                  |           | Neo.2-Quat.                   | Rare Recent species  | N22   | <i>Emiliana huxleyi</i> Zone          | Mixed P <sub>3</sub> -Quaternary species   | Neo.2-Quat.                          | Neo.2-Quat.  |  |  | Barren  | Barren  |                   |
|  | 1                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 2                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 3                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 4                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 5                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 6                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 7                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 8                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 9                  |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 10                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 11                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 12                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 13                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 14                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 15                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 16                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 17                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 18                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 19                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 20                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 21                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 22                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 23                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 24                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 25                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 26                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 27                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 28                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 29                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 30                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 31                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 32                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 33                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 34                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 35                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 36                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 37                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 38                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  | 39                 |           |                               |  |   |                                       |  |                                      |  |  |  |   |   |                   |
|  |                    |           | early Oligocene               | Assemblage with <i>B. cubensis</i> , <i>A. spissiformis</i> , <i>O. umbonatus</i> , <i>G. girardiana</i> , <i>G. planulata</i> , <i>C. tenuicostatum</i> , <i>C. rahri</i> , etc.            | <i>Globigerina anguloroloides</i> Zone—upper part of <i>G. brevis</i> Zone  | <i>Clausicococcus fenestrata</i> Zone | <i>Theocyrtis tuberosa</i> —early <i>Dorcadopyrtis steuchus</i> zonal equivalent | <i>Rhizosolenia gravida</i> Zone     | <i>Naviculopsis constricta</i> to <i>Corbisera archangeliskiana</i> Zone | <i>N. canstricta/Dictyocha deflandrei</i> Zone   | Assemblage of <i>I. victorianum</i> , <i>K. capulatum</i> , <i>H. rigaudi</i> , <i>C. incompositum</i> | Assemblage of glass sponges ( <i>Hyalospongiae</i> ) with rare <i>Tetraxonida</i> | Abundant gymnosperm pollen ( <i>Podocarpus</i> , <i>Dacrydium</i> , etc.) and subordinate angiosperm pollen ( <i>Nothofagus</i> , <i>Myricaceae</i> , <i>Casuarina</i> , etc.) and spores | Barren            |
|  |                    |           | late Eocene                   |  | <i>G. linaperta</i> Zone/lower <i>G. brevis</i> Zone  | <i>R. osamaruensis</i> Zone           | <i>Thyrocyrtis bromia</i> zonal equivalent                                       | <i>Rylandsia inaequiradiata</i> Zone | <i>Mesocena occidentalis</i> Zone (upper Eocene to lowermost Oligocene)  | <i>A. ornata</i> , <i>Adriatospheeridium</i> sp., <i>Beriacosphaera</i> sp., <i>Ochetodinium</i> sp. | Barren   | Assemblage of <i>Tetraxonida</i>  |   |                   |
|  |                    |           | Paleocene—Eocene              | Barren   | Barren  | Barren                                | middle to early Eocene species   |                                      |  |  |  |   | Barren  |                   |
|  |                    |           | late Campanian?—Maastrichtian | <i>B. incrassata</i> , <i>R. szajnochae</i> , <i>G. quadratus</i> etc.   | Assemblage of <i>Hieberella</i> , <i>Heteronelix</i> , <i>Rugoglobigerina</i> , <i>Globigerinelloides</i>   | <i>Biscutum coronum</i> Zone          | late Cretaceous species  |                                      |  |  |  |   | Barren  | Abundant          |
|  |                    |           | Campanian                     | Impoverished assemblage of long-ranging species  | Barren  | Barren                                |  |                                      |  |  |  |   |   | Rare              |
|  |                    |           | Campanian                     | Diverse, mostly calcareous species of <i>Dentalina</i> , <i>Margulinina</i> , <i>Margulinopsis</i> , <i>Gyrogonia</i> , <i>Gyrogonoides</i> , <i>Pullenia</i> , <i>Globorotalites</i> , etc. | Assemblage with <i>G. plummerae</i> , <i>G. arca</i> , <i>G. coronata</i> , <i>G. lineolata</i> , <i>G. marginata</i> , <i>G. globigerinoides</i> , <i>G. bulloides</i> , <i>G. cretacea</i> , <i>S. multispinata</i> | <i>Martiniasterites furcatus</i> Zone |  | Barren                               | Barren   | <i>I. letum</i> , <i>C. portiera</i> , <i>Amphidadena</i> , <i>A. nucula</i>                         | Barren   | Barren  | Sporadic pollen and spores  | Rare to very rare |

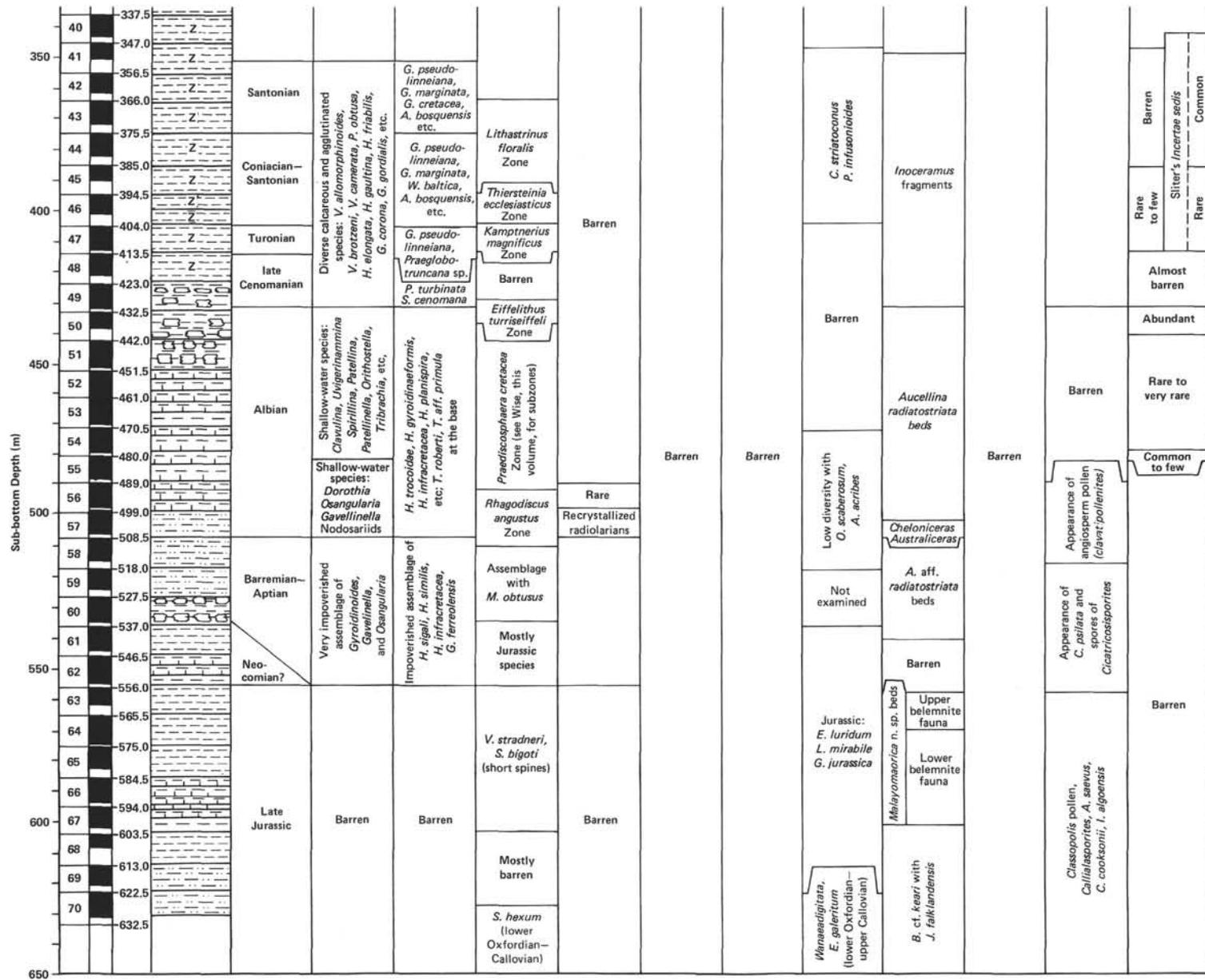


Figure 3. Correlation of Upper Jurassic to Recent microfossil groups, Site 511.

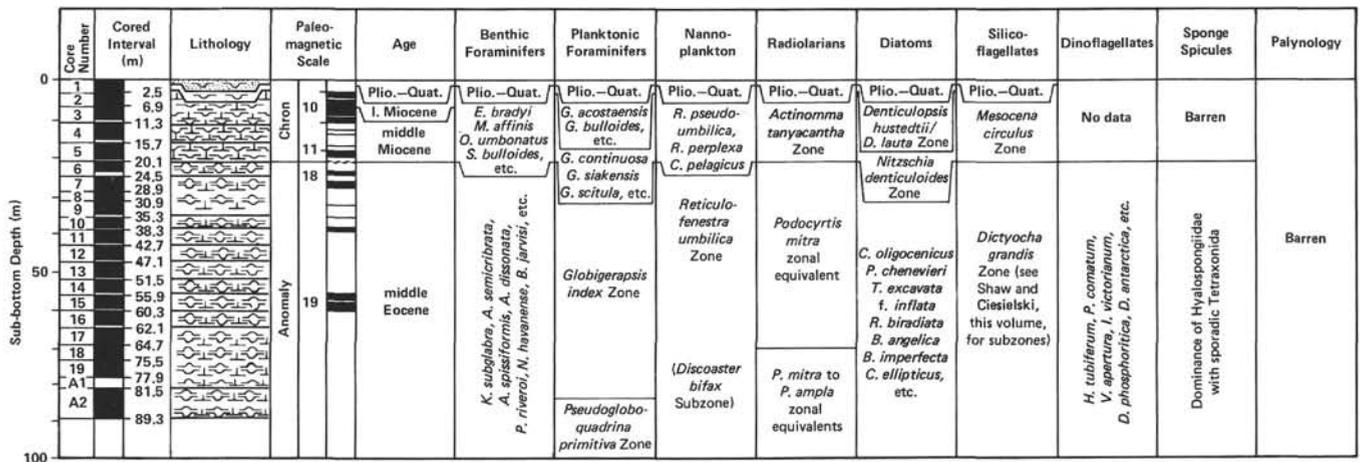


Figure 4. Correlation of Eocene to Recent microfossil groups, Site 512.

keeled *Globotruncana* among the planktonic foraminifers. Core 42 contains a foraminiferal assemblage transitional to the Campanian. Nannoplankton restrict the age of these sediments to the late Santonian, a determination based on the last appearance datum of *Lithastrinus floralis*. The sediments are characterized by a rather diverse assemblage of benthic foraminifers composed of long-ranging species. *Inoceramus* fragments as well as calcisphaerulids are present rarely and irregularly throughout the interval.

**Campanian**

Campanian calcareous claystones of significant thickness (137.5 m) were recovered in the interval from Sample 511-27-1, 32–34 cm to Sample 511-41-3, 55–57 cm. They are characterized by rich assemblages of planktonic foraminifers which include *Globotruncana* of definitely Campanian age. Diverse and abundant calcareous nannoplankton place the age of the sediments within the early Campanian. Benthic foraminifers, also diverse, abundant, and well-preserved, contain some species likewise attributed to the Campanian. The Campanian/Santonian boundary is established on the basis of planktonic foraminifers just above Sample 511-41,CC, but it is quite possible that it could be drawn somewhat lower. Placement of the upper boundary of the Campanian is more dependent on calcareous nanofossils, because sediments of Cores 27–29 contain only a very poor assemblage of agglutinated foraminifers (dissolution facies). Calcisphaerulids are common.

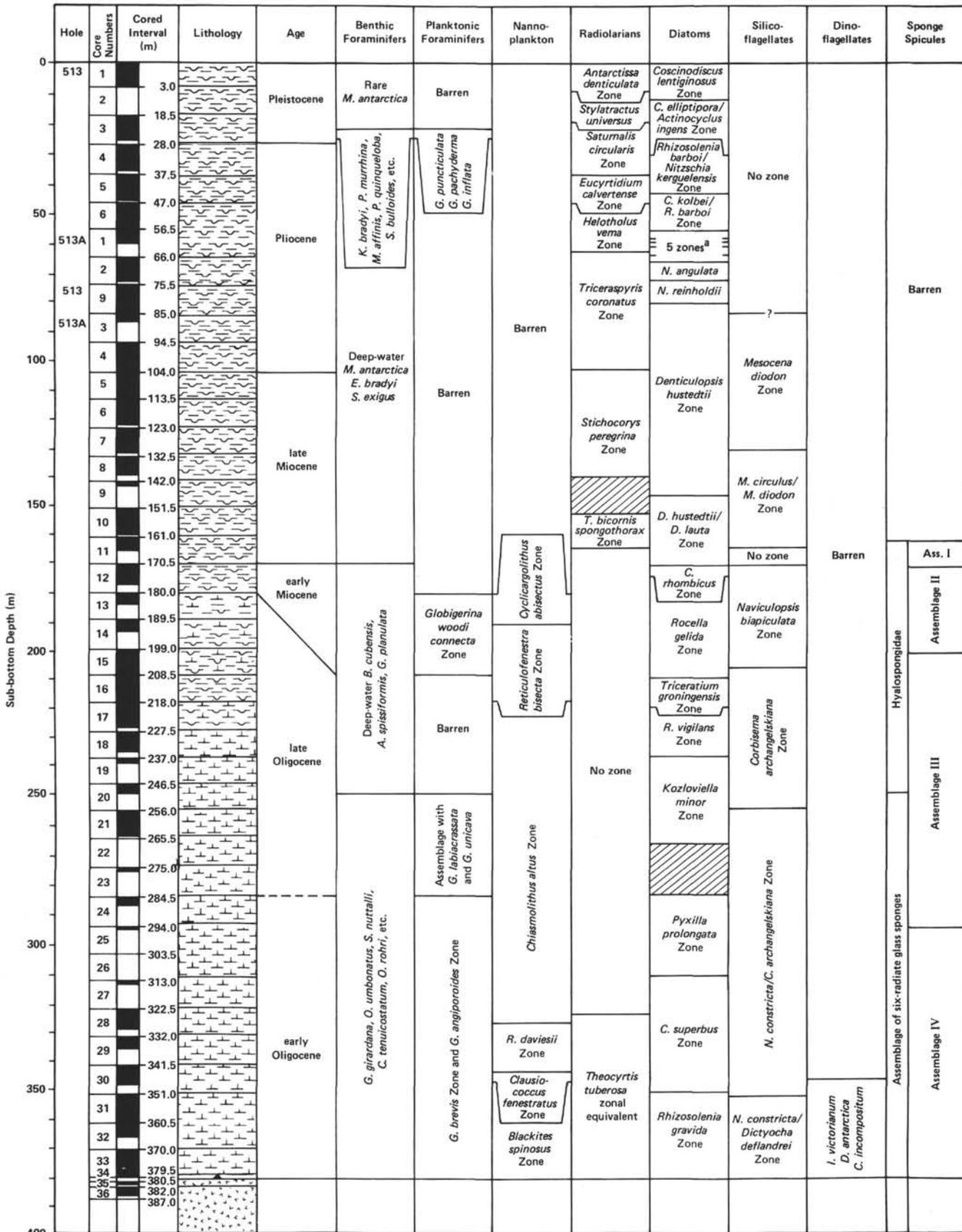
**Upper Campanian?–Lower Maestrichtian**

The Mesozoic sequence on the Falkland Plateau is terminated by upper Campanian?–lower Maestrichtian deposits. Clays and foraminiferal oozes of this age were recovered in the interval from Sample 511-23-1, 78–80 cm to Sample 511-26,CC. A rich assemblage of well-preserved planktonic foraminifers (though *Globotruncana* species are absent) dates the sediments as late Campanian–Maestrichtian but, taking into consideration the thick sequence of the underlying Campanian sediments, it seems hardly possible that the age of these oozes is

older than Maestrichtian. Calcareous nannoplankton are quite diverse; they support this age determination and make it possible to attribute the sediments to the *Biscutum coronum* Zone or to the *Reinhardtites anthophorus* and *R. levis* zones of lower latitudes. Diverse and abundant benthic foraminifers do not yield a precise age determination, but a few key species (*Pullenia coryelli*, *Globorothalites spineus*, *Gyroidinoides quadratus*, *Reussella szajnochae*, and *Bolivina incrassata*) are Campanian–Maestrichtian forms and do not contradict the data provided by other groups of microfossils. The upper boundary of the Maestrichtian sequence is tentative, since it is overlain by Paleogene–Eocene pelagic clays which are almost barren of microfossils (dissolution facies). The lower boundary of the Maestrichtian sequence is rather arbitrary because Cores 25 and 26 are barren of stratigraphically useful microfossils.

**CENOZOIC**

Cenozoic sediments were penetrated at all four sites drilled during Leg 71. Paleocene–Eocene, middle Eocene, upper Eocene–Oligocene, middle–upper Miocene, and Pliocene–Quaternary sediments were recovered on the Falkland Plateau at Sites 511 and 512. Oligocene, lower and upper Miocene, and Pliocene–Quaternary sediments were recognized in the Argentine Basin at Sites 513 and 514. The Cenozoic deposits are represented by dissolution facies in the Paleocene–Eocene and by calcareous biogenic oozes in the middle–upper Eocene which are gradually replaced by siliceous–calcareous oozes of the Oligocene and Neogene. The gradual transition from calcareous sediments to siliceous oozes reflects the climatic deterioration in the Southern Hemisphere which accompanied the onset of glaciation in the Antarctic and the subsequent formation of the circum-Antarctic current after the ultimate opening of Drake Passage. The climatic deterioration and the change in the character of sediment accumulation means that the primary groups used for age determination shift from calcareous microfossils to siliceous microfauna and microflora. Although middle–upper Eocene sediments are subdivided on the basis of the planktonic foraminifers



<sup>a</sup> From top to bottom, these five zones are *C. vulnificus* Zone, *Coscinodiscus insignis* Zone, *Nitzschia weaveri* Zone, *N. intertrigida/C. vulnificus* Zone, and *N. praeintertrigida* Zone.

Figure 5. Correlation of Oligocene to Recent microfossil groups, Site 513 (Letter A indicates Hole 513A cores).

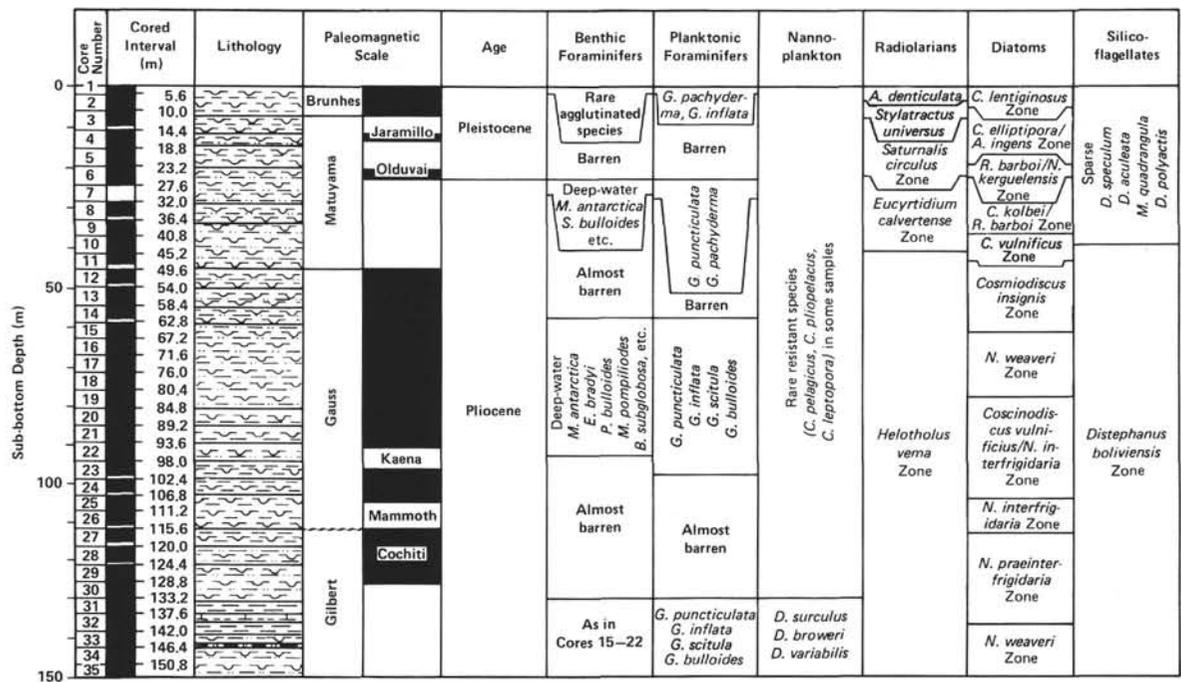


Figure 6. Correlation of Pliocene to Recent microfossil groups, Site 514.

and calcareous nannoplankton, the Oligocene deposits are subdivided using both calcareous and siliceous microfossils. The latter become the lead group for age definition in the Neogene, yielding high stratigraphic resolution, whereas calcareous microfossils permit approximate determinations only.

**Paleocene–Eocene Undifferentiated**

Undifferentiated sediments of this age were recovered at Site 511 on the Falkland Plateau in the interval from Sample 511-21-1, 34–36 cm to Sample 511-23-1, 3–4 cm. They are composed of pelagic clays which contain no calcareous microfossils (dissolution facies). Rare radiolarians and diatoms found in Core 21 date these sediments as Paleocene–Eocene. The relative narrowness (18 m) of the Paleocene–Eocene section and the composition of the sediments suggest the presence of a hiatus at the lower and upper boundaries that appears to be regional in character.

**Eocene**

Sediments of this age were penetrated at Sites 511 and 512 on the Falkland Plateau. At Site 512 (the eastern edge of the bank), middle Eocene siliceous nanno–foraminiferal oozes were recovered in the interval from Sample 512-6-1, 70–72 cm to Sample 512A-2-2, 69–71 cm (approximately 63 m thick). On the basis of the planktonic foraminiferal distribution, the middle Eocene section is subdivided into two zones of the New Zealand zonal scale. Its lowermost section (about 7 m thick) is assigned to the *Pseudogloboquadrina primitiva* Zone and the rest is attributed to the *Globigerapsis index* Zone.

Abundant but rather uniform assemblages of calcareous nannoplankton restrict the middle Eocene sedi-

ments to within the combined *Discoaster distinctus/Reticulofenestra hampdenensis* zones of Edwards’s zonal scheme (1971) or to within the *Discoaster bifax* Subzone of the *Reticulofenestra umbilica* Zone of Bukry’s low-latitude zonal scheme (Bukry, 1973). Diverse assemblages of benthic foraminifers support a middle Eocene age for these deposits. Siliceous microfossils (radiolarians, diatoms, and silicoflagellates) and dinoflagellates are also diverse and abundant. By means of radiolarian and diatom data, middle Eocene sediments are subdivided into two parts. Direct correlation to siliceous low-latitude zonal scales is impossible because index species of the tropical–subtropical zonal schemes are missing here. The distribution pattern of the radiolarian secondary maker species *Lophocyrtis biaurita* and *Liphapium mitra* correlates the interval from Core 512-6 through Core 512-17 to the *Podocyrtis mitra* Zone of the tropical–subtropical radiolarian zonation (Riedel and Sanfilippo, 1977). The interval from Core 512-18 down to the bottom of the section correlate to the *P. mitra* to *P. ampla* radiolarian zones.

Sponge spicules are present throughout the middle Eocene section and yield an impoverished assemblage which differs distinctly from that of the upper Eocene.

Sediments of late Eocene age were penetrated near the western edge of the Maurice Ewing Bank at Site 511 in the interval from Sample 511-17-1, 90–92 cm to Sample 511-20,CC (38 m thick). Diatomaceous nannofossil oozes of the upper Eocene contain a rather diverse assemblage of planktonic foraminifers and are correlated with the tropical–subtropical *Globigerapsis semiinvoluta*, the *Globorotalia cocoensis* and probably the *G. cunia-lensis* zones and with the *Globigerina linaperta* Zone and the lower part of the *G. brevis* Zone of New Zealand. Common and well-preserved coccoliths make it

possible to assign this interval to the *Reticulofenestra oamaruensis* Zone of Edwards. Common to abundant siliceous microfossils also place the sediments in the upper Eocene. A quite different association of sponge spicules compared to that of the middle Eocene is characteristic of these sediments.

The contact between the middle Eocene and Paleocene–Eocene sediments at Site 512 is distinctly expressed lithologically. The upper Eocene/Oligocene boundary at Site 511 is not lithologically distinguishable but is well defined by microfossils. A rather pronounced change in the planktonic foraminiferal assemblage at this boundary may indicate a short hiatus corresponding to the *G. cunialensis* Zone which, in lower latitudes, contains transitional Eocene–Oligocene microfaunas and transcends the very basal layers of the Oligocene. A similar abrupt change in the nannoflora between Cores 511-17 and 511-15 may also indicate such a hiatus. Unfortunately, Core 511-16, which could possibly have provided evidence of a transitional nannoflora, was barren of coccoliths.

### Oligocene

Thick Oligocene sequences were recovered on the Maurice Ewing Bank (Site 511) and in the Argentine Basin (Site 513). On the Falkland Plateau the Oligocene (Cores 511-2 to 511-16; 145 m thick) is represented in the upper part by olive to dark gray muddy diatomaceous oozes and in the lower part by muddy nannofossil diatomaceous oozes resting, apparently conformably, on the Eocene. Calcareous microfossils are more diverse in the lower part of the section, gradually decreasing up the section. Impoverished assemblages of planktonic foraminifers limit the age of sediments to within the *Globigerina tapuriensis* through *G. ampliapertura* zones of the tropical zonal scheme and within the *G. angiporoides* Zone of New Zealand (lower Oligocene). The *Blackites spinosus* Zone (lower Oligocene) in the interval of Cores 511-4, CC to 511-16 and the *Clausiococcus fenestratus* and *Reticulofenestra daviesii* zones in the interval from Core 511-2 to Section 511-4-3 are based upon coccoliths. Diverse and abundant siliceous microfossils support the early Oligocene age of these sediments. The systematic composition of the dinoflagellates is monotonous throughout the section, but diatoms and silicoflagellates are characterized by high stratigraphic resolution and are used to subdivide Oligocene sediments of Site 511 into five and four zonal units, respectively.

In the Argentine Basin, Oligocene nannofossil diatomaceous and nannofossil oozes 172 meters thick, recovered at Hole 513A in the interval from Core 15 to Core 33, overlie the basalt basement. The lower part of the section at this site (Cores 513A-26 to 513A-33) correlates with the lower Oligocene of Site 511. The most reliable links are provided by the three coccolith zones already mentioned and by the diatom *Rhizosolenia gravida* and *Coscinodiscus superbus* zones, which are also found at both sites.

The upper part of the section that bears calcareous microfossils (Cores 513A-25 to 513A-13) can be assigned either to the upper Oligocene only, or partially to the

lower Miocene (Cores 513A-15 to 513A-13), depending on the scheme that is used to correlate zones with the low latitudes. The zonation of Bukry (1973) places the two coccolith zones in this interval, the *Reticulofenestra bisecta* and *Cyclicargolithus abisectus* zones, in the upper Oligocene. This nannofossil zonation, however, is closely tied to the low-latitude planktonic foraminiferal zonation. The correlations of Toumarkine (1978) and Jenkins (1978) would place the foraminiferal zone recognized in the interval in question, the *Globigerina woodi connecta* Zone, within the lower Miocene. The same zone, however, had previously been correlated by Bolli and Krasheninnikov (1977) within the uppermost Oligocene. In this chapter, we indicate the uncertainty by a slanted line on our correlation chart (Fig. 5).

Two morphologically different sponge spicule assemblages are characteristic of the lower and upper Oligocene. The former is similar to a sponge spicule assemblage from the lower Oligocene sediments of Site 511.

The coccoliths, diatoms, and silicoflagellates permit us to subdivide the Oligocene of Site 513 into biostratigraphic zones with boundaries which do not always correspond. Used together, these datums can provide a higher biostratigraphic resolution than when they are used separately.

### Miocene

Siliceous sediments of Miocene age were observed on the Maurice Ewing Bank at Site 512 and in the Argentine Basin at Site 513. In both areas the Miocene is characterized by incomplete sequences. On the Falkland Plateau, calcareous and siliceous microorganisms differentiate the middle (Samples 512-2-1, 121–123 cm to 512-6-1, 1–3 cm) and upper (Samples 512-1-1, 131–133 cm to 512-1, CC) Miocene. In the Argentine Basin, the lower and upper Miocene, separated by a stratigraphic break, are identified. Miocene sediments contain abundant and diverse assemblages of siliceous microfossils and calcareous assemblages of low diversity. Among the coccoliths, numbers of individuals are often quite high. Foraminifers and coccoliths permit only approximate age determinations, and radiolarians, diatoms and silicoflagellates provide the zonal subdivisions for these sediments. The lower and upper Miocene of Site 513 contain two different assemblages of sponge spicules.

Taken together, the various nannofossil groups provide many useful datums for correlation within the Southern Ocean, as shown on Figure 7. Here biostratigraphic datums are correlated with the paleomagnetic time scale and are traced in drill sequences from both the Atlantic (Holes 329, 512, and 513A) and Pacific (Holes 266 and 278) sectors of the Antarctic Ocean.

### Pliocene

Pliocene muddy diatomaceous oozes, 30 meters and 130 meters thick respectively, were penetrated at Sites 513 and 514 in the Argentine Basin. Siliceous microfossils (radiolarians, diatoms, and silicoflagellates) provide high stratigraphic resolution, whereas the calcareous groups are very poor and occur sporadically throughout the section. A correlation of radiolarian and diatom da-

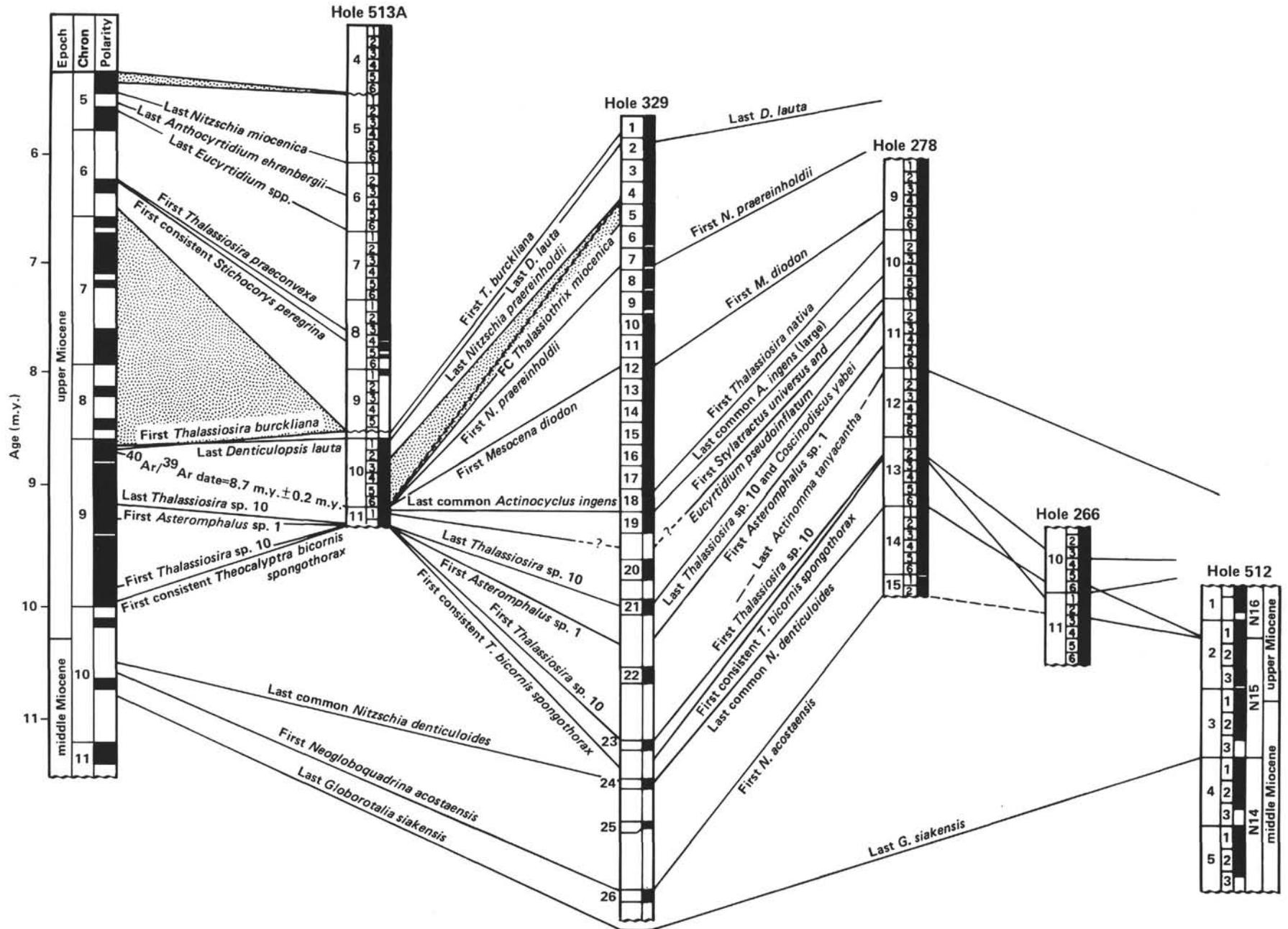


Figure 7. Correlation of Atlantic (Holes 329, 512, and 513A) and Pacific (Holes 266 and 278) Southern Ocean drill sites using biostratigraphic datums keyed against the paleomagnetic time scale (see also Ciesielski and Weaver, this volume).

tums used to subdivide the upper Miocene–Pliocene section at Site 513 is shown in Figure 8 (from Ciesielski, this volume) in order to illustrate the fine stratigraphic resolution that was achieved at this locality. Paleomagnetic studies made it possible to recognize the Matuyama and Gauss chrons (with the Kaena and Mammoth subchrons), and the Gilbert Chron (with the Cochiti Subchron) and to correlate the siliceous biostratigraphic zones with absolute time. Hiatuses between the Gauss and Gilbert chrons at Site 514 and within the middle Pliocene at Site 513 were identified.

#### Quaternary

Quaternary sediments are identified in all Leg 71 sites. On the Falkland Plateau they are only a few meters thick and lie unconformably on the subjacent Pliocene sediments of Sites 511 and 512. The Quaternary sediments are represented by siliceous, gravelly sands and foraminiferal or foraminifer-rich oozes with rather abundant planktonic foraminifers. The age is defined by means of siliceous microfossils.

Quaternary sediments composed of diatomaceous clay and muddy diatomaceous oozes with deep-water benthic foraminiferal fauna are thickest in the Argentine Basin at Sites 513 and 514 (30 m and 20 m respectively). The zonation of the sediments is based on siliceous microfossils. Planktonic foraminifers and coccoliths are largely missing, except at the very top of the section on the Falkland Plateau.

#### SUMMARY AND CONCLUSIONS

Difficulties in subdividing the Mesozoic and Cenozoic sediments of the high latitudes of the South Atlantic (the Falkland Plateau and Argentine Basin) are connected with peculiarities of the fauna and flora of this realm. Nevertheless, using various groups of fauna and flora we were able to achieve a regional stratigraphy for the Mesozoic and Cenozoic sediments and to find correlative links with zones of the tropical and subtropical belts. In the final analysis, local stratigraphic subdivisions can be assigned their proper position in international stratigraphic schemes. Although different groups of fauna and flora were independently investigated, the various stratigraphies gave similar age determinations. Figures 3–7 demonstrate this point well.

The lower part of the Site 511 black shale sequence is attributed to the Upper Jurassic (mostly Tithonian) on the basis of macrofauna, spores, and pollen. Dinoflagellates and nannofossils support the existence of more ancient deposits at the base of the cored section, possibly as old as Callovian or early Oxfordian.

The upper part of the black mudstones is of Early Cretaceous age, on the basis of macrofauna, pollen and spores, and planktonic foraminifer assemblages. With the exception of Core 511-61, the various fossil groups yield similar ages, with most of the black shale section dated as Barremian–Aptian and early Albian. Subdivision of much of the black shale sequence is extremely difficult, however, because of the impoverished organic remains.

Planktonic foraminifers and nannofossils are the primary groups for subdividing the Albian and Upper Cretaceous deposits. They yield similar or identical stage boundary determinations (Albian to Maestrichtian). The impoverishment of the planktonic foraminifers, arising from the high latitude and/or poor preservation, does not permit us to use low-latitude zones. Provincial zones are used, in conjunction with more standard low-latitude coccolith zones for this interval. Siliceous plankton are missing from the Upper Cretaceous sediments.

In the Paleogene the stratigraphic resolution of the calcareous plankton (foraminifers, nannoplankton) diminishes, but they are important for correlation with sediments of the tropical–subtropical area. The middle and upper Eocene sections of Sites 511 and 512 are incomplete; therefore, it is difficult to estimate the resolution of the siliceous plankton. It is certainly very high in the Oligocene of the Falkland Plateau and Argentine Basin, which is subdivided into a number of closely spaced zones by means of diatoms and silicoflagellates. The middle Eocene (Site 512) and upper Eocene (Site 511) are discriminated on the basis of data from all groups of the calcareous and siliceous plankton. The middle Eocene is separated into two parts by means of both radiolarians and diatoms, and boundaries between these units coincide very closely.

The Eocene/Oligocene boundary is often a subject of strong debate. Thus it is interesting that it has been drawn at the same level through evidence from planktonic foraminifers, diatoms, dinoflagellates, sponge spicules, and nannoplankton, a fact that perhaps suggests a short hiatus in the section.

One of the main achievements of DSDP Leg 71 is the development of a complete Oligocene zonal stratigraphy based on diatoms and silicoflagellates. It should be noted that the respective zonal boundaries do not coincide; thus together they provide a means of high-resolution biostratigraphy within the region. Fortunately, a number of calcareous nannofossil datums within this interval allow direct correlation of some of these siliceous zones with calcareous microfossil zones of the lower latitudes.

As was discussed previously, the Oligocene/Miocene boundary was determined by planktonic foraminifers, nannofossils, diatoms, and radiolarians in somewhat different ways, but within a narrow time interval. This can be accounted for by the fact that (1) the exact position of the Oligocene/Miocene boundary is still debated among specialists in the different microfossil groups; (2) correlation with sequences of the warmer latitudes is a rather complicated task. For example, the *Globigerina woodi connecta* Zone begins in the Miocene in the New Zealand stratigraphic scheme, but its relation to the tropical–subtropical zonal scale is known in only a general way. Further study of the Oligocene/Miocene boundary at Site 513 may help resolve this problem.

A significant change in the composition of sponge spicule assemblages in the vicinity of the Oligocene/Miocene boundary probably reflects changing current conditions connected with the opening of the Drake

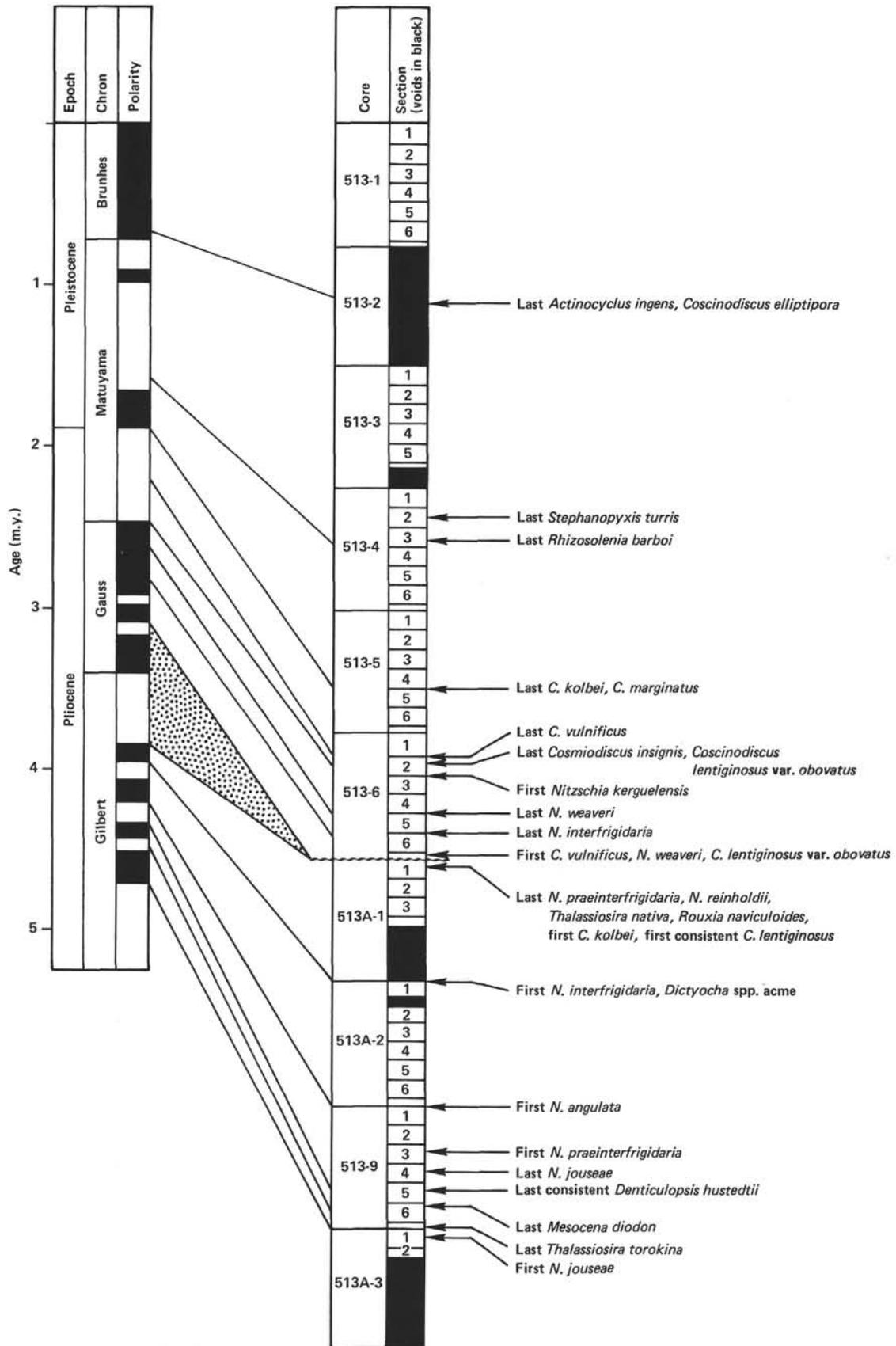


Figure 8. Positions of significant diatom and radiolarian datums in Holes 513 and 513A and their correlation to paleomagnetic stratigraphy (see also Ciesielski, this volume).

Passage. This same event also caused major changes in sedimentation and in plankton communities in the southwest Atlantic (Ciesielski and Wise, 1977).

Stratigraphic sequences in the lower, middle, and upper Miocene are incomplete because they are separated by hiatuses. Certainly, this circumstance makes it easier to delineate boundaries, and the subdivision of the Miocene by means of planktonic foraminifers and different groups of siliceous plankton is in good general agreement. Only the siliceous plankton, however, allow the Miocene to be subdivided into a series of zonal units.

Pliocene and Quaternary sediments are subdivided into zones of high resolution by means of diatoms, radiolarians, and silicoflagellates. Combinations of biostratigraphic and paleomagnetic methods gave excellent results (Site 514).

In summary, independent determinations by means of different groups of fauna and flora have led to similar conclusions regarding the stratigraphic subdivision of the Mesozoic and Cenozoic sediments of the Falkland Plateau and the southern Argentine Basin. The comparatively detailed stratigraphic schemes so generated have laid the groundwork upon which the geologic history, paleoclimatic evolution, and water mass history of the Leg 71 study area can be further investigated.

Results of these stratigraphic studies of Mesozoic and Cenozoic sediments on the Falkland Plateau and Argentine Basin are directly related to general problems of stratigraphy. We wish to conduct analyses of geological history on a global scale, but this task requires the creation of a world-wide, unified, stratigraphic scheme. Correlation of sediments of the tropical-subtropical and Austral belts is an important component of such work.

In our study area it is not clear how such a stratigraphic compendium will be constructed for those Jurassic-Albian and Upper Cretaceous sediments of the Falkland Plateau which contain impoverished assemblages of planktonic foraminifers and calcareous nannoplankton and have no siliceous microfossils. A somewhat different set of problems arises in the Cenozoic, especially in the Oligocene, Neogene, and Quaternary. The calcareous plankton gradually lose their utility for the subdivision of sediments, but the widely developed siliceous plankton are characterized by high resolution, on the same order as calcareous plankton in the tropical-subtropical realm. Whether the change in calcareous and siliceous plankton from the tropical-subtropical to the Austral belts is synchronous or asynchronous is still not clear. To clarify this it will be necessary, therefore, to carry out investigations of planktonic microorganisms from temperate areas (southern part of the Walvis Ridge, Agulhas Bank, etc.). If changes in the fauna and flora turn out to be synchronous, we may eventually expect to see the creation of a world-wide Cenozoic stratigraphic scale.

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#### APPENDIX

##### Species Listed in Figures 3-6 (excluding zonal designations)

##### Benthic Foraminifers

*Alabamina dissonata*  
*Anomalinoidea semicribrata*  
*A. spissiformis*  
*Bolivina incrassata*  
*Bolivinoopsis cubensis*  
*Bradynella subglobosa*  
*Bulimina jarvisi*  
*Chrysalogonium tenuicostatum*  
*Eggerella bradyi*  
*Glomospira corona*  
*G. gordialis*  
*Gyroidina girardana*  
*G. planulata*  
*Gyroidinoidea quadratus*  
*Hyperammia elongata*  
*H. friabilis*  
*H. gaultina*  
*Karriella bradyi*  
*K. subglabra*  
*Martinottiella antarctica*  
*Melonis affinis*  
*M. pompilioides*  
*Nonion havanense*  
*Oridorsalis umbonatus*  
*Orthomorphina rohri*  
*Pleurostomella obtusa*  
*Pullenia bulloides*  
*P. quinqueloba*  
*P. riveroi*  
*Pyrgo murrhina*  
*Reussella szajnochae*  
*Sphaeroidina bulloides*  
*Spirolocamina exigua*  
*Stilostomella nuttalli*  
*Valvulineria allomorphinoides*  
*V. brotzeni*  
*V. camerata*

##### Planktonic Foraminifers

*Archaeoglobigerina bosquensis*  
*Chiloguembelina cubensis*  
*Globigerina angiporoides*  
*G. bulloides*  
*G. labiacrassata*  
*Globigerinellinoides ferreolensis*  
*Globigerinita unicava*  
*G. pachyderma*  
*Globorotalia acostaensis*  
*G. continuosa*  
*G. gemma*  
*G. hirsuta*  
*G. inflata*  
*G. munda*  
*G. punctulata*  
*G. siakensis*  
*Globotruncana arca*  
*G. bulloides*  
*G. coronata*  
*G. cretacea*

*G. globigerinoides*  
*G. linneiana*  
*G. marginata*  
*G. plummerae*  
*G. pseudolinneiana*  
*Hedbergella gyroidinaeformis*  
*H. infractretacea*  
*H. planispira*  
*H. sigali*  
*H. similis*  
*H. trochoidea*  
*Praeglobotruncana turbinata*  
*Schackoina cenomana*  
*S. multispinata*  
*Ticinella aff. primula*  
*T. roberti*  
*Whiteinella baltica*

##### Nannoplankton

*Coccolithus pelagicus*  
*Micratholithus obtusus*  
*Reticulofenestra perplexa*  
*R. pseudoumbilica*  
*Stephanolithon bigoti*  
*S. hexum*  
*Vekshinella stradneri*

##### Diatoms

*Brightwellia imperfecta*  
*Coscinodiscus ellipticus*  
*C. oligocenicus*  
*Pseudotriceratium chenevieri*  
*Trinacria excavata f. inflata*

##### Silicoflagellates

*Dictyocha aculeata*  
*D. polyactus*  
*Distephanus speculum*

##### Dinoflagellates

*Alisocysta ornata*  
*Amphidiadema nucula*  
*Angustidinium acribes*  
*Conosphaeridium striatoconus*  
*Corrudinium incompositum*  
*Deflandrea antarctica*  
*D. phosphoritica*  
*Endoscrinium galeritum*  
*E. luridum*  
*Gonyaulocista jurassica*  
*Hystrichokolpoma rigaudiae*  
*Hystrichosphaeridium tubiferum*  
*Impagidinium victorianum*  
*Isabeladidium latum*  
*Kallosphaeridium capulatum*  
*Leptodinium mirabile*  
*Odontochitina porifera*  
*Oroidinium scaberosum*  
*Palaeohystrichopora infusonioides*  
*Phthanoperidinium comatum*  
*Vozzhennikovia apertura*

##### Macrofauna

*Aucellina aff. radiostriata*  
*Belemnopsis cf. keari*  
*Jeletzkiella falklandensis*

##### Pollen and Spores

*Antulsporites saevus*  
*Contignosporites cooksoni*  
*Cyclusphaera psilata*  
*Interulobites algoensis*