2. EXPLANATORY NOTES[1]

Shipboard Scientific Party[2]

Standard procedures for both drilling operations and preliminary shipboard analysis of the material recovered have been regularly amended and upgraded since 1968 during the Deep Sea Drilling Project and Ocean Drilling Program drilling. In this chapter we have assembled information that will help the reader understand the data-gathering methods on which our preliminary conclusions are based and help the investigator select samples for further analysis. This information primarily concerns shipboard operations and analyses described in the Leg 113 site reports and underway geophysics chapter (this volume). Geophysical data acquired and the results of sediment-trap deployments aboard the ice-picket boat *Maersk Master* are also described in this volume. Methods used by various investigators for further shore-based analysis of Leg 113 data will be detailed in the individual scientific contributions published in the Scientific Results.

RESPONSIBILITY OF AUTHORSHIP

Authorship of the site reports is shared among the entire shipboard scientific party. The Leg 113 site chapters are organized into the following sections, with authors' names listed alphabetically in parentheses:

Site Summary (Barker, Kennett)
Geologic Setting and Objectives (Barker, Kennett)
Operations (Hanson)
Lithostratigraphy and Sedimentology (Egeberg, Fütterer, O'Connell, Pereira, Pudsey, Robert)
Clay Mineralogy (Robert)
Basement Rocks and Ice-rafted Dropstones (Schandl)
Biostratigraphy (Burckle, Gersonde, Lazarus, Mohr, Stott, Thomas, Wise)
Paleomagnetics (Hamilton, Spiess)
Accumulation Rates (Burckle, Gersonde, Hamilton, Lazarus, Mohr, Stott, Thomas, Spiess, Wise)
Organic Geochemistry (Thompson)
Inorganic Geochemistry (Egeberg)
Physical Properties (Bryant, Nagao)
Downhole Measurements (Golovchenko, Pereira)
Seismic Stratigraphy (Barker)
Summary and Conclusions (Barker, Kennett)

Following the text are summary graphic lithologic and biostratigraphic logs, core descriptions ("barrel sheets"), and photographs of each core.

Data and preliminary interpretations in the site chapters reflect knowledge obtained only from shipboard analyses and preliminary post-cruise analyses. We have, however, already benefited from data and analyses generously contributed by shore-based collaborators, and are pleased to acknowledge the following colleagues for their assistance:

Alastair Crame (macrofossil biostratigraphy),
Brian Huber (Late Cretaceous planktonic foraminifers),
Mark Leckie (Early Cretaceous planktonic foraminifers),
Kevin McCartney (silicoflagellate biostratigraphy),
Jorge Muttenlose (Early Cretaceous calcareous nannofossils),
James Pospichal (Late Cretaceous-Paleogene calcareous nannofossil biostratigraphy),
Michael Thomson (macrofossil biostratigraphy), and
Wuchang Wei (Cenozoic calcareous nannofossil biostratigraphy).

Results of the more detailed shore-based work will be presented in the special studies chapters in the Scientific Results, Volume 113. In some cases the more refined reports may necessitate reinterpretation of these preliminary site results.

SURVEY AND DRILLING DATA

The survey data used for specific site selection are discussed in each site chapter. Short surveys using a precision echo sounder and single-channel seismic reflection profiler were made on board *JOIDES Resolution* approaching each site. All geophysical survey data collected during Leg 113 are presented in the "Underway Geophysics" chapter (this volume). This includes the underway magnetic data that were collected aboard the ice-picket vessel, *Maersk Master*.

The standard seismic sources used during the cruise were two 80-in.^{3} water guns. The seismic system was controlled by a supermicro Masscomp 561 computer. A 15-in.-wide Printronix high-resolution graphic printer (160 dots/in.) and a 22-in.-wide Versatec plotter (200 dots/in.) were available to plot the data. The raw data were recorded on digital magnetic tape using the SEG-Y format at a density of 1600 bpi (bytes/in.). Real-time seismic data were also displayed in analog form on two Raytheon LSR 1807M dry-paper recorders, after amplification and band-pass filtering.

Navigation data were collected on the bridge by a Magnavox MX702A (Transit Satellite) and Magnavox 4400 Global Positioning System (GPS) and aft with a Magnavox 1107-GPS (Transit and GPS).

Bathymetric data were obtained with both 3.5-kHz and 12-kHz echo-sounders, using two Raytheon correlators (CESP-III), transceivers (PER 10513), and recorders (LSR 1807M).

The depths were read on the basis of an assumed 1500-m/s sound velocity. The water depth (in meters) at each site was corrected (1) according to the tables of Carter (1980) and (2) for the depth of the hull transducer (6.8 m) below sea level. The drilling platform was assumed to be 11.1 m above the water line. On board *Maersk Master*, magnetic field measurements were made on passage and around some sites, using a Barringer DMS123 proton precession magnetometer on loan from Research Vessel Services, Barry, South Wales. The sensor was towed 150 m astern. Transit satellite fixes were obtained using a Shipmaster RS5000, single-channel receiver.

[1] Barker, P.B., Kennett, J.P., et al., 1988. *Proc. ODP, Init. Repts.*, 113: College Station, TX (Ocean Drilling Program).
[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.

DRILLING CHARACTERISTICS

Because water circulation down the hole is open, cuttings are lost onto the seafloor and cannot be examined. The only available information about sedimentary stratification in uncored or unrecovered intervals, other than from seismic data or wireline logging results, is from an examination of the behavior of the drill string as observed on the drill platform. The harder the layer being drilled, the slower and more difficult it is usually to penetrate. There are, however, a number of other factors which determine the rate of penetration, so it is not always possible to relate this directly to the hardness of the layers. The parameters of bit weight and revolutions per minute are recorded on the drilling recorder and influence the rate of penetration.

DRILLING DEFORMATION

When cores are split, many show signs of significant sediment disturbance. Such disturbance includes the concave-downward appearance of originally horizontal bands, the haphazard mixing of lumps of different lithologies (mainly at the top of cores) and the near-fluid state of some sediments recovered from tens to hundreds of meters below the seafloor. Core deformation may occur during one of at least three different steps: cutting, retrieval (with accompanying changes in pressure and temperature), and core handling on deck.

SHIPBOARD SCIENTIFIC PROCEDURES

Numbering of Sites, Holes, Cores, and Samples

ODP drill sites are numbered consecutively from the first site drilled by *Glomar Challenger* in 1968. Site numbers are slightly different from hole numbers. A site number refers to one or more holes drilled while the ship is positioned over a single acoustic beacon. Several holes may be drilled at a single site by pulling the drill pipe above the seafloor (out of one hole), moving the ship some distance from the previous hole, and then drilling another hole.

For all ODP sites, a letter suffix distinguishes each hole drilled at the same site. The first hole takes the site number with suffix A, the second hole takes the site number with suffix B, and so forth. This procedure is different from that used by the Deep Sea Drilling Project (Sites 1-624), but prevents ambiguity between site and hole number designations.

All ODP core and sample identifiers include core type. The following abbreviations are used: R = rotary barrel; H = hydraulic piston core (HPC/APC); X = extended core barrel (XCB); I = *in-situ* water sample; and W = wash core recovery.

The cored interval is measured in meters below seafloor (mbsf). The depth interval of an individual core is the depth below seafloor that the coring operation began to the depth that the coring operation ended. Each cored interval is as long as 9.7 m, which is the maximum capacity of a core barrel (although expansion occurs in some cores, so they may be slightly longer). The cored interval may, however, be shorter. Cored intervals are not necessarily adjacent but may be separated by drilled intervals. In soft sediment, the drill string may be "washed ahead," keeping the core barrel in place but not recovering sediment, by pumping water down the pipe at high pressure to wash the sediment out of the way of the bit and up the annulus between the drill pipe and the wall of the hole. If, however, thin, hard-rock layers are present, it is possible to get inadvertent partial sampling of these resistant layers within the washed interval.

Cores taken from a hole are numbered serially from the top of the hole downward. Maximum full recovery for a single core is 9.7 m of sediment or rock in a plastic liner (6.6-cm inner diameter), plus about a 0.2-m-long sample (without a plastic liner) in a core catcher (CC). The core catcher, a device at the bottom of the core barrel, prevents the core from sliding out when the barrel is being retrieved from the hole. A portion of the core catcher is given directly to the paleontologists for dating and its volume is not entered into the core log.

The sediment core, which is in the plastic liner, is then laid out on the catwalk and cut into 1.5-m-long sections, which are numbered serially from the top of the sediment core (Fig. 1); the routine for handling hard rocks is described in the section on basement rocks and ice-rafted dropstones (this chapter). When full recovery is obtained, the sections are numbered from 1 through 7, the last section being shorter than 1.5 m. For sediments and sedimentary rocks, the core-catcher sample is placed below the last section and is treated as a separate section. For igneous and metamorphic rocks, material recovered in the core catcher is included at the bottom of the last section.

When recovery is less than 100%, whether or not the recovered material is contiguous, the recovered sediment is placed at the top of the cored interval, and the 1.5-m-long sections are numbered serially, starting with Section 1 at the top. There are as many sections as needed to accommodate the length of the core recovered (Fig. 1); for example, 3 m of core sample in a plastic liner will be divided into two 1.5-m-long sections. Sections are cut starting at the top of the recovered sediment, and the last section may be shorter than the normal 1.5-m length. If, after the core has been split, fragments that are separated by a void appear to have been contiguous *in situ*, a note is made in the description of the section. All voids, whether natural or artificial, are curatorially preserved.

Samples are designated by distances in centimeters from the top of each section to the top and bottom of the sample interval in that section. A full identification number for a sample consists of the following information: (1) leg, (2) site, (3) hole, (4) core number and type, (5) section, and (6) interval in centimeters. For example, the sample identification number "113-689A-6H-3, 98-100 cm" indicates that a sample was taken between 98 and 100 cm from the top of Section 3 of hydraulic piston core 6, from the first hole drilled at Site 689 during Leg 113. A sample from the core catcher of this core might be designated "113-689A-6H, CC, 8-9 cm."

The depth below the seafloor from which a sample numbered "113-689A-6H-3, 98-100 cm" was collected is the sum of the depth to the top of the cored interval for Core 6H (40.6 m) plus the 3 m included in Sections 1 and 2 (each 1.5 m long) plus the 98 cm below the top of Section 3. The sample in question is therefore located at 44.58 meters below seafloor (mbsf) which, in principle, is the sample subseafloor depth (sample requests should refer to a specific interval within a core section, rather than to the depth in meters below seafloor). Note that this assignment of the subseafloor depth is of course an arbitrary convention; in the case of less than 100% recovery, the sample could have come from any depth within the cored interval.

Core Handling

As soon as a core was retrieved on deck, a sample was taken from the core catcher and brought to the paleontological laboratory for an initial assessment of the age of the sample.

Next, the core was placed on the long horizontal rack on the catwalk, and gas samples were taken from some cores by piercing the core liner and withdrawing gas into a vacuum-tube sampler. Voids within the core were sought as sites for the gas sampling. Some of the gas samples were stored for shore-based study, but others were analyzed immediately as part of the shipboard safety and pollution-prevention program. The core was then marked into section lengths; each section was labeled, and the core cut into sections. Interstitial water (IW) and organic geochemistry (OG) whole-round samples were then taken from designated cores. Each section was sealed at the top and bottom with a plastic cap, blue to identify the top of a section and clear

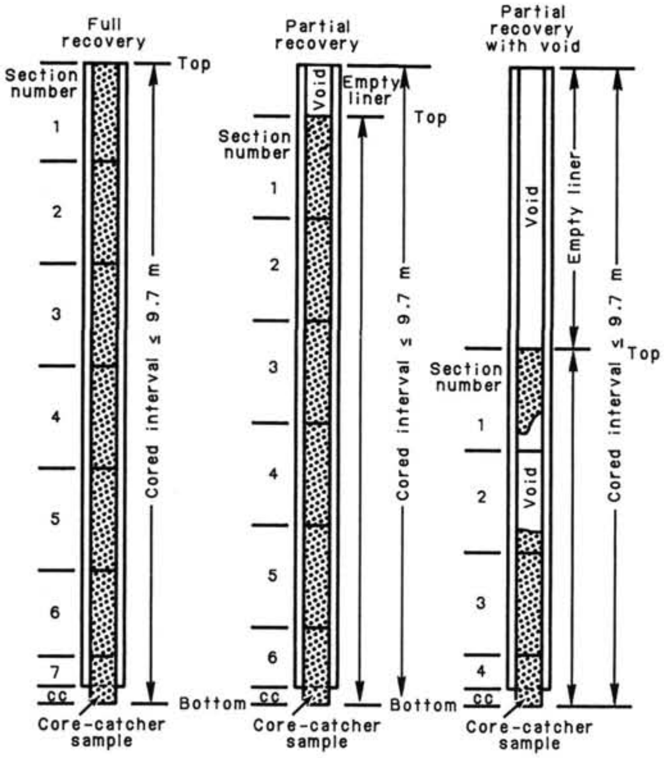

Figure 1. Examples of numbered core sections.

for the bottom. A yellow cap was placed on section ends from which a whole-round core sample had been removed. Red end-caps were placed on the removed whole-round sections. The caps were usually attached to the liner by coating the end of the liner and the inside rim of the end cap with acetone.

The cores were then carried into the laboratory, and the complete identification was engraved on each section. The length of core in each section and the core-catcher sample was measured to the nearest centimeter; this information was logged into the shipboard core-log data-base program.

The whole-round sections were then run through the gamma-ray attenuation porosity evaluation (GRAPE) device for estimating bulk density and porosity (see "Physical Properties" section, this chapter; Boyce, 1976) and the *P*-Wave Logger (PWL). Thermal conductivity measurements were made occasionally on the unsplit cores. For these, the cores were first stored for 4 hr, to ensure thermal equilibrium with the laboratory.

Cores of relatively soft material were split lengthwise into *work* and *archive* halves. The cores were split from top to bottom with a wire, a band saw, or a diamond saw depending upon the degree of induration. In soft sediments, split with a wire, some smearing of material can occur, with younger material transported downcore on the split face of each section. Scientists should be aware that the very near-surface part of the split core may be contaminated.

The work half was sampled for both shipboard and shore-based laboratory studies. Each sample was logged in the sampling computer program by location and by the name of the investigator receiving the sample. Records of all samples are kept by the ODP Curator at Texas A&M University. The samples were sealed in plastic vials or bags and labeled with a computer-printed label. Samples were routinely taken for shipboard measurement of compressional sonic velocity by the Hamilton Frame method, of bulk density and water content, and of percent calcium carbonate (coulometer). Discrete samples were also taken for measurement of natural remanent magnetization (see "Paleomagnetics" section, this chapter). Many of these data are reported in the site chapters.

The color, texture, structure, physical disturbance, and composition of each archive half were described visually. Smear slides were made from samples taken from the archive half. Thin sections of sediments were occasionally made from samples from the working half. The archive half of each core was then photographed with both black-and-white print and color slide film. At designated intervals close-up black and white photographs were taken to illustrate a particular feature and are included in the site chapters.

Both halves were then put into labeled plastic tubes, sealed, and transferred to cold-storage space aboard the drilling vessel. Samples and whole core sections collected for organic geochemistry studies were frozen immediately on board and kept frozen. With the exception of frozen sections dedicated to geochemical analysis, Leg 113 cores were transferred from the ship in the Falkland Islands and flown to Houston. From there they were transported via refrigerated vans to cold storage at the Ocean Drilling Program (ODP) East Coast Repository at Lamont-Doherty Geological Observatory, Palisades, New York. The interstitial water (IW) and organic geochemistry (OG) samples are stored at the Ocean Drilling Program Gulf Coast Repository at Texas A&M University, College Station, Texas.

SEDIMENT CORE-DESCRIPTION FORMS ("BARREL SHEETS")

The core-description forms (Fig. 2), or "barrel sheets," summarize the data obtained during the shipboard analysis of each core. The following discussion explains the ODP conventions used in compiling data for each part of the Core Description Form and the exceptions to these procedures adopted by the Leg 113 scientists.

Core Designation

Cores are designated using leg, site, hole, and core number and type (see "Numbering of Sites, Holes, Cores, and Samples" discussion above). In addition, the cored interval is specified in terms of meters below sea level (mbsl) and meters below sea floor (mbsf). On Leg 113, these depths were based on the drill-pipe measurement, as reported by the SEDCO coring technician and the ODP operations superintendent.

Age Data

Microfossil abundances, preservation, and zone assignment, as determined by shipboard paleontologists, appear on the core-description form under the heading "Biostratigraphic Zone/Fossil Character." Blank columns indicate that the assemblage was not looked for in that particular case. The geologic age determined from the paleontological and/or paleomagnetic results appears in the "Time-Rock Unit" column. Detailed information on the zonations and terms used to report abundance and preservation appears in the "Biostratigraphy" section (this chapter).

Paleomagnetic, Physical Properties, and Chemical Data

Columns are provided on the core-description form to record the paleomagnetic results, location of physical properties samples, (bulk density, γ; velocity, v; undrained shear strength, r; porosity, ϕ; and thermal conductivity, To) and chemical data (percentage $CaCO_3$, determined by coulometric analysis). Additional information on shipboard procedures for collecting these types of data appear in the "Paleomagnetics," "Physical Properties," and "Inorganic Geochemistry" sections (this chapter).

Graphic Lithology Column

The lithology of the recovered material is represented on the core-description forms by a single symbol or by a group of two

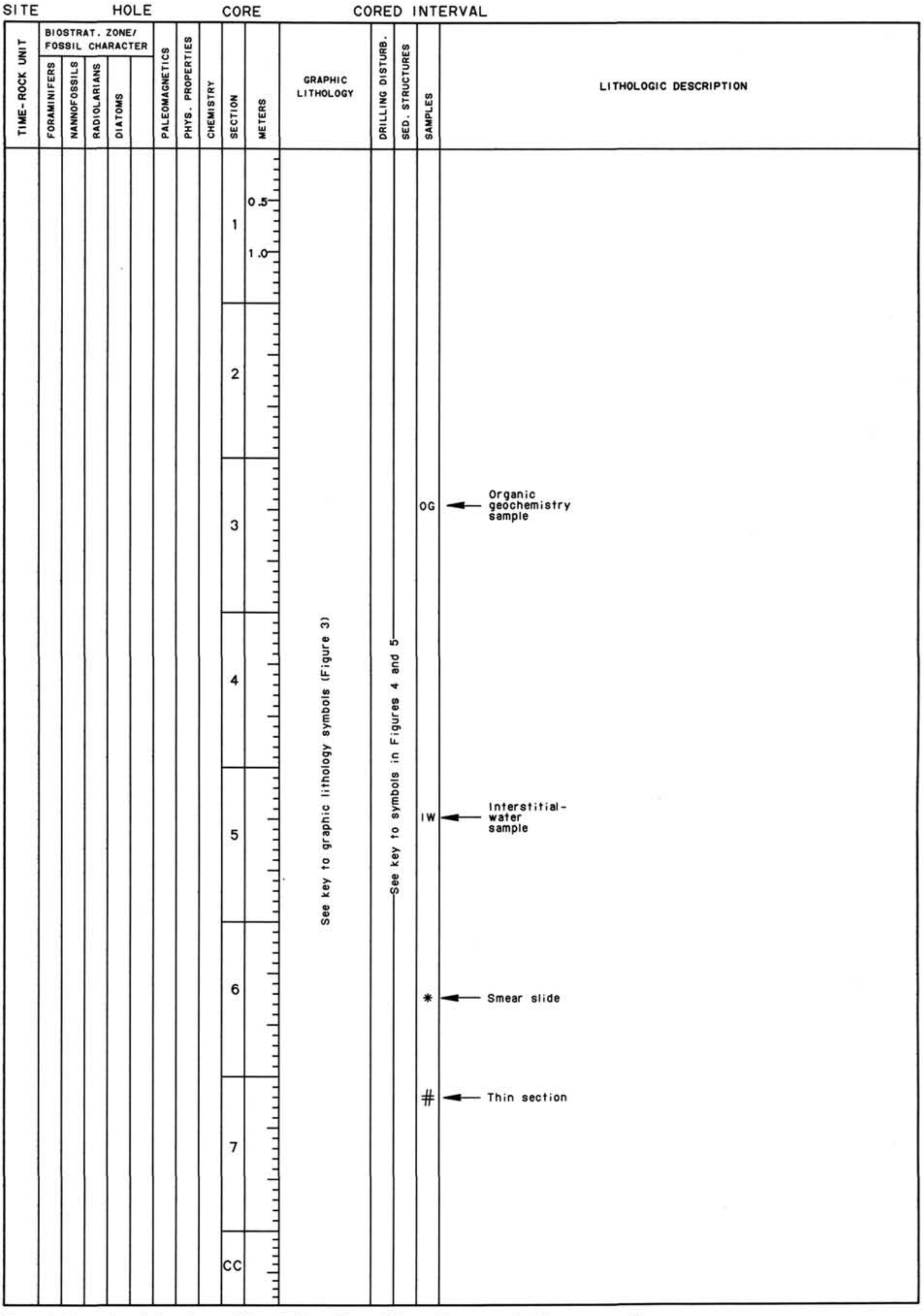

Figure 2. Core-description forms ("barrel sheets") used for sediments and sedimentary rocks.

or more symbols (Fig. 3) in the column titled "Graphic Lithology." Modifications and additions made to the graphic lithology representation scheme recommended by the JOIDES Sedimentary Petrology and Physical Properties Panel (SP^4) are discussed in the "Lithostratigraphy" section (this chapter). The symbols in a group correspond to end-members of sediment constituents, such as nannofossil ooze or radiolarian ooze. For sediments that are mixtures of siliciclastic and biogenic components, the symbol for the minor constituent at the top of the core is on the left side of the column, with larger constituents progressively to the right. The abundance of any component approximately equals the percentage width of the graphic column that its symbol occupies. For example, the left 20% of the column may have a diatom ooze symbol and the right 80% may have a clay symbol, indicating sediment composed of 20% diatoms and 80% clay. Where different types of sediment are thinly interbedded, the graphic lithology symbols are separated by a solid vertical line while dashed vertical lines are used to refer to a mixed assemblage of major components within the particular sediment type.

Drilling Disturbance

The coring technique, which uses a 25-cm-diameter bit with a 6-cm diameter core opening, can result in extreme disturbance of the recovered core material. The "Drilling Disturbance" column on the core-description form uses the symbols in Figure 4 to indicate the following disturbance categories for soft and firm sediments:

1. Slightly deformed: Bedding contacts are slightly bent.
2. Moderately deformed: Bedding contacts have undergone extreme bowing.
3. Highly deformed: bedding is completely disturbed and may show diapiric or flow structures.
4. Soupy: Intervals are water saturated and have lost all aspects of original bedding and continuity.

The following categories describe the degree of fracturing in sedimentary, igneous, and metamorphic rocks:

1. Slightly fragmented: Core pieces are in place and contain very little drilling slurry or breccia.
2. Moderately fragmented: Core pieces are in place or partly displaced, but original orientation is preserved or recognizable. Drilling slurry may surround fragments.
3. Highly fragmented: Pieces are from the interval cored and probably in correct stratigraphic sequence (although they may not represent the entire section), but original orientation is totally lost.
4. Drilling breccia: Core pieces have completely lost their original orientation and stratigraphic position and may be completely mixed with drilling slurry.

Sedimentary Structures

The location and types of sedimentary structures in a core are shown by graphic symbols in the "Sedimentary Structures" column in the core description form (Fig. 2). Figure 5 gives the key for these symbols. It should be noted, however, that it may be extremely difficult to distinguish between natural structures and structures created by the coring process.

Color

Colors of the recovered material were determined by comparison with Munsell soil color charts immediately after the cores were split and while they were still wet. Information on the core colors is given in the text of the "Lithologic Description" on the core-description forms (Fig. 2). In addition to the standard Munsell colors, when cores were very white, they were called very white 10YR 8/0 and 2.5Y 8/0.

Samples

The position of samples taken from each core for shipboard analysis is indicated in the "Samples" column on the core-description form. An asterisk (*) indicates the location of smear slide samples, a number symbol (#) indicates the location of thin-section samples (basement rocks only). The symbols IW, OG, HS, and PP designate whole-round interstitial water, organic geochemistry, headspace, and physical properties samples, respectively.

Although not indicated in the "Samples" column, locations of samples for routine coulometer (calcium carbonate) analyses are indicated by a dot in the "Chemistry" column; positions of samples for routine physical properties analyses are indicated by a dot in the "Physical Properties" column.

Shipboard paleontologists usually base their age determinations on core-catcher samples, although additional samples from other parts of the core may be examined when required. Location of additional samples is indicated by the location of the abundance and preservation symbol in the biostratigraphy columns.

Lithologic Description—Text

The lithologic description which appears on each core-description form consists of two parts: (1) a heading that lists, in order of abundance, all of the major lithologies observed in the core (as determined using the sediment classification system; see "Sediment Classification" discussion below), followed by a description of the color and sedimentary structures, and (2) a description of minor lithologies observed in the cores, including data on color, occurrence in the core, and any other significant features. Information about rock clasts and bioturbation follow.

Smear Slide Summary

A table summarizing data from smear slides appears on each core-description form. The section and interval from which the sample was taken is noted, and whether the sample represents a dominant (D) or minor (M) lithology in the core is indicated. The percentage of all identified components (totaling 100%) is listed. As explained in the following text, these data are used to classify the recovered material.

SEDIMENT CLASSIFICATION

The classification system used during Leg 113 was a modification of that devised by the Sedimentary Petrology and Physical Properties Panel (SP^4) which was adapted by the JOIDES Planning Committee in March 1974. The modifications incorporated here are based on those adopted during Leg 101 (Austin, Schlager, Palmer, et al., 1986), Leg 105 (Srivastava, Arthur, Clement, et al., 1987), and Leg 108 (Shipboard Scientific Party, 1988) to classify sediments solely on the basis of composition, texture, and induration. These data were primarily determined on board ship by (1) microscopic observation of smear slides and thin sections, (2) visual observation of cores using a hand lens and binocular microscope, and (3) unaided visual observation. Calcium carbonate content was estimated in smear slides and by using the coulometric analyses. Other geologic features determined were color, sedimentary structures, and firmness. Textural criteria are most important for terrigenous sediments, whereas composition becomes more significant in categorizing pelagic sediments. As in all classifications, however, the divisions between certain categories are somewhat arbitrary.

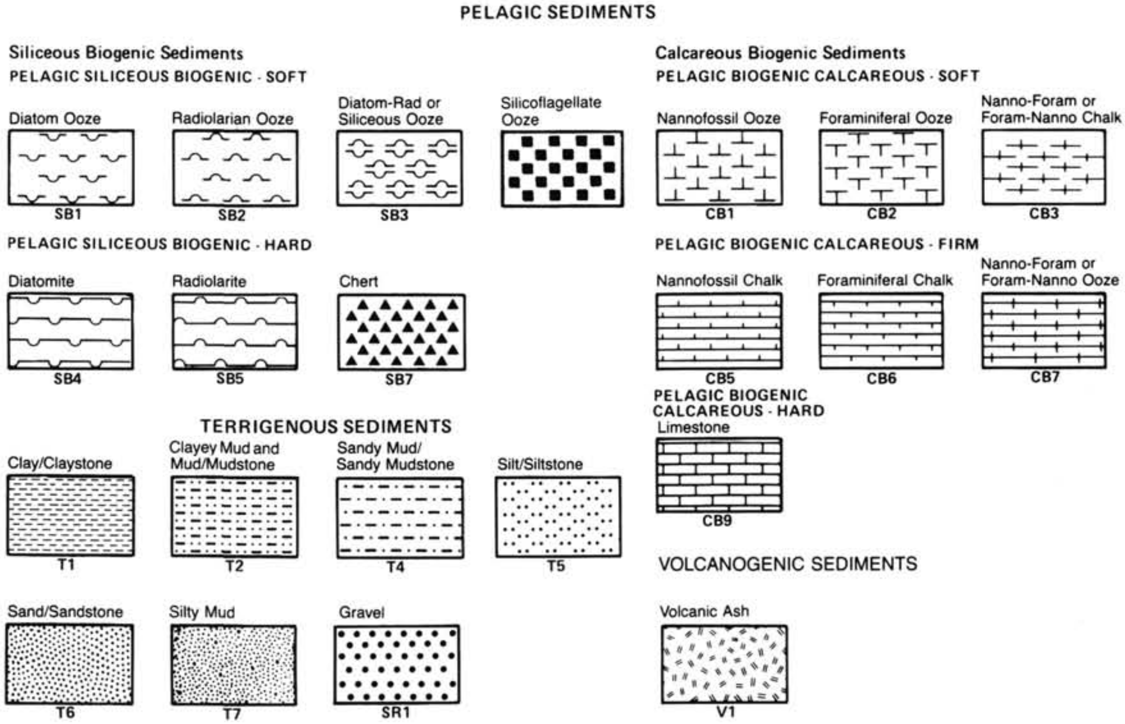

Figure 3. Key to lithologic symbols used in "Graphic Lithology" column on core-description forms (see Fig. 2).

Firmness

Determination of induration is very subjective. The criteria of Gealy et al. (1971) were used for calcareous deposits having more than 50% calcium carbonate; subjective estimates of behavior in core cutting or, more commonly, the "fingernail test" were used for transitional calcareous sediments of less than 50% calcium carbonate, biogenic siliceous sediment, pelagic clay, and terrigenous sediment.

We used three classes of firmness for calcareous sediments (Gealy et al., 1971):

1. Soft: Sediments that have little strength and are readily deformed under the fingernail or broad blade of the spatula are termed ooze.
2. Firm: Partly lithified ooze or friable limestone is called chalk. Chalks are readily deformed under the fingernail or the edge of a spatula blade.
3. Hard: The term limestone is restricted to nonfriable cemented rock.

We used only two classes of firmness for transitional calcareous and noncalcareous sediments:

1. Soft: Sediment core can be split with a wire cutter or can readily be deformed under the fingernail. Soft biogenic siliceous sediments are termed ooze, soft terrigenous sediment, and transitional calcareous and siliceous biogenic sediments are termed sand, silt, clay, or mud.
2. Hard: Sediment core must be cut with a band saw or diamond saw and cannot be easily deformed under the fingernail.

If the material consists of biogenic siliceous material and if the particular microfossil can be identified, it is termed diatomite or radiolarite. If microfossil identification is not possible and the material is lustrous with conchoidal fractures, it is termed chert. If the material consists of more than 50% siliciclastic sediment, the suffix -stone is added to the soft-sediment name (e.g., sandstone, siltstone, claystone, mudstone).

General Rules of Classification

Every sample of sediment is assigned a main name that defines its sediment type (e.g., ooze, silt, mud), a major modifier(s) that describes the composition and/or texture of grains that are present in abundance between 20%-30% and 100%, and a minor modifier(s) that describes the compositions and/or textures of grains that are present in abundances between 30% and 50% (biogenic in siliciclastic), 20%-50% (biogenic in biogenic) and 20%-50% (siliciclastic in siliciclastic). Grains that are present in abundances between 0% and 10% are considered insignificant and are not included in this classification, unless their presence implies something important about the depositional environment, in which case an additional modifier with the suffix -rich is applied.

The minor modifiers are always listed first in the string of terms that describe a sample, and are attached to the suffix -bearing which distinguishes them from major modifiers. When two or more minor modifiers are employed, they are listed in order of increasing abundance. The major modifiers are always

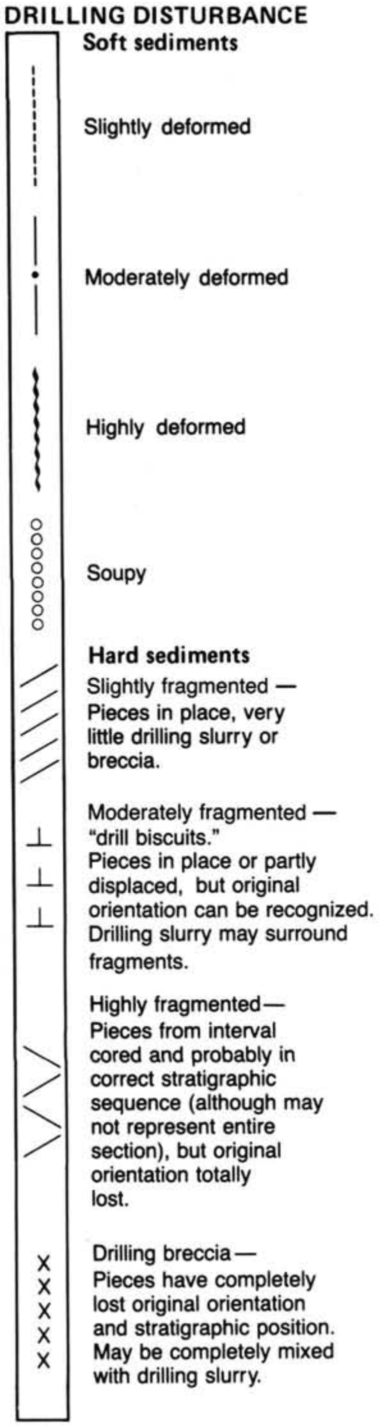

Figure 4. Drilling disturbance symbols used on Leg 113 core-description forms.

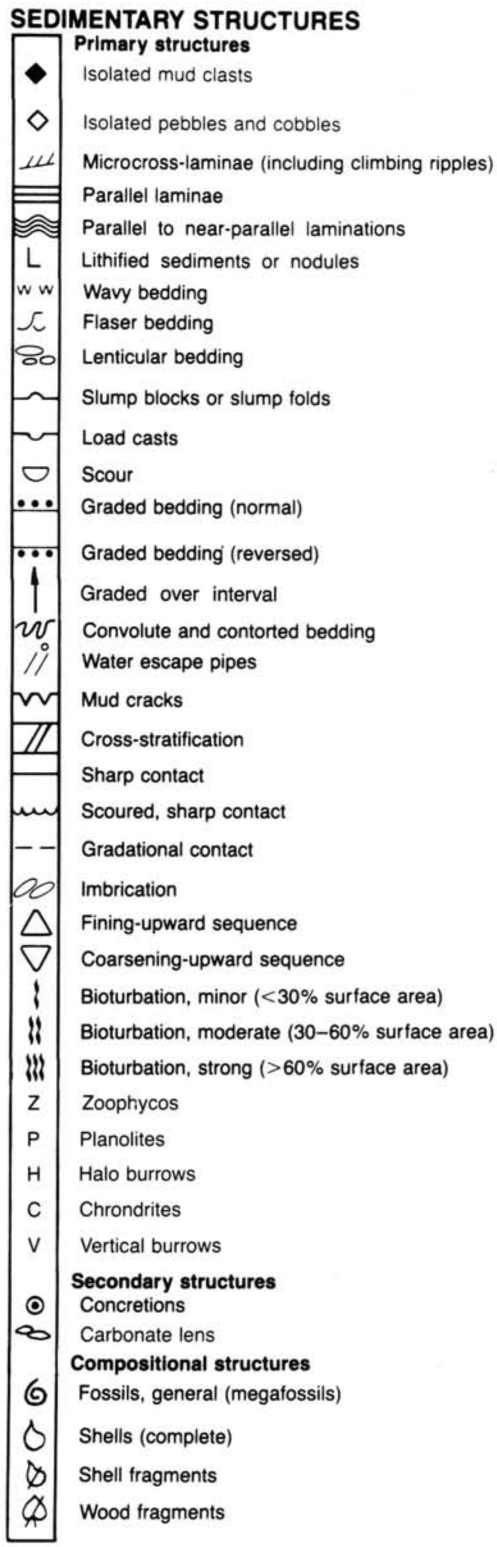

Figure 5. Sedimentary structure symbols for sediments and sedimentary rocks.

listed second in the string of terms that describes a sample, and are also listed in order of increasing abundance. The main name is the last term in the string.

The types of main names and modifiers that are employed in this classification scheme differ between the three basic sediment types (Table 1, Fig. 6), and are described in succeeding sections. The classifications are designed for marine data originating principally from on-board visual examination of smear slides using a petrographic microscope. The estimates of component and size abundance are by area on the slide and may differ somewhat from more accurate analyses of grain size, carbonate content, and mineralogy. From past experience, quantitative estimates of distinctive minor components are accurate to within 1%–2%, but for major constituents accuracy is only ± 10%.

Table 1. Summary of nomenclature of basic sediment types.

Minor modifiers	Major modifiers	Main name
	Siliciclastic sediments	
1. composition of minor siliciclastic grains 2. composition of minor biogenic grains, in order of abundance if more than two microfossil groups are present	1. composition of major siliciclastic grains 2. composition of minor biogenic grains	1. texture of terrigenous grains (sand, silt, etc.) 2. texture of volcaniclastic grains (ash, lapilli, etc.)
	Siliceous biogenic sediments	
Minor modifiers	Major modifiers	Main name
1. composition of minor biogenic grains 2. texture of minor siliciclastic grains	1. composition of major biogenic grains 2. texture of major siliciclastic grains	1. ooze 2. radiolarite 3. diatomite 4. porcellanite 5. chert
	Calcareous biogenic grains	
Minor modifiers	Major modifiers	Main name
1. composition of minor biogenic grains 2. composition of minor siliciclastic grains	1. composition of major biogenic grains 2. composition of major siliciclastic grains	1. ooze 2. chalk 3. limestone

Basic Sediment Types: Definitions

Three basic sediment types are defined on the basis of variations in the relative proportions of siliciclastic, siliceous biogenic, and carbonate biogenic grains: siliciclastic sediments, siliceous biogenic sediments, and calcareous biogenic sediments.

Siliciclastic Sediments

Siliciclastic sediments are composed of greater than 50% terrigenous and volcaniclastic grains (i.e., rock and mineral fragments) and less than 50% calcareous and siliceous biogenic grains.

The main name for a siliciclastic sediment describes the texture of the siliciclastic grains and its degree of consolidation. The Wentworth (1922) grain-size scale (Fig. 7) is used to define the textural class-names for siliciclastic sediments that contain greater amounts of terrigenous grains than volcaniclastic grains. When terrigenous sediments are hard or indurated, the word "stone" is applied to the textural group; e.g., claystone, mudstone, siltstone.

When more than 70% of the sediments are terrigenous the textural classification follows the triangular diagram shown in Figure 8. A single-component sediment class (i.e., end-members such as sand, silt, or clay) occurs where the dominant component exceeds 80%.

Where no one component exceeds 80%, the sediment is called mud. Within the mud category, the modifier depends upon the dominant grain size (sandy mud, silty mud, and clayey mud).

The scheme for the siliciclastic sediments (Fig. 8) is modified where a fourth component is present. The term gravel applies to sediment where >80% of the clasts are coarser than sand (fig. 9). If gravel constitutes 50%–80%, gravel is modified by such terms as muddy, sandy, calcareous. If gravel forms 50%–25%, the sediment name is modified by the term gravelly; and if 10%–25% gravel, the sediment name is modified by gravel-bearing. Isolated stones (<10%) do not affect the sediment name, but are noted separately in the description and in the sedimentary structures column. A pyroclastic term is applied to sediment where a pyroclastic component is present. The pyroclastic term applied depends on the degree of size and consolidation according to the textural scheme of Wentworth and Williams (1932). The textural groups are (1) volcanic breccia (>32 mm in size) (2) volcanic lapilli (4–32 mm in size) and (3) volcanic ash, tuff if indurated (less than 4 mm in size). The term is further modified depending upon the percentage of pyroclastic component.

The major and minor modifiers for a siliciclastic sediment describe the compositions of the siliciclastic grains as well as the compositions of accessory biogenic grains. The compositions of terrigenous grains can be described by terms such as "quartz," "feldspar," "glauconite," or "lithic." All compositional modifiers are followed by the suffix "-bearing" when the grain component is present in minor (10%–25%) amounts.

If the total siliciclastic component is between 50% and 70%, the sediment assumes a nonbiogenic sediment name (Figs. 6, 8), for example MUD, with appropriate modifier if identifiable, e.g. silty mud. SAND, SILT, and CLAY (with or without modifiers) may be substituted for mud. In cases where the biogenic component is between 30% and 50% an additional biogenic major modifier is used, e.g., diatom clayey mud (Fig. 6).

In a similar fashion, if the total biogenic component exceeds 10%, but is less than 30%, then the appropriate name(s) is used as modifiers (e.g., if calcareous nannofossils = 12%, clay = 40%, and silt = 48%, the sediment is designated a "nannofossil-bearing silty mud"; or if calcareous nannofossils = 6%, diatoms = 8%, clay = 56%, and silt = 30%, the appropriate sediment name is "nannofossil- and diatom-bearing clayey mud").

Siliceous Biogenic Sediments

Siliceous biogenic sediments are composed of less than 50% siliciclastic grains and greater than 50% biogenic grains, but contain greater proportions of siliceous biogenic grains than calcareous biogenic grains (Fig. 6). The major and minor modifiers for a siliceous biogenic sediment describe the compositions of the siliceous biogenic grains, as well as the compositions of accessory calcareous biogenic grains and the textures of accessory siliciclastic grains. The compositions of siliceous biogenic grains can be described by the terms "radiolarian," "diatom," "silicoflagellate," and "siliceous" (for unidentifiable siliceous biogenic debris), followed by the suffix "-bearing" when the component is present in minor (10%–25%) amounts. The compositions of accessory calcareous grains are described by terms that are discussed below; the textures of accessory terrigenous grains are described by terms that are discussed in the previous section. For example if a sediment contained 8% siliciclastic sediment, 20% nannofossils, 35% radiolarians, and 37% diatoms, it would be called nannofossil-bearing radiolarian diatom ooze.

Calcareous Biogenic Sediments

Calcareous biogenic sediments are composed of less than 50% siliciclastic grains and greater than 50% biogenic grains, but contain greater proportions of calcareous biogenic grains than siliceous biogenic grains (Fig. 6). The major and minor modifiers for a calcareous biogenic sediment describe the compositions of calcareous biogenic grains, as well as the compositions of accessory siliceous biogenic grains and the textures of accessory siliciclastic grains. For example, when 25%–50% of an ooze consists of nonbiogenic components, the term clayey, sandy, silty, or muddy is used as a modifier. When 10%–25% of an ooze consists of nonbiogenic components, the term clay-, sand-, silt-, or mud-bearing is used as a modifier.

The compositions of calcareous biogenic grains are described by the terms "foraminifer," "nannofossil," or "carbonate" (for unidentifiable carbonate fragments), followed by the suffix "-bearing" when the grain-components are present in minor

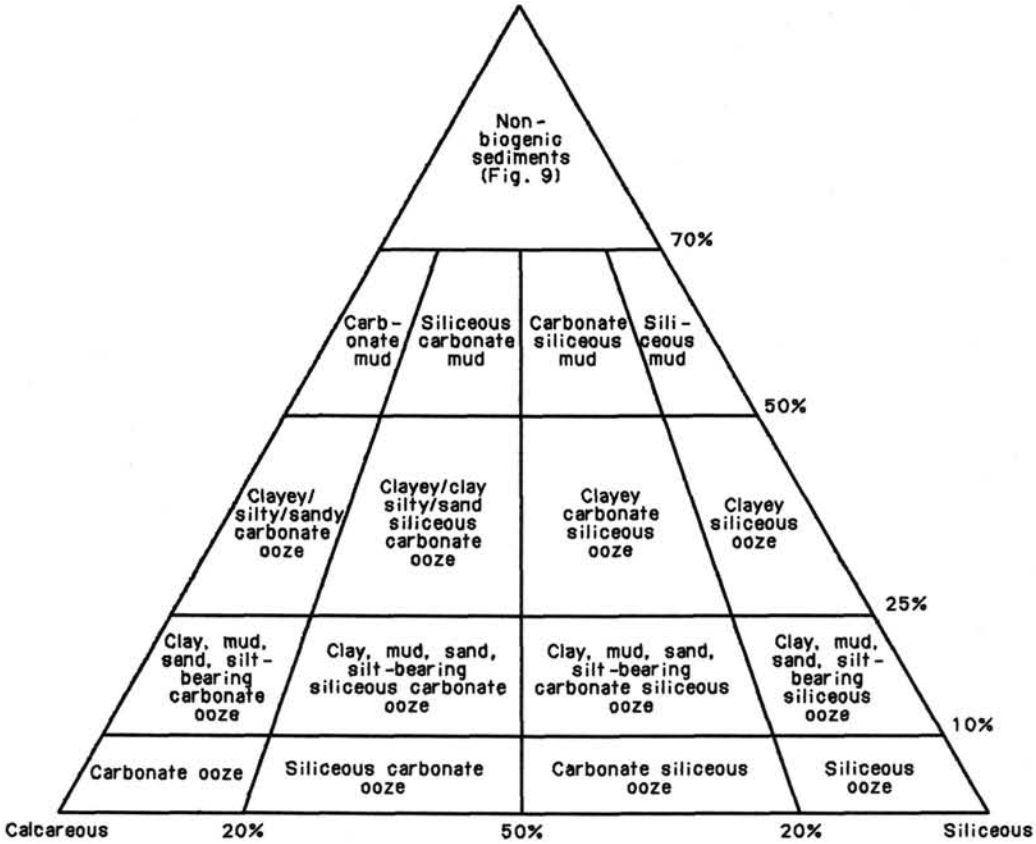

Figure 6. Compositional classification for biogenic marine sediments, with a nonbiogenic third component.

(10%–25%) amounts. The compositions of siliceous biogenic grains and the textures of siliciclastic grains are described by the terms discussed above. For example if a sediment contained 9% foraminifers, 15% siliciclastic sediments in the mud size range, 16% diatoms, and 60% nannofossils, the sediment would be called a mud- and diatom-bearing nannofossil ooze.

CLAY MINERALOGY

The purpose of this study is to recognize the major variations that occurred in the paleoenvironments as expressed by the changing nature and abundance of clay minerals, using a sampling interval of one per 1–3 cores.

Methodology

The samples were deflocculated using Calgon (sodium hexametaphosphate) solution and homogenized. The clay fraction (<2 μm) was separated and washed repeatedly using a centrifuge. The clay residue was then deposited onto glass slides and dried in an oven. Three separate X-ray analyses were run on each of the samples, from 2° to 32°2Θ at scan-speed of 1°2Θ/min, using Cu radiation, a Ni filter, and a monochromator. These were (1) on a natural slide, (2) on a slide saturated with ethylene glycol, and (3) on a slide heated to 550°C for 1 hr. Results are characterized into six classes, depending upon the abundances of the clay minerals.

BASEMENT ROCKS

Core Description

Petrological investigations (hand specimen and petrography) were carried out on board on igneous basement rocks recovered from Site 690, and on igneous and metamorphic rocks occurring as ice-rafted "dropstones." Textural description of igneous and metamorphic rocks follows the guidelines established by Jackson (1970), Bates and Jackson (1980), and Tomkeieff (1983). Descriptions of individual minerals (name, color, habit, etc.) follow Deer, Howie, and Zussmann (1978) and Kerr (1977).

Rock Classification

Rock classification was based on mineralogy and geochemistry (major and trace elements). Both XRF and XRD analyses were utilized on board. Basalts were classified using the ternary diagram of Pearce and Cann (1973). For a detailed description of instruments and their capabilities, see Austin, Schlager, Palmer, et al. (1986).

Analytical Techniques

Major and trace element analyses were carried out on board on eight whole-rock samples. Sample preparation procedures and operating conditions of the on-board XRF system (ARL 8420) are described in detail (Becker, Sakai, Merrill, et al., 1988).

Major elements were determined on fused glass beads to reduce matrix effects, and the trace elements determined on pressed powder pellets. Contamination of W, Co, and Ta results from grinding the sample in a tungsten carbide vessel, but samples were not analyzed for these elements.

Petrographic description of dropstones follows Kerr (1977), Williams et al. (1981), and Craig and Vaughan (1981).

Plagioclase composition is determined by the Michele-Levy method (Kerr, 1977). All thin sections prepared on board are polished, in order to distinguish opaque minerals, and for microprobe studies at a later date.

MILLIMETERS		µm	PHI (Ø)	WENTWORTH SIZE CLASS	
			-20		
	4096		-12	Boulder (-8 to -12 Ø)	
	1024		-10		
	256		-8		
	64		-6	Cobble (-6 to -8 Ø)	
	16		-4	Pebble (-2 to -6 Ø)	GRAVEL
	4		-2		
	3.36		-1.75		
	2.83		-1.5	Granule	
	2.38		-1.25		
	2.00		-1.0		
	1.68		-0.75		
	1.41		-0.5	Very coarse sand	
	1.19		-0.25		
	1.00		0.0		
	0.84		0.25		
	0.71		0.5	Coarse sand	
	0.59		0.75		
1/2	0.50	500	1.0		
	0.42	420	1.25		
	0.35	350	1.5	Medium sand	SAND
	0.30	300	1.75		
1/4	0.25	250	2.0		
	0.210	210	2.25		
	0.177	177	2.5	Fine sand	
	0.149	149	2.75		
1/8	0.125	125	3.0		
	0.105	105	3.25		
	0.088	88	3.5	Very fine sand	
	0.074	74	3.75		
1/16	0.0625	63	4.0		
	0.053	53	4.25		
	0.044	44	4.5	Coarse silt	
	0.037	37	4.75		
1/32	0.031	31	5.0		
1/64	0.0156	15.6	6.0	Medium silt	
1/128	0.0078	7.8	7.0	Fine silt	
1/256	0.0039	3.9	8.0	Very fine silt	MUD
	0.0020	2.0	9.0		
	0.00098	0.98	10.0	Clay	
	0.00049	0.49	11.0		
	0.00024	0.24	12.0		
	0.00012	0.12	13.0		
	0.00006	0.06	14.0		

Figure 7. Grain-size categories used for classification of terrigenous sediments (from Wentworth, 1922).

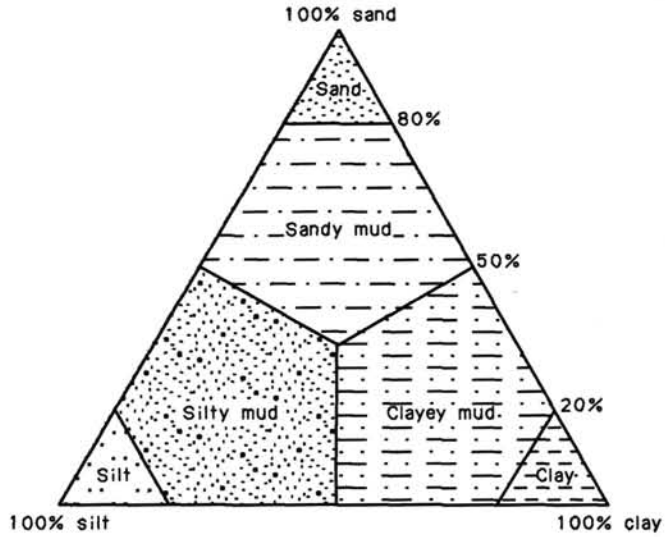

Figure 8. Compositional classification for sediments with a greater than 70% terrigeneous component. Additional modifiers would be applied for the 10%–30% biogenic component. The biogenic modifiers would carry the suffix -bearing.

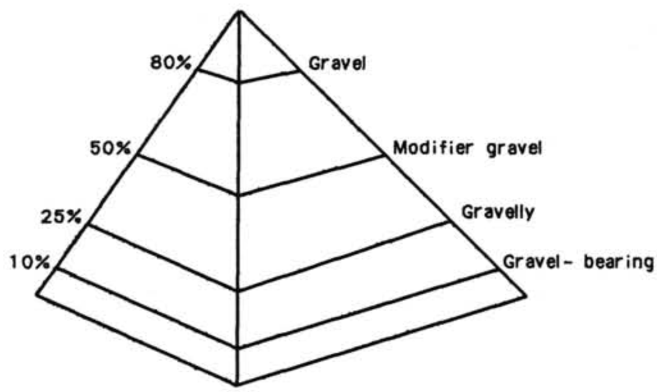

Figure 9. Classification scheme where fourth component is gravel. Base of tetrahedron is the classification scheme for nonbiogenic clastic sediments given in Figure 8.

BIOSTRATIGRAPHY

Planktonic Foraminifer Zonation

The only existing Neogene planktonic foraminiferal biostratigraphic zonal scheme available for the Antarctic region of the Southern Ocean is that of Kennett (1970), and Keany and Kennett (1972) for the Quaternary. Subantarctic planktonic foraminiferal zonations are not applicable to the Neogene in Leg 113 sites. Nonetheless, chronostratigraphic ages are estimated for Neogene intervals in Leg 113 sites using known biostratigraphic ranges from cool temperate to Subantarctic latitudes (Jenkins, 1975; Vella and Watkins, 1980; Srinivasan and Kennett, 1981; Jenkins and Srinivasan, 1985). In such instances the age estimates are given in broad geochronologic terms (i.e., early Miocene). With sufficient magnetostratigraphic control it may be possible in the future to better calibrate the Neogene planktonic foraminiferal biostratigraphy in the Antarctic.

Similarity exists between Leg 113 Paleogene faunas and those described from other high-southern-latitude DSDP sites, including, for example, the Paleogene of Leg 28 sites (Kaneps, 1975) and the Paleogene (Tjalsma, 1977; Krasheninnikov and Basov, 1983a) and Cretaceous of the Falkland Plateau (Sliter, 1977; Krasheninnikov and Basov, 1983b). However, no formal planktonic foraminiferal zonation was proposed for those sites. Subsequent paleontologic investigations of South Atlantic DSDP sites (e.g., Boersma and Premoli-Silva, 1983; Boersma, et al., 1987) have attempted to place South Atlantic sequences into a standardized zonal scheme using the "P" zonations set forth by Berggren (1969) and Blow (1979). In the middle to high latitudes of the South Atlantic however, most of the zonal index species for the "P" Zones do not occur or their ranges are abbreviated. Such zonal assignments are therefore based on ranges of secondary index species and/or assemblage composition.

In the present treatment of Leg 113 sequences, we do not make formal zonal assignments but approximate biostratigraphic levels by comparing assemblage composition in Leg 113 intervals with those described from low-latitude sequences where biostratigraphic schemes do exist. In the Paleogene, we follow Boersma et al. (1987) and approximate biostratigraphic assignments using "P" Zone designations. In the absence of primary index species an (*) is used to denote a zonal equivalence. These biostratigraphic approximations are aided in some instances by the occurrence of datum levels which we believe to be useful chronostratigraphic markers (i.e., the first evolutionary appearance of *Pseudohastigerina* at the Paleocene/Eocene boundary). An attempt was made here post-cruise to apply existing Cretaceous zonations.

The Upper Cretaceous Maud Rise sites can be correlated with the upper Maestrichtian *Abathomphalus mayaroensis* Zone of Caron (1985), but no other zones are applicable.

Benthic Foraminifers Zonation

There are no benthic foraminiferal time zonations for the Antarctic region. We compared our data with the zonation of Tjalsma and Lohmann (1983) for the Paleocene-Eocene of the South Atlantic Ocean, but ranges of many benthic foraminiferal species at Sites 689 and 690 are different from the ranges as described by these authors.

Several depth zonations for Recent benthic foraminifers in the Antarctic region have been proposed, but there are many differences from one area to another, and no universally valid depth zonation can be used. Data from Sites 695 and 696 suggest that depth ranges of species in the Scotia Sea area in the Pliocene were considerably different from Recent ranges as described by Echols (1971).

Calcareous Nannofossil Zonation

The Cenozoic calcareous nannofossil zonations used in these reports is that of Okada and Bukry (1980) and Martini (1971) with selected modifications from Wise and Wind (1977) and Wise (1983). The Mesozoic zonation is derived from Wise and Wind (1983) and Wise (1983), which draws on previous work in the area by Wise and Wind (1977) and Wind (1977a, b). For the middle Campanian-Maestrichtian interval, the zonation is as follows:

Nephrolithus frequens Zone

Definition. Interval from the last appearance datum (LAD) of *Biscutum magnum* to the extinction datum of Cretaceous taxa.

Range. Upper Maestrichtian.

Reference locality. Hole 690C, 288–248 mbsf (see "Site 690" chapter, this volume).

Biscutum magnum Zone

Definition. Interval from the LAD of *Biscutum coronum* to the LAD of *Biscutum magnum*.

Range. Lower lower to middle Maestrichtian.

Biscutum coronum Zone

Definition. Interval from the LAD of *Marthasteristes furcatus* to the LAD of *Biscutum coronum*.

Range. Middle Campanian to lower lower Maestrichtian.

Wind and Wise (1983) also found the more cosmopolitan Maestrichtian zonation of Sissingh (1977) to be of use when applied to their sequence on the Falkland Plateau. For shipboard work, however, where the preservation of the Maestrichtian was not always ideal, the high-latitude zonation was considered to be the more applicable.

Diatom Zonation

Cretaceous through Pleistocene diatoms and diatom assemblages have been described from Southern Ocean sediments. For the Cretaceous and Paleogene, we note contributions by McCollum (1975), Gombos (1976, 1983), Hajos (1975, 1976), Schrader (1976), Weaver and Gombos (1981), Gombos and Ciesielski (1983) and Fenner (1984). Many of these data are summarized by Fenner (1985). Unfortunately, except for DSDP Site 274, investigated by Fenner (1984), and Harwood's (1986) study of the MSSTS (McMurdo Sound) core on the Antarctic continent (Pacific sector), most studies of high-southern-latitude Cretaceous and Paleogene diatoms have been confined to the Subantarctic and the northern part of the Antarctic zones. Thus, although we use Fenner (1984, 1985) to zone the Paleogene in Leg 113 for this volume, we may define a new zonation for Volume 113, Scientific Results.

We can make similar comments for the Neogene. Although the zonal scheme of Weaver and Gombos (1981) is used in this volume, we note some deviations from it. For example, the proposed biostratigraphic tie to the magnetostratigraphy for the interval older than the middle Pliocene is to be considered tentative (Fig. 10). Further, because we could not define some zonal boundaries, several zones have been combined. Our general comments on the existing Neogene zonations are given in the discussion on diatoms (see "Site 697" chapter, this volume). We will propose a new zonation for the Scientific Results volume.

Radiolaria Zonation

The radiolarian zonation used on Leg 113 is a preliminary one, based on a variety of datums, both published and unpublished. It is expected that additional radiolarian datums will be identified by taxonomic and stratigraphic studies planned for inclusion in the Leg 113 Proceedings, Scientific Results. It should also be noted that the calibration of the Miocene portion of the zonation is tentative, and will almost certainly be modified as additional magnetostratigraphic, isotopic, and biostratigraphic data become available. This calibration is based on Weaver and Gombos' (1981) synthesis of the diatom stratigraphy of DSDP Sites 266 and 278, Chen's (1975) radiolarian report for Site 266, and unpublished data on the radiolarian stratigraphy of Site 278 (D. B. Lazarus). The Neogene radiolarian zonation is summarized in Figure 10. It is based on earlier zonations by Hays (1965) and Chen (1975), with the following additions and deletions:

Several forms used as zonal markers by Hays and Chen occur too rarely in many Antarctic sediments to be used as more than secondary indicators. Species in this category include: *Stylatractus universus* Hays, 1965, *Saturnalis planetes* Haeckel (= *S. circularis* in Chen, 1975), and *Pterocanium charybdeum trilobum* (Müller) Lombari and Lazarus, in press (= *P. trilobum* of Hays, 1965) in the Pliocene, and *Eucyrtidium punctatum* Ehrenberg of Chen (1975) and *Calocyclas disparidens* Chen, 1975 in the Miocene.

Cycladophora golli regipileus (Chen) Lombari and Lazarus, in press and *Helotholus vema* Hays, 1965 have evolutionary first appearances which are not precisely defined, and thus the base of their respective zones (the *Lophocyrtis regipileus* Zone of Chen, and the Upsilon Zone of Hays) are difficult to identify.

The first appearance of *Antarctissa conradae* Chen, 1975—as noted by Weaver (1983)—is not very consistent, and often occurs within the range of *Cycladophora spongothorax* (Chen) Lazarus and Lombari (in press), the range of which defines Chen's *Theocalyptra bicornis spongothorax* Zone. Following Weaver's (1983) suggestion, the *A. conradae* Zone is eliminated, and Chen's *Actinomma tanyacantha* Zone is extended to run from the FAD of *A. tanyacantha* (Chen, 1975) to the FAD of *C. spongothorax*.

The LAD of *Antarctissa ewingi* Chen, 1975 is used to mark the Pliocene/Pleistocene boundary. The exact range of this species is not known, but its last common occurrence is reported by

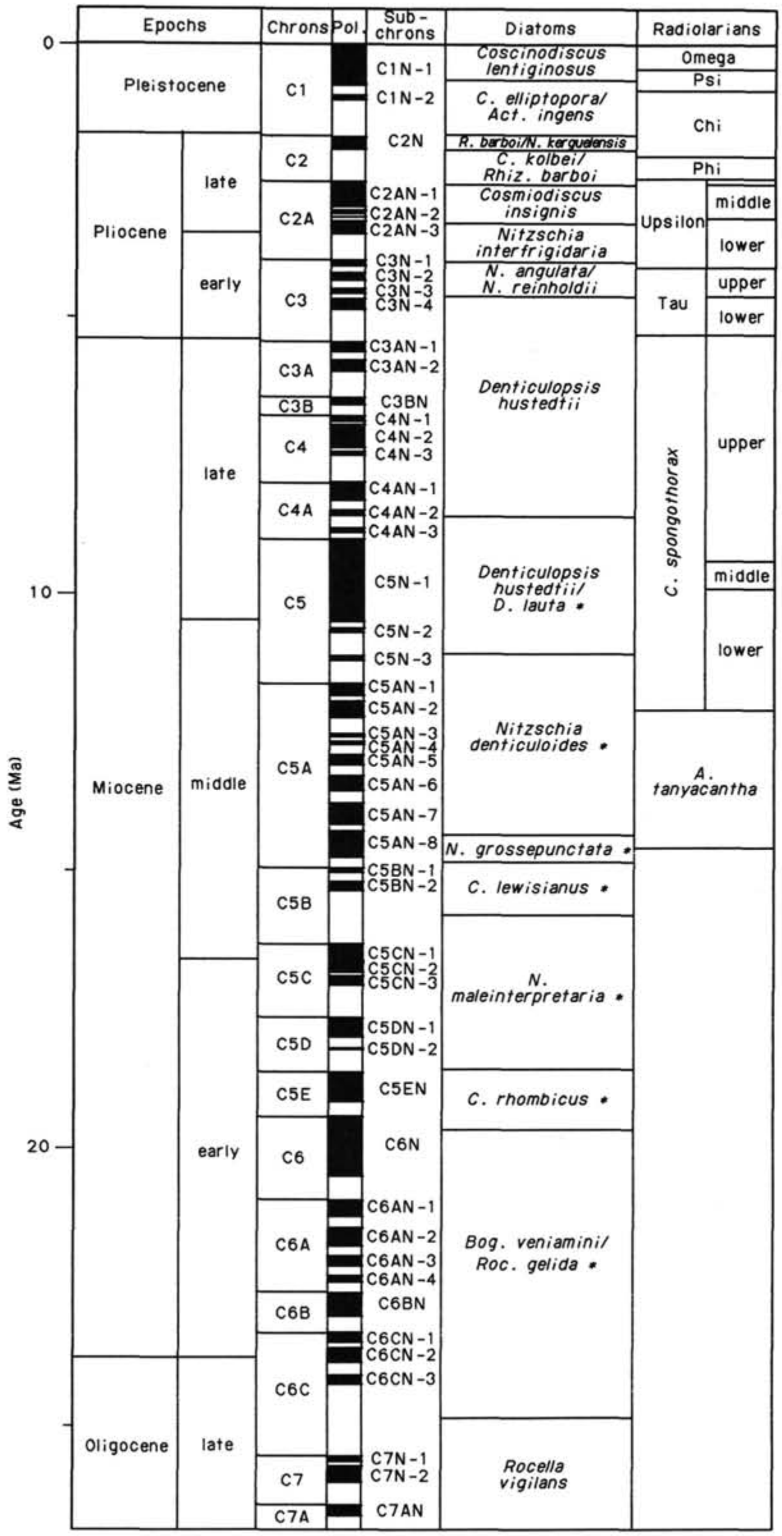

Figure 10. Geomagnetic polarity time scale of Berggren et al., (1985a, b, and c) and correlation to diatom and radiolarian biostratigraphic zones as used in ODP Leg 113, Initial Reports. Diatom zones are grouped together in some sites in the following way: *D. hustedtii/D. lauta* and *Nitzschia denticuloides* Zones; *Nitzschia grossepunctata* and *Coscinodiscus lewisianus* Zones; *N. malinterpretaria* and *Coscinodiscus rhombicus* Zones; *Bogorovia veniamini* and *Rocella gelida* Zones. Correlation of diatom zones is done according to Weaver and Gombos (1981) for the Quaternary and Pliocene (except for a refinement of the *C. insignis/N. interfrigidaria* Zone boundary. Correlation for Miocene and Paleogene zones is very tentative. Radiolarian zonation, while based on those developed by Hays (1965) and Chen (1975), has been substantially modified, as discussed in text.

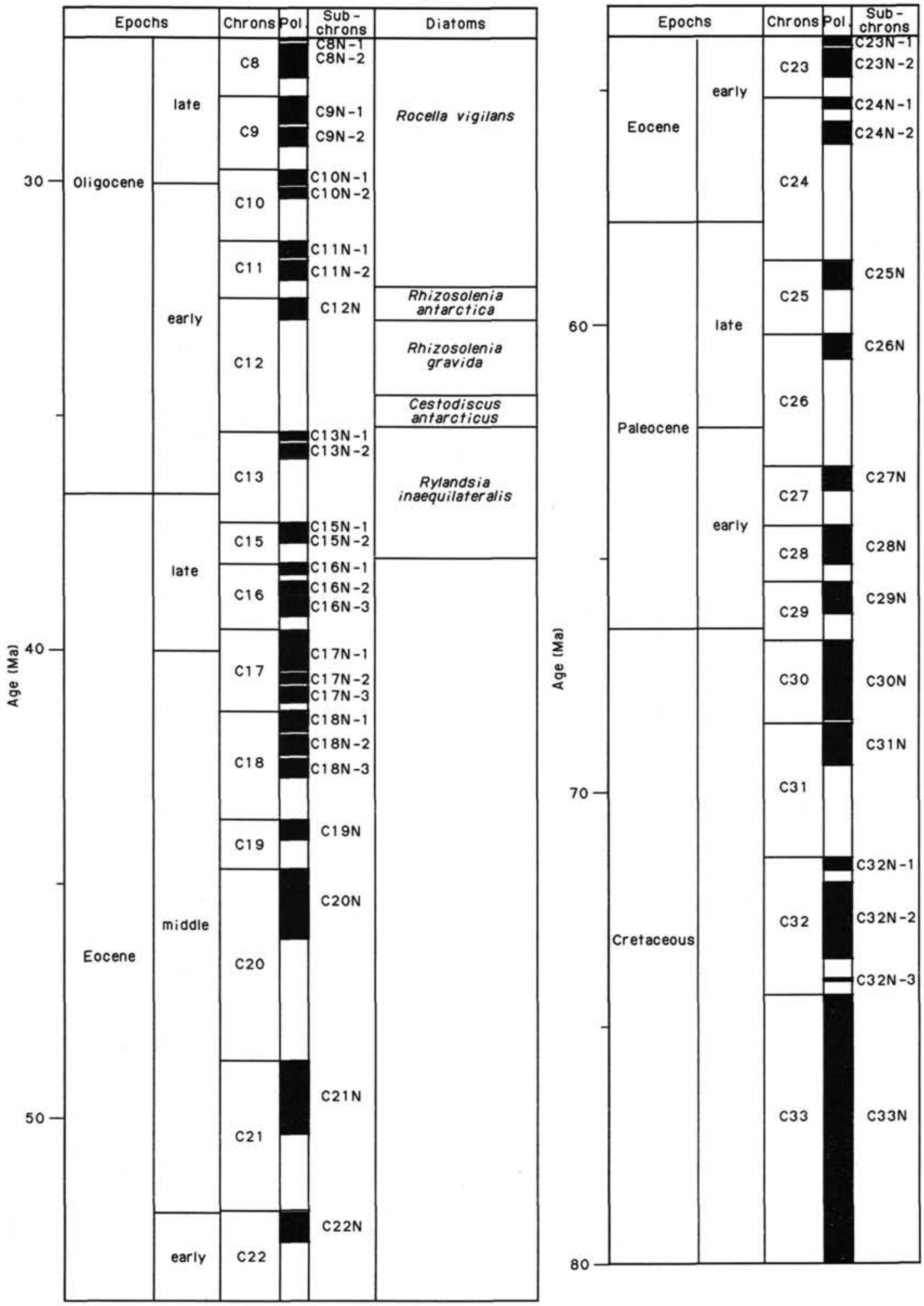

Figure 10 (continued).

Chen (1975) to be close to the Pliocene/Pleistocene boundary, and the species is consistently common to abundant throughout its stratigraphic range, unlike the species used by Hays (1965) and Chen (1975) to mark the Pleistocene.

The FAD of *Cycladophora davisiana* Ehrenberg at ~2.5 Ma appears to be a nearly global event (J. D. Hays, unpublished observations). This FAD occurs first below the LAD's of *Helotholus vema* and *Desmospyris spongiosa* (Hays, 1965; e.g., Site 695), and is used to mark the uppermost part of the Upsilon Zone.

The LAD of *Prunopyle titan* Campbell and Clark, 1944 is used to mark the boundary between the middle and lower parts of the Upsilon Zone. This datum was reported to occur within the Gauss by Hays and Opdyke (1967), although their piston cores lack a complete Gauss section, preventing a precise calibration of the datum. At DSDP Site 514, *P. titan*'s LAD is between Section 514-26, CC, and Section 514-27, CC (Weaver, 1983). Using the paleomagnetic interpretation of this site adopted by Leg 113 biostratigraphers (see discussion on diatoms, "Site 695" and "Site 697" chapters, this volume), *P. titan*'s LAD is within the lower reversal event of the Gauss (C2AR2).

The LAD of *Lychnocanium grande* Campbell and Clark, 1944 is used to subdivide the Tau Zone of Hays (1965) into upper and lower parts. This datum is reported by Hays and Opdyke (1967) to occur near the 'C' event of the Gilbert (C3N3 and 4), a calibration confirmed by reanalysis of piston cores E13-17 and E14-8, and by stratigraphic analysis of other lower Pliocene Antarctic piston cores (D. B. Lazarus, unpublished observations).

The FAD of *Eucyrtidium pseudoinflatum* Weaver, 1983 is used to separate the upper and middle parts of the *Cycladophora spongothorax* Zone, while the LAD of *Actinomma tanyacantha* is used to separate the middle and lower parts of the *Cycladophora spongothorax* Zone. Although the absolute ages of these two events are not known, they occur in the same sequence relative to each other and to the top and bottom of the *Cycladophora spongothorax* Zone, both in Leg 113 sites (e.g., Site 693) and in Pacific Antarctic DSDP Site 278 (this volume; D. B. Lazarus, unpublished observations).

No zonation has previously been proposed for pre-Neogene Antarctic radiolarians. Age estimates for Paleogene radiolarians are based on rare occurrences of low-latitude stratigraphic indicator species (Weaver, 1983; Sanfilippo et al., 1985). Cretaceous age estimates are based on stratigraphically useful taxa listed by Sanfilippo and Riedel (1985).

Silicoflagellate Zonation

The silicoflagellate zonation is based on those of Ciesielski (1975), Bukry (1975), Busen and Wise (1977), and Shaw and Ciesielski (1983).

Dinocyst Zonation

Cenozoic dinocyst zonation has been published only on middle- to high-latitude sites from the Northern Hemisphere. For this reason previously established zonal schemes may not be applicable to Leg 113 southern latitude sites. Nevertheless, the maximum stratigraphic range of dinocyst datums with reference to the published literature (Williams and Bujak, 1985) will be used to provide age estimates.

Paleogene biostratigraphy is well established for North Atlantic sites by Williams and Bujak (1977), Costa and Downie (1976, 1979), and Bujak et al. (1980). For the South Atlantic region there exists only a poor data base. Middle to late Paleocene dinocyst stratigraphy has been documented by Harris (1976; Leg 36, Falkland Plateau), as well as middle Eocene to early Oligocene correlations by Goodman and Ford (1983; Falkland Plateau). Similar assemblages have been reported from the Ross Sea region by Kemp (1975; Leg 28) and by Haskell and Wilson (1975; Leg 29) off the coast of southeastern Australia.

Cretaceous zonal schemes have been elaborated by Edgell (1964), Evans (1966), and by Morgan (1980) for Australia. A nearly complete Cretaceous zonation is published in Williams and Bujak (1985) and Helby et al. (in press). The zones, including assemblage zones, partial range zones, and Oppel zones, were based on dinoflagellate assemblages from cores and subsurface sequences. Dinoflagellate correlations with Europe and North America are poor in the lower part, but for the upper Cretaceous, dating is based on foraminifers and is regarded as good.

Spore and Pollen Grain Zonation

No pollen record younger than late Eocene/early Oligocene(?) age was recovered because of the Antarctic glaciation (Truswell, 1986). For Cretaceous and early Paleogene southern high-latitude floras, a zonation scheme (and/or magnetostratigraphy and nannofossil stratigraphy) does not exist that is correlatable to northern hemisphere floras. The known pollen assemblages of this age are found to be reworked in Oligocene to Quaternary sediments (Truswell, 1983; Truswell and Drewry, 1984).

Methods

Planktonic Foraminifers

Material for study of planktonic foraminifers was dried under heat lamps or in an oven at 35°C, soaked in water, and washed through a 63-μm sieve. Somewhat indurated samples were soaked in Calgon. Strongly indurated samples were dried in an oven at 100°C for an hour, soaked in kerosene, then heated in water and washed through a 63-μm sieve.

To identify planktonic foraminiferal species, and to estimate their abundances, dried residues were sieved at 63 μm and 150 μm and then split using a microsplitter to obtain approximately 300 specimens of each size fraction. These splits were then strewn over a picking tray divided into 40 quadrants. Taxa which were represented by several or more specimens per quadrant were considered abundant. Taxa which occurred once per quadrant were considered common, and those which occurred, on average, in every several quadrants were considered few. If a taxon was observed only once or twice per tray, it was considered rare. The abundance estimates cited for taxa occurring in both size fractions were based on estimates from the size fraction in which they were most common. All estimates are intended only as a qualitative reference for further research.

Benthic Foraminifers

Samples for study of benthic foraminifers were dried under a heat lamp or in an oven at 35°C, soaked in water and calgon, and washed through a 63-μm sieve. More indurated samples were dried in an oven for at least an hour at 100°C, soaked in kerosene for several hours, then heated in water and washed through a 63-μm sieve.

Quantitative studies of benthic foraminifers were made following the methods described by Thomas (1985). Rarefaction curves (number of species vs. number of specimens) showed that in the diverse Paleogene and older faunas at Sites 689 and 690, 250–300 specimens must be counted to obtain good representation of species. Splits were made with a microsplitter to obtain about 300 specimens of benthic foraminifers. All specimens were picked and mounted on cardboard slides. The size fraction larger than 63-μm size fraction was used in order to obtain consistent counts of cylindrical species (see Thomas, 1985).

Calcareous Nannofossils

Smear slides were prepared from raw sediment for examination of calcareous nannofossils. The overall abundance of nannofossils was estimated at a magnification of 1000X using the system proposed by Hay (1970), which is:

A = abundant (1–10 specimens per field of view);
C = common (1 specimen per 2–10 fields of view);
F = few (1 specimen per 11–100 fields of view);
R = rare (1 specimen per 101–1000 fields of view);

The state of preservation of nannofossils was designated as follows:

G = little or no evidence of overgrowth and/or etching of specimen;

M = some degree of overgrowth and/or etching, but identification generally not impaired;

P = substantial overgrowth and/or etching, identification of specimens difficult but still possible.

Diatoms

Shipboard sample preparation for diatoms follows the method described in Schrader and Gersonde (1978). Strewn slides of raw and acid-cleaned material were prepared on both 22 × 40 mm and 18-mm diameter cover glasses, and mounted on 25 × 75 mm glass slides using Hyrax or Naphrax mounting medium (r.i. = 1.65). Strewn slides were examined using a Zeiss compound microscope. At least 450 fields of view (0.5-mm diameter) were examined at 500X, with species identification confirmed when necessary at 1000X. Species were considered *abundant* when five or more were present in one field of view at 500X, *common* if two specimens were observed in one field of view, *few* if 10 specimens were observed in one horizontal traverse of the 18-mm cover glass and 20 in one traverse of the 40-mm cover glass, respectively. Species were considered as *rare* when less than one was present in a traverse of the 18-mm cover glass and two in one traverse of the 40-mm cover glass, respectively. If no diatoms were encountered in the slide, the sample was recorded as *barren*. Criteria for distinguishing whole from partial diatoms follow Schrader and Gersonde (1978).

Preservation was considered *good* if valves showed no obvious signs of dissolution. *Moderate* preservation was characterized by evidence of slight dissolution. Preservation was regarded as *poor* when only robust silicified valves were preserved, combined with extensive breakage.

Radiolaria

Standard radiolarian strewn slides were prepared from the carbonate and clay-free >63-μm residue of each sediment sample. Samples were broken down using one of two methods. For samples of biogenic ooze, ~ 10 cm^3 of sediment was broken down in 35% H_2O_2, followed by boiling in a Calgon solution. Carbonate-containing samples were treated with 10% HCl and rinsed prior to the addition of Calgon. Clay-rich samples were treated with 35% H_2O_2 and dried in a 60°C oven. Kerosene was added to the dried sediment while still warm. After soaking in kerosene for ~ 20 min, the excess was decanted, Calgon solution added, and the sample boiled for between 20 min and 2 hr. Ten percent HCl was added to the clay-free residue when needed to remove carbonate. Ultrasound was used sparingly as needed to clean difficult samples. Semiquantitative abundance estimates for selected taxa were made according to the following scale: Abundant = one or more per field of view at 100X; Common = several per long track (at 100X) of 22 × 40 mm cover slip; Few = average of about one specimen per track; Rare = only a few specimens encountered on entire slide; Present = only one specimen seen.

Silicoflagellates

Aboard ship, silicoflagellates were only examined in smear slides made from the core-catcher samples. On shore, raw samples from within the cores were treated for 2–4 hr with small amounts of 30% H_2O_2, ultrasonicated, and then treated with HCl. Samples were then centrifuged, decanted twice, and washed once before strewn slides were made. Because of the small numbers of specimens in most samples, all specimens on a slide were usually counted.

Palynology

Because of the safety restrictions on board *JOIDES Resolution*, it was impossible to use HF (normally employed to destroy silicate minerals) routinely. Therefore, the preparation technique was modified as follows: (1) treatment with HCl (10%); (2) disaggregation in a 1% solution of Calgon, (3) separation in in $ZnBr_2$ solution; (4) sieving at 20 μm.

Therefore the on-board palynological results may not represent the total palynomorph content of the sediments. Further onshore studies will be necessary to complete the palynological record. The abundance of palynomorphs per slide is estimated as follows : Rare = 1–10; Few = 10–100; Common = 100–1000; Abundant = more than 1000.

PALEOMAGNETICS

Measurements of natural remanent magnetization (NRM) were made on discrete samples using the Molspin spinner magnetometer. The magnetometer was calibrated using the short spin-time setting. Remanence measurements on sediment sample cubes were undertaken routinely on the long spin-time setting except for samples of high NRM intensity. Lithified sediments and igneous rocks were sampled using 10-cm^3 minicores drilled from segments of the working half of the core.

Limited magnetic cleaning is possible for samples whose NRM intensities are sufficiently strong to be measured reliably on the Molspin. This is achieved through alternating field (AF) demagnetization on the Schonstedt single-axis demagnetizer for each orthogonal sample axis. For most of the samples, however, determination of the primary characteristic magnetization requires identification of a stable end-point from careful progressive demagnetization. This could not be done with the time and facilities available on board ship, and such investigations are deferred to shore-based study. Our primary objective aboard ship was to provide preliminary magnetostratigraphy for each of the holes.

The measured magnetization vector can be interpreted in terms of the polarity state of the Earth's magnetic field, if the sample contains only a record of a single magnetic polarity. On the assumption that the remanent magnetization was acquired during depositional remanent magnetization (DRM) or shortly after sedimentation (post-depositional remanent magnetization, PDRM), an interpretation of polarity state can be reliably based on the inclination value alone for sediments accumulating at high latitudes. Since the vertical component of the magnetization vector is directed along the core liner, absolute horizontal orientation is not required for magnetostratigraphic purposes. Depending on the anticipated sampling interval, the accuracy of defining the boundaries of magnetozones is half the interval in length. By the assignment of magnetozones to a geomagnetic polarity time scale, the resolution of the dating method is connected to the sedimentation rate. Samples were taken at an interval of 25 cm; with an assumed sedimentation rate of 0.5–5 cm/1000 yr, age resolution lies between 50,000 and 5,000 yr.

We have adopted the geomagnetic polarity timescale (GPTS) of Berggren et al. (1985a, b, and c) modifying the chron nomenclature as shown in Figure 10. Our modification follows the scheme proposed by Tauxe et al. (1984) being correlative to the marine magnetic anomaly sequence.

Magnetic susceptibility measurements were made to monitor downhole lithological changes. The loop sensor of the Bartington Instruments type M.S.1 magnetic susceptibility meter was used to measure the susceptibility of 5-cm intervals down whole core sections. Calibration was performed using a Mn_2O_3 standard contained in a 25-cm-long cylinder. Volume susceptibility values given as downcore computer-processed output from the susceptibility meter are in units of 10^{-6} c.g.s.

ORGANIC GEOCHEMISTRY

Shipboard analytical processes comprise light hydrocarbon monitoring, heavy hydrocarbon monitoring and kerogen evaluation by Rock-Eval pyrolysis, and organic carbon and total carbon determination by combustion and coulometric means. Whole-round 25-cm-long samples were removed every third core, provided sufficient material was recovered, and frozen for shore-based organic geochemistry studies.

Light-Hydrocarbon Monitoring

Determination of the light-hydrocarbon content of sediments (methane, ethane, propane, and occasionally heavier components) is employed in the basic safety monitoring program, intended to avoid accidentally encountering accumulated gas or oil.

Vacutainers

Gases which were encountered in partings or pockets in the core upon recovery were sampled through the liner with the use of an evacuated glass vial, or "vacutainer." They were analyzed immediately by gas chromatography to evaluate the methane/ethane ratio. Values greater than 1000 suggest methane of dominantly bacterial origin which is not known to form substantial accumulations of free gas in oceanic sediments. Lower ratios are characteristic of petroleum-related gases, or advanced levels of catagenesis. Low ratios, accompanied by appropriate changes in gas concentration in the sediments, are adequate reason to terminate coring. Vacutainer data are quoted in terms of gas composition by volume, exclusive of air contamination.

Headspace Analysis

Dissolved and adsorbed light hydrocarbons are analyzed semi-quantitatively in a routine sampling program employing 10 cm^3 of fresh sediment from the first through the sixth core, and subsequently every third core. The sample, sealed in a 22-cm^3 glass vial, is heated at 70°C for 30 min. The headspace of the vial is then analyzed by a Hewlett Packard Natural Gas Analyser, requiring an additional 30 min. Data are expressed in microliters of hydrocarbon per liter of moist sediment.

Heavy Hydrocarbons and Kerogens

Kerogen and nonvolatile extractable organic matter in the sediments are partially analyzed on board using a Rock-Eval II (Girdel Inc.) instrument. Samples are dried, powdered, and weighed (100 mg) prior to analysis, detracting from the real-time capability of the analytical cycle (30 min). The data obtained usually reveal the nature of the kerogen, whether marine or terrestrial, whether or not oxidized, its level of thermal transformation or maturity, and the relative amount of potentially solvent-extractable organic matter. High levels of the latter are suggestive of the presence of migrated petroleum liquids.

Rock-Eval Data

Four analytical parameters are determined by the instrument, and these are employed in standard calculations in conjunction with sample weight and total organic carbonate (TOC) to obtain other commonly derived parameters. The observed parameters are:

S1 = (mg desorbed organic materials/g rock): the originally present adsorbed volatile organic matter, substantially heteromolecular in immature sediments, hydrocarbons in mature ones, desorbed at or below 300°C.

S2 = (mg pyrolitic organic materials/g rock): the volatile organic pyrolysis products released by kerogen cracking between 300°C and 550°C. These organic compounds are substantially oxygenated in the case of terrestrial kerogen (Type III), principally hydrocarbons in the case of marine kerogens (Type II).

S3 (mg carbon dioxide/g rock): pyrolytic carbon dioxide released in the interval 300°–390°C.

T_{max}(°C) = pyrolytic temperature at which the rate of release of products maximizes.

T_{max} is a function of maturity and kerogen type.

Other parameters are derived from the above, particularly these:

Hydrogen Index (HI = 100 × S2/TOC, mg hydrocarbons/g organic carbon): a measure of the hydrogen-richness of the kerogen, which correlates with percent elemental hydrogen.

Oxygen Index (OI = 100 × S3/TOC, mg carbon dioxide/g organic carbon): a measure of the oxygen-richness of the kerogen which correlates with percent elemental oxygen.

Production Index (PI = S1 + S2): a conventionally quoted ratio expressing the relative proportion of desorbable organics. In the context of oceanic sediments which are generally immature, PI values do not exceed 0.2 unless migrated hydrocarbons are present.

Interpretations of kerogen type are made from HI and OI values. Marine kerogens of a bacterial-algal nature (Type II) which are potential petroleum sources if not oxidized, have OI values below 50, and high values of HI (300–800). Terrestrial kerogens representing higher plant detritus (Type III) have HI values below 100, and high OI values (100–300). All indices are decreased by increasing maturity.

Organic Carbon

Two shipboard methods of determining TOC are available. Firstly, the Rock-Eval II device possesses a TOC module wherein all nonpyrolysed organic carbon is oxidized and summed with the pyrolitic carbon. The second means, a combination of a Coulometrics 5020 Total Carbon Apparatus and 5010 CO_2 Coulometer, provide total carbon and carbonate carbon. The difference is computed as organic carbon.

INORGANIC GEOCHEMISTRY

Sections (5 cm and 10 cm) of whole-round core were taken every third core. They were squeezed with a stainless steel hydraulic press at ambient temperature. Recovered water was filtered through 0.45 μm nucleopore filters which were rinsed in distilled water, soaked in distilled water for 24 hr, and then dried. Interstitial water samples were analyzed for pH, salinity, total alkalinity, dissolved calcium, magnesium, potassium, ammonia, chloride, sulfate, orthophosphate, and silicate.

The pH was measured using a combined glass electrode calibrated with NBS-buffers at pH 4.01, 6.86, and 7.41. The electrode was stored in surface sea water between measurements.

An estimate of salinity was obtained by determining the refractive index employing an AO Scientific Instruments optical refractometer. Results were read directly in ‰. It should be noted that this method was developed for oceanic waters and requires constant ionic proportions for an accurate measurement.

The total alkalinity was determined by direct potentiometric titration of 5–10 mL samples with 0.1N HCl. The endpoint was determined by extrapolation of the linear interval of the Gran function.

The concentrations of calcium and magnesium were determined titrimetrically using the method described by Gieskes (1974).

The concentration of potassium was measured employing a Dionex 2120i Ion Chromatograph (dual channel).

Ammonia and orthophosphate was determined spectrophotometrically by the methods described by Solorzano (1969) and Presley (1971), respectively.

The method used for analyzing dissolved silica (described by Mann and Giskes, 1975) is adapted from Strickland and Parsons (1968).

The concentration of chloride was determined by argentiometric titration using potassium chromate as indicator.

The concentration of sulfate was measured employing the Dionex 2120i Ion Chromatograph.

PHYSICAL PROPERTIES

Several physical properties measurement programs were carried out during coring on Leg 113. They were: (1) Index Properties—gravimetric determinations of density, porosity, and water content; (2) Vane Shear Strength—a measure of the resistance of the sediment to loads; (3) Compressional Wave Velocity—the speed of sound in the sediment; and (4) Thermal Conductivity—the ability of the sediment to transport heat out of the earth. Wherever possible, these measurements were made on the same interval of core or immediately adjacent to one another. In this manner, with a well-characterized sample set, the results of measurements at subsequent sites can be compared and conclusions drawn about the character of high-latitude sediments.

Thus the goal of the physical properties program on Leg 113, beyond aiding geophysical interpretation, was to establish the nature of the physical properties of high-latitude sediments, specifically those of the Weddell Sea, for which no physical properties data exist. In addition to the applications mentioned a new line of stratigraphic investigation called "geotechnical stratigraphy" was attempted. This approach used geotechnical parameters as stratigraphic indicators and boundary markers in an attempt to improve the resolution of the other stratigraphic studies.

Index Properties

Index properties measured during Leg 113 included water content, porosity, bulk density, and grain density. Water content is reported in two manners; (1) weight of water related to the weight of dry solids (used in text), and (2) weight of water related to the total wet sample weight. Weights were obtained using a programmed, dual ScienTech pan system with an estimated error of ± 0.03 g. Volumetric measurements were obtained by using a helium-purged Quantachrome pycnometer with an estimated error of ± 0.02 cm^3 (multiple measurements) or ± 0.05 cm^3. All index properties reported herein are corrected for salt assuming a pore water salinity of 35‰. Further details of calculations can be found in Boyce (1976). Samples were freeze-dried for a minimum of 12 hr, weighed, volume remeasured, and then split for carbonate (coulometer) and bulk mineralogy (XRD) analysis.

Bulk densities and porosities were also obtained from GRAPE scanning of whole-round core sections. All core sections from Leg 113 were logged in the GRAPE unit, from which bulk densities and porosities are computed assuming a grain density of 2.75 g/cm^3. Further details of this analytical tool are discussed by Boyce (1976).

Compressional Wave Velocity

Sonic velocities (V_p) in sediments were measured using two techniques. A continuous measurement of V_p was made through the whole core using the PWL installed next to the GRAPE source and detector. The PWL employs two 1-MHz transducers which are pressed against the side of the core liner as it passes between them on a belt-driven track. The distance between the acoustic transducers is measured by a pair of displacement transducers affixed to the measuring surfaces. Traveltime is calculated from the full waveform signal, using an automatic peak picking routine on the dedicated microcomputer, and corrections for the thickness and delay time of the liner are employed to arrive at the velocity of the material within the liner. As with the GRAPE scan, this method is most effective when core sections are totally filled with undisturbed material, such as during APC operations. Core disturbance, core biscuiting, and undersized core (or voids) severely degrade the data.

On more consolidated sediments, discrete velocity determinations were made on samples removed from the core, generally with one measurement from every section. In intervals of severe core disturbance, measurements were made only on competent core biscuits or not at all. The Hamilton Frame Velocimeter was used for the determinations and the procedures followed were generally those of Boyce (1976) with the addition of an automatic timing circuit provided by ODP. Lucite and aluminum standards were run prior to drilling, and the timing mechanism was found to be accurate to 1% when adequate signal strength was achieved. Signal strength criteria were employed during actual measurements to determine whether sample disturbance in the core precluded accurate velocity measurements.

Shear Strength

The undrained shear strength of the sediment was determined using the ODP motorized miniature vane shear device following the procedures of Boyce (1976). The ODP device has a variable rate motor which was set to 56°/min. The instrument measures the torque and strain at the vane shaft using a torque transducer and potentiometer, respectively. Output for torque and strain are recorded in volts. The vane size used for all measurements has a 1:1 blade ratio with a dimension of 1.27 cm.

The shear strength reported is the peak strength determined from the torque vs. strain plot. In addition to the peak strength, the residual strength was determined from the torque vs. strain curve as the postpeak value in tests where the failure was not dominated by cracking of the sample. Additional strength measurements were made with a 1.27-cm vane attached to a torque wrench.

Thermal conductivity

The thermal conductivity of sediment samples of Leg 113 were measured following the methods of Von Herzen and Maxwell (1959) using the needle-probe technique. The probes were controlled by a Thermocon-85 unit manufactured by Woods Hole Oceanographic Institution. The measurements were made after the core was at room temperature. The needle-probe was inserted through a drilled hole in the core liner so that the probes were oriented perpendicular to the core axis. If there was not sufficient time to allow the cores to come to thermal equilibrium, because of the necessity of splitting the cores to examine for gas, etc., "oblique" and "end" insert methods were used on the split cores.

The standard sample was tested at the beginning and end of each site. The pre-site test showed good results. Measured thermal conductivity values showed a good coincidence in comparison with a recommended standard value within a standard deviation. However, the result of post-site test always showed 15% to 20% higher. At this stage, we could not determine that, when and how this phenomenon (drift and/or tear) occurred.

DOWNHOLE MEASUREMENTS

The purpose of downhole logging is the direct determination of *in-situ* formation properties adjacent to the borehole wall. Geophysical log data are recorded using probes which are lowered on the end of a wireline through the drill pipe and into the previously drilled borehole. Only the gamma ray, caliper, resistivity, and sonic tools (seismic stratigraphy combination) were run on Leg 113.

Because of problems on previous ODP legs with sediment bridges (sediments closing into the hole and preventing the logging tool from passing), a special Sidewall Entry Sub (SES) was deployed. The SES attaches to the drill pipe to allow the cable to be run outside the pipe; it is installed with the open end of the pipe above the top of the interval to be logged, and tools are then run into the hole as usual with the cable passing through the SES. Open-hole logs are recorded as pipe is simultaneously pulled back up and hole is exposed. This significantly reduces the amount of logging time and improves the recovery of logs in soft sediments.

Log Types

The seismic stratigraphic combination includes the long spacing sonic (LSS), dual induction (DIL), gamma ray (GR), and caliper (MCD) tools. Its value to seismic stratigraphy is that it directly measures compressional wave sound velocity and indirectly measures the two variables that most often affect velocity: porosity and clay mineral percentage.

Data Acquisition and Computer Analysis

The computer on the Schlumberger recording sled is designed primarily for data acquisition and display of the primary log curves. However, it can run a few analyses to obtain a "quick look" at computed values. In general however, the Schlumberger computer is used only for data acquisition and to produce clean data tapes and log playbacks for the shipboard party.

The MASSCOMP logging computer in the Downhole Measurements Lab runs a log analysis package called Terralog, which is an interactive system consisting of a large number of log manipulation and plot options. Preliminary log interpretation as well as display in standard log format can be carried out on board; more detailed analysis is done at the LDGO Log Analysis Center.

Heat flow

Detection of *in-situ* hole temperatures and measurement of the thermal conductivity of sediments recovered from the bottom of the hole at adjacent levels were used to measure heat flow. Methods for the thermal conductivity are described in the "Physical Properties" section (this chapter). Usually, the thermal conductivity values measured in the laboratory were corrected to *in-situ* temperature and pressure conditions following Ratcliffe (1960). However, these effects never exceeded 3% (Morin and Von Herzen, 1986). In this leg, the drift and/or tear problem, as mentioned in the "Physical Properties" section, is more serious. Therefore, the temperature and the pressure effects have not been corrected.

In-situ temperatures were measured by the Von Herzen APC (advanced piston corer) tool (Horai and Von Herzen, 1986) and Uyeda T-probe (Yokota et al., 1980). The APC tool was inserted into the cutting shoe of the APC to record temperature where the sediment is undisturbed by drilling. Two instruments of this type were available (#1 and #5) on board the *JOIDES Resolution*. According to the APC tool, usually, the sediment temperature was recorded for at least 10 min. The temperature record contains a disturbance due to frictional heating associated with penetration of the APC into the sediment. The equilibrium formation temperature was extrapolated from the decay curve of the disturbance according to the theory of Horai and Von Herzen (1986).

The Uyeda T-probe can be housed in the pressure case of the Barnes pore-water sampler. The temperature sensor is installed in a probe at the nose of the sampler. During pore-water sampling, the sediment temperature was recorded at 1-min intervals together with the APC tool.

REFERENCES

Abbott, W. H., 1974. Temporal and spatial distribution of Pleistocene diatoms from the southeast Indian Ocean. *Nova Hedwigia*, 15:291–346.

Austin, J. A., Jr., Schlager, W., Palmer, A., et al. 1986. *Proc. ODP, Init. Repts.*, 101: College Station, TX (Ocean Drilling Program).

Barron, J.A., 1985. Miocene to Holocene planktonic diatoms. *In* Bolli, H.M., Saunders, J. B., Perch-Nielsen (Eds.), *Plankton Stratigraphy*: Cambridge (Cambridge Univ. Press), 763–809.

Bates, R. L., and Jackson, J. A., 1980. *Glossary of Geology*. Falls Church, VA (American Geological Inst.).

Becker, K., Sakai, H., Merrill, R., et al., 1988. *Proc. ODP, Init. Repts.*, 111: College Station, TX (Ocean Drilling Program).

Berggren, W. A., 1969. Cenozoic chronostratigraphy, planktonic foraminiferal zonation and the radiometric time scale: Nature, 224: 1072–1075.

Berggren, W. A., Kent, D. V., Flynn, J. J., and Van Couvering, J. A., 1985a. Cenozoic geochronology. *Geol. Soc. Am. Bull.*, 96:1407–1418.

Berggren, W. A., Kent, D. V., and Van Couvering, J. A., 1985b. The Neogene: Part 2 Neogene geochronology and chronostratigraphy. *In* Snelling, N. J. (Ed.), *Geochronology of the Geological Record*, Geol. Soc. London, Mem. 10:211–260.

Berggren, W. A., Kent, D. V., and Flynn, J. J., 1985c. Paleogene geochronology and chronostratigraphy. *In* Snelling, N. J. (Ed.), *Geochronology of the Geological Record*, Geol. Soc. London, Mem. 10: 141–195.

Blow, W. H., 1979. *The Cainozoic Globigerinida*. Leiden (E. J. Brill).

Boyce, R. E., 1976. Definitions and laboratory techniques of compressional sound velocity parameter and water content, wet bulk density, and porosity parameters by gravimetric and gamma ray attenuation techniques. *In* Schlanger, S. O., Jackson, E. D., et al., *Init. Repts. DSDP*, 33: Washington (U.S. Govt. Printing Office), 931–955.

Brown, S., and Downie, C., 1985. Dinoflagellate cyst biostratigraphy of Late Paleocene and Early Eocene sediments from Holes 552, 553A, and 555, Leg 81, Deep Sea Drilling Program (Rockall Plateau). *In* Roberts, D. G., Schnitker, D., et al., *Init. Repts. DSDP*, 81: Washington (U.S. Govt. Printing Office), 565–579.

Bujak, J. P., 1984. Cenozoic dinoflagellate cysts and acritarchs from the Bering Sea and northern North Pacific, Deep Sea Drilling Project, Leg 19. *Micropaleontology*, 30:180–212.

Bujak, J. P., Downie, D., Eaton, G. L., and Williams, G. L., 1980. Dinoflagellate cysts and acritarchs from the Eocene of southern England. *Spec. Pap. in Paleontol.*, 24:1–100.

Bukry, D., 1975. Silicoflagellate and coccolith stratigraphy, Deep Sea Drilling Project, Leg 29. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 845–872.

Busen, K. E., and Wise, S. W., Jr., 1977. Silicoflagellate stratigraphy, Deep Sea Drilling Project, Leg 36. *In* Barker, P., Dalziel, I.W.D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 697–743.

Campbell, A. S., and B. L., Clark. 1944. Miocene radiolarian faunas from Southern California. *Geol. Soc. Am. Spec. Pap.*, 51:1–76 p.

Caron, M., 1985. Cretaceous planktic foraminifera. *In* Bolli, H. et al., (Eds.) *Plankton Stratigraphy*, Cambridge (Cambridge Univ. Press), 17–86.

Carter, D.J.T., 1980. *Echo-sounding correction tables (NP139).* Taunton, U.K. (Br. Ministry Defense, Hydrogr. Dept.).

Chen, P. H. 1975. Antarctic radiolaria. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 407–474.

Ciesielski, P. F., 1975. Biostratigraphy and paleoecology of Neogene and Oligocene silicoflagellates from cores recovered during Antarctic Leg 28, Deep Sea Drilling Project. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 625–691.

———, 1983. The Neogene diatom biostratigraphy DSDP Leg 71, subantarctic sediments. *In* Ludwig, W. J., Krasheninikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 635–665.

Costa, L., and Downie, C., 1976. The distribution of the dinoflagellate Wetzeliella in the Palaeogene of north-west Europe. *Paleontology*, 19:591–614.

———, 1979. Cenozoic cyst stratigraphy of Sites 403 to 406, Rockall Plateau, Leg 48, Deep Sea Drilling Project. *In* Montadert, L., Roberts, D. G., et al., *Init. Repts. DSDP*, 48: Washington (U.S. Govt. Printing Office), 513-529.

Craig, J. R., and Vaughan, D. J. 1981. *Ore Microscopy and Ore Petrography*: New York (Wiley).

Deer, W. A., Howie, R. A., and Zussman, J., 1978. *An Introduction to the Rock Forming Minerals*: New York (Longman Group Ltd.).

Donahue, J. G., 1970. Diatoms as Quaternary biostratigraphic and paleoclimatic indicators in high latitudes of the Pacific Ocean [Ph.D. dissert.]. Columbia Univ.

Echols, R. J., 1971. Distribution of Foraminifera in sediments of the Scotia Sea area, Antactic waters. Antarctic Research Series. *Am. Geophys. Union*, 15:93-168.

Edgell, H. S., 1964. The correlative value of microplankton in the Cretaceous of the Perth Basin, WA. Reports of the Department of Mines of Western Australia for 1963, 100-5.

Edwards, L. E., 1985. Miocene dinocysts from Deep Sea Drilling Project Leg 81, Rockall Plateau, Eastern North Atlantic Ocean. *In* Roberts, D.G., Schnitker, D., et al., *Init. Repts. DSDP*, 81: Washington (U.S. Govt. Printing Office), 581-594.

Evans, P. R., 1966. Mesozoic stratigraphic palynology in Australia. *Australasian Oil and Gas Journal*, 12:58-63.

Fenner, J., 1984. Eocene-Oligocene planktonic diatom stratigraphy in the low latitudes and the high southern latitudes. *Micropaleontology*, 30:319-342.

———, 1985. Late Cretaceous to Oligocene planktonic diatoms. *In* Bolli, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy*: Cambridge (Cambridge Univ. Press), 713-762.

Gealy, E. L., Winterer, E. L., and Moberly, R. M., Jr., 1971. Methods, conventions, and general observations. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7; Pt. 1: Washington (U.S. Govt. Printing Office), 9-26.

Gieskes, J. M., 1974. Interstitial water studies. Leg 25. *In* Simpson, E.S.W., Schlich, R., Gieskes, J. M., et al., *Init. Repts. DSDP*, 25: Washington (U.S. Govt. Printing Office), 361-394.

Gombos, A. M., 1976. Paleogene and Neogene diatoms from the Falkland Plateau and Malvinas Outer Basin: Leg 36, Deep Sea Drilling Project. *In* Barker, P., Dalziel, I.W.D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 575-690.

———, 1983. Late Paleocene diatoms in the Cape Basin. *In* Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office), 495-511.

Gombos, A. M., and Ciesielski, P. F., 1983. Late Eocene to early Miocene diatoms from the southwest Atlantic. *In* Ludwig, W. J., Krashneninikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 583-684.

Goodman, D. K., and Ford, L. N., Jr., 1983. Preliminary dinoflagellate biostratigraphy for the Middle Eocene to Lower Oligocene from Southwest Atlantic Ocean. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 859-877.

Hajos, M., 1975. Late Cretaceous archaeomonadaceae, diatomaceae and silicoflagellatae in southwestern Pacific sediments. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 913-1009.

———, 1976. Upper Eocene and lower Oligocene diatomaceae, archaeomonadaceae, and silicoflagellates in southwestern Pacific sediments. *In* Hollister, C. D., Craddock, C. et al., *Init. Repts. DSDP*, 35: Washington (U.S. Govt. Printing Office), 817-884.

Harland, R., 1979. Dinoflagellate biostratigraphy of Neogene and Quaternary sediment at Holes 400/400A in the Bay of Biscay (Deep Sea Drilling Project Leg 48). *In* Montadert, L., Roberts, D. G., et al., *Init. Repts. DSDP*, 48: Washington (U.S. Govt. Printing Office), 531-545.

Harris, W. K., 1976. Palynology of cores from Deep Sea Drilling Sites 327, 328, and 330, South Atlantic Ocean. *In* Barker, P., Dalziel, I.W.D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 761-815.

Harwood, D. M., 1986. Diatoms. *In* Barrett, P. J. (Ed.), *Antarctic Cenozoic history from the MSSTS-1 drillhole McMurdo Sound*: Wellington, 69-107.

Haskell, T. R., and Wilson, G. L., 1975. Palynology of Sites 280-284, DSDP Leg 29, off southeastern Australia and western New Zealand. *In* Kennett, J. P., Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 731-741.

Hay, W. W., 1970. Calcareous nannofossils from cores recovered on Leg 4. *In* Bader, R. G., Gerard, R. D., et al., *Init. Repts. DSDP*, 4: Washington (U.S. Govt. Printing Office), 455-501.

Hays, J. D., 1965. Radiolaria and late Tertiary and Quaternary history of Antarctic seas. *In* Llano, G. A. (Ed.), *Biology of the Antarctic Seas II*, Am. Geophys. Union, Antarct. Res. Ser., 5:125-184.

Hays, J. D., and Opdyke, N. D., 1967. Antarctic radiolaria, magnetic reversals, and climatic change. *Science*, 158:1001-1011.

Hinz, K., 1981. A hypothesis on terrestrial catastrophes: wedges of very thick oceanward dipping layers beneath passive margins: their origin and paleoenvironmental significance. *Geol. Jahrb.*, E(22):328.

Hinz, K., Dartmann, H. J., and Hanish, J., 1984. Structural elements of the Norwegian continental margin. *Geol. Jahrb.*, A(75):193-211.

Horai, K., and Von Herzen, R. P., 1986. Measurement of heat flow on Leg 86 of the Deep Sea Drilling Project. *In* Heath, G. R., Burckle, L. H., et al., *Init. Repts. DSDP*, 86: Washington (U.S. Govt. Printing Office), 759-777.

Jackson, K. C., 1970. *Textbook of Lithology*: New York (McGraw-Hill).

Jenkins, D. G., 1975. Cenozoic planktonic foraminiferal biostratigraphy of the southwestern Pacific and Tasman Sea, D.S.D.P. Leg 29. *In* Kennett, J. P., and Houtz, R. E., et al., *Init. Repts. DSDP*, 29: Washington (U.S. Govt. Printing Office), 795-834.

Jenkins, D. G., and Srinivasan, M. S., 1986. Cenozoic planktonic foraminifers of the southwest Pacific. *In* Kennett, J. P., and von der Borch, C. C., et al., *Init Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office), 795-834.

Kaneps, A. G., 1975. Cenozoic planktonic foraminifera from Antarctic deep-sea sediments, Leg 28, DSDP. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Printing Office), 573-584.

Kemp, E. M., 1975. Palynology of Leg 28 drill sites, Deep Sea Drilling Project. *In* Hayes, D. E., Frakers, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 599-623.

Kennett, J. P., 1970. Pleistocene paleoclimates and foraminiferal biostratigraphy in subantarctic deep-sea cores. *Deep-Sea Res.*, 17:125-140.

Kerr, Paul F., 1977. *Optical Mineralogy*: New York (McGraw-Hill).

Krasheninnikov, V. A., and Basov, I. A., 1983a. Cenozoic planktonic foraminifers of the Falkland Plateau and Argentine Basin, Deep Sea Drilling Project Leg 71. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 821-858.

———, 1983b. Stratigraphy of Cretaceous sediments of the Falkland Plateau based on planktonic foraminifers, Deep Sea Drilling Project, Leg 71. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Printing Office), 789-820.

Lombari, G., and Lazarus, D., (in press). Neogene *Cycladophorid* radiolarians from North Atlantic, Pacific and Antarctic sediments. *Micropaleontology.*

Mann, R., and Gieskes, J. M., 1975. Interstitial water studies, Leg 28. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 805-814.

Manum, S. B., 1976. Dinocysts in Tertiary Norwegian-Greenland Sea sediments (Deep Sea Drilling Project Leg 28), with observations on palynomorphs and palynodebris in relation to environment. *In* Talwani, M., Udintsev, G., et al., *Init. Repts. DSDP*, 38: Washington (U.S. Govt. Printing Office), 897-919.

Martini, E., 1971. Standard Tertiary and Quaternary calcareous nannoplankton zonation. *In* Farinacci, A. (Ed.), *Proc. Second Planktonic Conf.*: Rome (Ed. Tecnozcienza), 739-785.

Matthews, D. J., 1939. *Tables of Velocity of Sound in Pore Water and in Seawater:* London (Admiralty, Hydrogr. Department).

McCollum, D. W., 1975. Diatom stratigraphy of the southern Ocean. *In* Hayes, D. E., Frakes, L. A., et al., *Init. Repts. DSDP*, 28: Washington (U.S. Govt. Printing Office), 515-571.

Morgan, R., 1980. Palynostratigraphy of the Australian Early and Middle Cretaceous: Memoirs Geological Survey New South Wales. *Paleontology*, 18:1-153.

Morin, R. H., and Von Herzen, R. P., 1986. Geothermal measurements at Deep Sea Drilling Project Site 587. *In* Kennett, J. P., von der Borch, C. C., et al., *Init. Repts. DSDP*, 90: Washington (U.S. Govt. Printing Office): 1317-1324.

Okada, H., and Bukry, D., 1980. Supplementary modification and introduction of code numbers to the "Low-latitude coccolith biostratigraphic zonation" (Bukry, 1973; 1975). *Mar. Micropaleontol.*, 5: 321-325.

Pearce, J. A., and Cann, J. R., 1973. Tectonic setting of basic volcanic rocks determined using trace element analyses. *Earth Planet. Sci. Lett.*, 19:290–300.

Presley, B. J., 1971. Techniques for analyzing interstitial water samples; Part 1: Determination of minor and major inorganic constituents. *In* Winterer, E. L., Riedel, W. R., et al., *Init. Repts. DSDP*, 7 (Pt. 2):1749–1755.

Ratcliffe, E. H., 1960. The thermal conductivities of ocean sediments. *J. Geophys. Res.*, 65:1535–1541.

Sanfilippo, A., and W. R. Riedel. 1985. Cretaceous radiolaria. *In* Bollii, H. M., Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy.* Cambridge (Cambridge Univ. Press), 573–630.

Sanfilippo, A., Westberg-Smith, M. J., and Riedel, W. R., 1985. Cenozoic radiolaria. *In* H. M. Bollii, Saunders, J. B., and Perch-Nielsen, K. (Eds.), *Plankton Stratigraphy*, Cambridge (Cambridge Univ. Press), 631–712.

Schrader, H. J., 1976. Cenozoic planktonic diatom biostratigraphy of the Southern Pacific Ocean. *In* Hollister, C. D., Craddock, C., et al., *Initial Repts. DSDP*, 35: Washington (U.S. Govt. Printing Office), 605–672.

Schrader, H. J. and Gersonde, R. 1978. Diatoms and Silicoflagellates. *Utrecht Micropaleontol. Bull.*, 17:129–176.

Shaw, C. A., and Ciesielski, P. F., 1983. Silicoflagellate biostratigraphy of middle Eocene to Holocene subantarctic sediments recovered by Deep Sea Drilling Project Leg 71. *In* Ludwig, W. J., Krasheninnikov, V. A., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 687–737.

Shipboard Scientific Party, 1988. Introduction and explanatory notes. *In* Ruddiman, W., Sarnthein, M., Baldauf, J., et al., *Proc. ODP, Init. Repts.*, 112: College Station, TX (Ocean Drilling Program), 5–28.

Sliter, W. V., 1977. Cretaceous foraminifers from the southwestern Atlantic Ocean, Leg 36, Deep Sea Drilling Project. In Barker, P., Dalziel, I.W.D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 519–574.

Solorzano, L., 1969. Determination of ammonia in natural waters by phenolhypochlorite method. *Limnol. Oceanogr.*, 14:799–801.

Srinivasan, M. S., and Kennett, J. P., 1981. Neogene planktonic foraminiferal biostratigraphy and evolution: equatorial to subantarctic, South Pacific. *Mar. Micropaleontol.*, 6:499–533.

Srivastava, S. P., Arthur, M., Clement, B., et al., 1987. *Proc. ODP, Init. Repts.*, 105: College Station, TX (Ocean Drilling Program).

Strickland, J.D.H., and Parsons, T. R., 1968. A manual for seawater analysis. *Bull. Fish. Res. Bd. Can.*, 167:311.

Talwani, M., Mutter, J., and Eldholm, O., 1981. The initiation of opening of the Norwegian Sea. *Oceanological Acta.*

Talwani, M., Mutter, J., and Hinz, K., 1983. Ocean continent boundary under the Norwegian continental margin. *In* Bott, M.H.P., Saxov, S., Talwani, M., Thiede, J., *Structure and Development of the Greenland-Scotland Ridge: New Methods and Concepts*, NATO Conference Series IV, 8:121–131.

Tauxe, L., Tucker, P., Petersen, N. P., and LaBrecque, J. L., 1984. Magnetostratigraphy of Leg 73 sediments. *In* Hsü, K. J., LaBrecque, J. L., et al., *Init. Repts. DSDP*, 73: Washington (U.S. Govt. Printing Office), 609–621.

Thomas, E., 1985. Late Eocene to Recent deep-sea benthic foraminifers from the central equatorial Pacific Ocean. *In* Mayer, L., Theyer, F., et al., *Init. Repts. DSDP*, 85: Washington: (U.S. Govt. Printing Office), 655–694.

Tjalsma, R. C., 1977. Cenozoic foraminifera from the South Atlantic, DSDP Leg 36. *In* Barker, P., Dalziel, I.W.D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 493–517.

Tjalsma, R. C., and Lohmann, G. P., 1983. Paleocene-Eocene bathyal and abyssal benthic foraminifera from the Atlantic Ocean. *Micropaleontology*, 4:1–90.

Tomkeieff, S. I., 1983. *Dictionary of Petrology*: New York (Wiley).

Truswell, E. M., 1983. Recycled Cretaceous and Tertiary pollen and spores in Antarctic marine sediments: a catalogue. *Palaeontographica B*, 186:121–174.

———, 1986. Palynology. *In* Barrett, P. J. (Ed.), *Antarctic Cenozoic History from the MSSTS-1 Drillhole, McMurdo Sound*: Victoria, New Zealand (Antarctic Research Centre), 131–134.

Vella, P., and Watkins, N. D., 1980. Middle and Late Quaternary paleomagnetism and biostratigraphy of four subantarctic deep-sea cores from southwest of Australia. *In O. L. Bandy Memorial Volume*, Spec. Contrib. Cushman Found. Foraminiferal Res.

Von Herzen, R. P., and Maxwell, A. E., 1959. The measurement of thermal conductivity of deep sea sediments by a needle-probe method. *J. Geophys. Res.*, 64:1557–1563.

Weaver, F. M., 1983. Cenozoic radiolarians from the southwest Atlantic, Falkland Plateau Region, Deep Sea Drilling Project Leg 71. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 667–679.

Weaver, F. M., and Gombos, A. M., 1981. Southern high-latitude diatom biostratigraphy. *Soc. Econ. Paleontol. Mineral. Spec. Publ.*, 32:445–470.

Wentworth, C. K., 1922. A scale of grade and class terms of clastic sediments. *J. Geol.*, 30:377–390.

Wentworth, C. K., and Williams, H., 1932. The classification and terminology of the pyroclastic rocks. *Rept. Comm. Sedimentation, Bull. Natl. Res. Counc. (U.S.)*, 80:10–53.

Williams, G. L., and Bujak, J. P., 1977. Cenozoic palynostratigraphy of offshore eastern Canada. *AASP, Contrib. Ser. 5A*, 14–47.

———, 1985. Mesozoic and Cenozoic dinoflagellates. *In* Bolli, H. et al. (Eds.), *Plankton Stratigraphy*: Cambridge (Cambridge Univ. Press), 847–964.

Williams, H., Turner, F. J., and Gilbert, C. M., 1981. *Petrography: An Introduction to the Study of Rocks in Thin Sections*: New York (Freeman and Co.).

Wind, F. H., 1979a. Late Campanian and Maestrichtian calcareous nannoplankton biogeography and high-latitude biostratigraphy (Ph.D. dissert.). Florida State Univ., Tallahassee.

———, 1979b. Maestrichtian-Campanian nannofloral provinces of southern Atlantic and Indian Oceans. *In* Talwani, M., Hay, W., and Ryan, W.B.F. (Eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment.* Am. Geophys. Union, Maurice Ewing Ser., 3:1–57.

Wind, F. H., and Wise, S. W., 1983. Correlation of Upper Campanian-Lower Maestrichtian calcareous nannofossil assemblages in drill and piston cores from the Falkland Plateau, Southwest Atlantic Ocean. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 551–563.

Wise, S. W., 1983. Mesozoic and Cenozoic calcareous nannofossils recovered by Deep Sea Drilling Project Leg 71 in the Falkland Plateau region, southwest Atlantic Ocean. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 481–550.

Wise, S. W., and Wind, F. H., 1977. Mesozoic and Cenozoic calcareous nannofossils recovered by DSDP Leg 36 drilling on the Falkland Plateau, southwest Atlantic sector of the Southern Ocean. *In* Barker, P. F., Dalziel, I. W. D., et al., *Init. Repts. DSDP*, 36: Washington (U.S. Govt. Printing Office), 269–492.

Yokota, T., Kinoshita, H., and Uyeda, S., 1980. New DSDP (Deep Sea Drilling Project) downhole temperature probe utilizing IC RAM (Memory) elements. *Bull. Earthquake Res. Inst., Univ. Tokyo*, 55: 75–88.

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