2. EXPLANATORY NOTES

Shipboard Scientific Party

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)
- Biostatigraphy (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:

- Alistair Crane (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.2 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.
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 core catcher was designated cores. Each section was sealed at the top and bottom, then marked into section lengths; each section was labeled, and 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 subseafoor 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 subseafoor 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
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 cap with acetone.

The cores were then carried into the laboratory, and the com-
plete 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 estima-
ting bulk density and porosity (see “Physical Properties” sec-
tion, 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 bot-
tom 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. Sci-
entists 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 sam-
ping computer program by location and by the name of the in-
vestigator 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 comput-
printed label. Samples were routinely taken for shipboard mea-
surements of compressional sonic velocity by the Hamilton Frame
method, of bulk density and water content, and of percent cal-
cium carbonate (coulometer). Discrete samples were also taken
for measurement of natural remanent magnetization (see “Pa-
leomagnetics” section, this chapter). Many of these data are re-
ported in the site chapters.

The color, texture, structure, physical disturbance, and com-
position 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 sam-

dles 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 pho-
tographs were taken to illustrate a particular feature and are in-
cluded 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 geochem-
istry 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 in-
terstitial 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,” sum-
marize 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/Fos-
il Character.” Blank columns indicate that the assemblage was
not looked for in that particular case. The geologic age deter-
mimed from the paleontological and/or paleomagnetic results ap-
pears in the “Time-Rock Unit” column. Detailed information
on the zonations and terms used to report abundance and pres-
ervation 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 sam-

dles, (bulk density, $\rho$; velocity, $v$; undrained shear strength, $r$;
porosity, $\phi$; and thermal conductivity, $K$) and chemical data
(percentage CaCO$_3$ determined by coulometric analysis). Addi-
tional information on shipboard procedures for collecting these
types of data appear in the “Paleomagnetics,” “Physical Prop-
erties,” 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) 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) which was adopted 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 (Silivastava, 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.
**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

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

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<table>
<thead>
<tr>
<th>Siliceous Biogenic Sediments</th>
<th>Calcareous Biogenic Sediments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pelagic Siliceous Biogenic - Soft</td>
<td>Pelagic Biogenic Calcareous - Soft</td>
</tr>
<tr>
<td>Diatom Ooze</td>
<td>Nannofossil Ooze</td>
</tr>
<tr>
<td>SB1</td>
<td>CB1</td>
</tr>
<tr>
<td>Radiolarian Ooze</td>
<td>Foraminiferal Ooze</td>
</tr>
<tr>
<td>SB2</td>
<td>CB2</td>
</tr>
<tr>
<td>Silicoflagellate Ooze</td>
<td>Nanno-Foram or Foram-Nanno Chalk</td>
</tr>
<tr>
<td>SB3</td>
<td>CB3</td>
</tr>
</tbody>
</table>

**Pelagic Siliceous Biogenic - Hard**

- Diatomite: SB4
- Radiolarite: SB5
- Chert: SB7

**Terrigenous Sediments**

- Clay/Claystone: T1
- Sandy Mud/Mud/Mudstone: T2
- Sandy Mudstone: T4
- Silt/Siltstone: T5

**Calcareous Biogenic Calcareous - Firm**

- Nannofossil Chalk: CB5
- Foraminiferal Chalk: CB6
- Nanno-Foram or Foram-Nanno Ooze: CB7

**Pelagic Biogenic Calcareous - Hard**

- Limestone: CB9

**Volcanogenic Sediments**

- Sand/Sandstone: T6
- Silty Mud: T7
- Gravel: SH1
- Volcanic Ash: V1

**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
### Explanatory Notes

#### Drilling Disturbance

<table>
<thead>
<tr>
<th>Soft sediments</th>
<th>Slightly deformed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Moderately deformed</td>
</tr>
<tr>
<td></td>
<td>Highly deformed</td>
</tr>
<tr>
<td></td>
<td>Soupy</td>
</tr>
</tbody>
</table>
| Hard sediments          | Slightly fragmented —
|                         | Pieces in place, very
|                         | little drilling slurry
|                         | or breccia.        |
|                         | Moderately fragmented —
|                         | "drill biscuits."  |
|                         | Pieces in place or partly
|                         | displaced, but original
|                         | orientation can be recognized.
|                         | Drilling slurry may surround
|                         | fragments.         |
| Highly fragmented —     | Pieces from interval
|                         | cored and probably in
|                         | correct stratigraphic
|                         | sequence (although may
|                         | not represent entire
|                         | section), but original
|                         | orientation totally
|                         | lost.              |
| Drilling breccia —      | Pieces have completely
|                         | lost original orientation
|                         | and stratigraphic position.
|                         | May be completely mixed
|                         | with drilling slurry. |

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#### Sedimentary Structures

<table>
<thead>
<tr>
<th>Primary structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isolated mud clasts</td>
</tr>
<tr>
<td>Isolated pebbles and cobbles</td>
</tr>
<tr>
<td>Microcross-laminae (including climbing ripples)</td>
</tr>
<tr>
<td>Parallel laminae</td>
</tr>
<tr>
<td>Parallel to near-parallel laminations</td>
</tr>
<tr>
<td>Lithified sediments or nodules</td>
</tr>
<tr>
<td>Wavy bedding</td>
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<tr>
<td>Flaser bedding</td>
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<tr>
<td>Lenticular bedding</td>
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<tr>
<td>Slump blocks or slump folds</td>
</tr>
<tr>
<td>Load casts</td>
</tr>
<tr>
<td>Scour</td>
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<tr>
<td>Graded bedding (normal)</td>
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<tr>
<td>Graded bedding (reversed)</td>
</tr>
<tr>
<td>Graded over interval</td>
</tr>
<tr>
<td>Convolute and contorted bedding</td>
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<tr>
<td>Water escape pipes</td>
</tr>
<tr>
<td>Mud cracks</td>
</tr>
<tr>
<td>Cross-stratification</td>
</tr>
<tr>
<td>Sharp contact</td>
</tr>
<tr>
<td>Scoured, sharp contact</td>
</tr>
<tr>
<td>Gradational contact</td>
</tr>
<tr>
<td>Imbrication</td>
</tr>
<tr>
<td>Fining-upward sequence</td>
</tr>
<tr>
<td>Coarsening-upward sequence</td>
</tr>
<tr>
<td>Bioturbation, minor (&lt;30% surface area)</td>
</tr>
<tr>
<td>Bioturbation, moderate (30–60% surface area)</td>
</tr>
<tr>
<td>Bioturbation, strong (&gt;60% surface area)</td>
</tr>
<tr>
<td>Zoophycos</td>
</tr>
<tr>
<td>Planolites</td>
</tr>
<tr>
<td>Halo burrows</td>
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<tr>
<td>Chronodrites</td>
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<tr>
<td>Vertical burrows</td>
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<tr>
<td>Compositional structures</td>
</tr>
<tr>
<td>Concretions</td>
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<tr>
<td>Carbonate lens</td>
</tr>
<tr>
<td>Fossils, general (megafossils)</td>
</tr>
<tr>
<td>Shells (complete)</td>
</tr>
<tr>
<td>Shell fragments</td>
</tr>
<tr>
<td>Wood fragments</td>
</tr>
</tbody>
</table>

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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%.
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 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 terrigenous 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 30%, but is less than 50%, 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”).

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 siliceous biogenic grains than calcareous biogenic grains (Fig. 6). The major and minor modifiers for a siliceous biogenic sediment describe the compositions of the siliciclastic 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 siliciclastic grains and the textures of accessory calcareous 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
(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.
### 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 inter-

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### Figure 7

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

<table>
<thead>
<tr>
<th>MILLIMETERS</th>
<th>µm</th>
<th>PHI (θ)</th>
<th>WENTWORTH SIZE CLASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>4096</td>
<td>-20</td>
<td>Boulder (-8 to -12 θ)</td>
<td></td>
</tr>
<tr>
<td>1024</td>
<td>-12</td>
<td>-10</td>
<td></td>
</tr>
<tr>
<td>256</td>
<td>-8</td>
<td>-6</td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>-4</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>-2</td>
<td>-1.75</td>
<td></td>
</tr>
<tr>
<td>4</td>
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<td></td>
</tr>
<tr>
<td>2.38</td>
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<td></td>
</tr>
<tr>
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</tr>
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<td>3.75</td>
<td>0.06</td>
<td>13.0</td>
<td></td>
</tr>
</tbody>
</table>

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### Figure 8

Compositional classification for sediments with a greater than 70% terrigenous 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.
vals 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 Maastrichtian Abathomphalus mayeroensis 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 Meso-Cenozoic 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-Maastrichtian 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 Maastrichtian.
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 Maastrichtian.

**Biscutum coronum Zone**
Definition. Interval from the LAD of Marthasterites furcatus to the LAD of Biscutum coronum.
Range. Middle Campanian to lower lower Maastrichtian.

Wind and Wise (1983) also found the more cosmopolitan Maastrichtian 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 Maastrichtian 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 included 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 Syrtaclactus universus Hays, 1965, Saturnalis planetes Haeckel (= S. circulatis in Chen, 1975), and Pterocanium charysteum trilobum (Müller) Lombardi and Lazarus, in press (= P. trilobum of Hays, 1965) in the Pliocene, and Eucyrtidium punctatum Ehrenberg of Chen (1975) and Calocycles dispersandens Chen, 1975 in the Miocene.

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

The first appearance of Antarcitissa conradae in the Campanian-Maastrichtian interval older than the middle Pliocene is to be considered tentative. 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.
Epochs
Pleistocene
Pliocene
Miocene
Oligocene

Chron Pol Sub-chrons Diatoms Radiolarians
C1N-1 C1N-2 C. elliptopora/ Act. ingens Omega
C2N
C2AN-1 C2AN-2 C2AN-3 Coscinodiscus lentiginosus
C3N-1 C3N-2 C3N-3 N. angulata/ N. reinholdi Chi
C3N-4 C3AN-1 C3AN-2 Denticulopsis hustedtii
C3AN-3 C3AN-4 D. lauta*
C4N-1 C4N-2 C4N-3 N. denticuloides *
C4AN-1 C4AN-2 C4AN-3 N. grossepunctata C. lewisianus*
C5N-1 C5N-2 C5N-3 C. tanyacantha
C5N-4 C5N-5 C5N-6 N. tanyacantha
C5N-7 C5N-8 C5BN-1 C5BN-2 C. insignis/N. interfrigidaria
C5B
C5CN-1 C5CN-2 C5CN-3 C. rhombicus*
C5DN-1 C5DN-2 C5DN-3 N. maleinterpretaria*
C5E C5EN C6N
C6A C6AN-1 C6AN-2 Bogorovia veniamini/ Roc. gelida*
C6AN-3 C6AN-4
C6B C6BN C6CN-1 C6CN-2
C6C C6CN-3
C6CN-4
C6D
C6EN
C6F

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. maleinterpretaria 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.
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 davisiannae* 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 696" 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 Paleocene Antarctic piston cores (D. B. Lazarus, unpublished observations).

The FAD of Eucyrtidium pseudoinflatum Weaver, 1983 is used to separate the upper middle and middle parts of the Cycladophora spongohorax Zone, while the LAD of Actinomma tanyacantha is used to separate the middle and lower parts of the Cycladophora spongohorax 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 spongohorax 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 Edgel (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 nanofossil stratigraphy) does not exist that is correctable 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).

Calcareaous Nanofossils
Smear slides were prepared from raw sediment for examination of calcareaous nanofossils. The overall abundance of nanofossils 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 nanofossils was designated as follows:

Methods
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 x 40 mm and 18-mm diameter cover glasses, and mounted on 25 x 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 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 cm³ of sediment was broken down in 35% H₂O₂, 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% H₂O₂ 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 h. 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 x 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% H₂O₂, 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 ZnBr₂ 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-cm³ 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 magnetostatigraphry for each of the holes.

The measured magnetization vector can be interpreted in terms of the polearity 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 magnetostatigraphic 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, 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.I magnetic susceptibility meter was used to measure the susceptibility of 5-cm intervals down whole core sections. Calibration was performed using a Mn₂O₃ 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 car-
ganic pyrolysis products released by kerogen cracking between 300°-390°C. These organic compounds are substantially desorbed at or below 300°C. 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.

**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 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 Analyzer, requiring an additional 30 min. Data are expressed in microliters of hydrocarbon per liter of moist sediment.

**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 Analyzer, 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:

- $S_1 = (mg$ adsorbed 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.
- $S_2 = (mg$ pyrolytic 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).
- $S_3 (mg$ carbon dioxide/g rock): pyrolytic carbon dioxide released in the interval 300°–390°C.

**Other Parameters**

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

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

**Interpretations of Kerogen Type**

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 pyrolytic carbon. The second method, a combination of a Coulometrics 5020 Total Carbon Apparatus and 5010 CO$_2$ Coulometer, provides 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 Giske, 1975) is adapted from Strickland and Parsons (1968).

The concentration of chloride was determined by argentometric 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 ±0.05 g. Volumetric measurements were obtained by using a helium-purged Quantachrome pycnometer with an estimated error of ±0.02 cm³ (multiple measurements) or ±0.05 cm³. 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/cm³. 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 log-
gging 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 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, the sediment temperature was recorded at 1-min intervals and 1-sec logging (advanced piston corer) tool (Horai and Von Herzen, 1986) and Barnes pore-water sampler. The temperature sensor is installed together with the APC tool.

REFERENCES


