

1. EXPLANATORY NOTES¹

Shipboard Scientific Party²

Standard procedures for both drilling operations and preliminary shipboard analysis of the material recovered during Deep Sea Drilling Project (DSDP) and Ocean Drilling Program (ODP) drilling have been regularly amended and upgraded since drilling began in 1968. In this chapter, we have assembled information that will help the reader understand the basis for our preliminary conclusions and also help the interested investigator select samples for further analysis. This information concerns only shipboard operations and analyses described in the site reports in the *Initial Reports*, of the Leg 114 *Proceedings of the Ocean Drilling Program*. Methods used by various investigators for further shore-based analysis of Leg 114 data will be detailed in the individual scientific contributions published in the *Final Reports*, of this volume.

AUTHORSHIP OF SITE REPORTS

Authorship of the site reports is shared among the entire shipboard scientific party, although the two co-chief scientists and the staff scientist edited and rewrote part of the material prepared by other individuals. The site chapters are organized as follows (authors are listed in alphabetical order in parentheses; no seniority is implied):

Site Data and Principal Results (Ciesielski, Kristoffersen)
Background and Objectives (Ciesielski, Kristoffersen)
Operations (Clement, Storms)
Sedimentology (Bourrouilh, Hodell, Müller, Warnke, Westall)
Basement Rocks (Bourrouilh, Hodell, Hughes, Müller, Perfit, Warnke, Westall)
Biostratigraphy (Crux, Fenner, Katz, Ling, Nocchi, Ciesielski)
Paleomagnetism (Clement, Hailwood)
Inorganic Geochemistry (Froelich)
Physical Properties (Mienert, Nobes)
Downhole Logging (Blangy, Mwenifumbo)
Seismic Stratigraphy (Kristoffersen, Ciesielski)
Summary and Conclusions (Ciesielski, Kristoffersen)

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

SURVEY AND DRILLING DATA

The survey data used for specific site selections are discussed in each site chapter. Short surveys using a precision echo-sounder and seismic profiles were made aboard *JOIDES Resolution* on approaching each site. Geophysical data collected during Leg 114 are presented in the "Underway Geophysics" chapter (this volume).

DRILLING CHARACTERISTICS

Because water circulation down the drill hole is open, cuttings are lost onto the seafloor and cannot be examined. The only available information about 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 and recorded on the drilling platform. Typically, the harder the layer, the slower and more difficult it is to penetrate. A number of other factors, however, determine the rate of penetration, so it is not always possible to relate drilling time directly to the hardness of the layers. Bit weight and revolutions per minute, recorded on the drilling recorder, also influence the penetration rate.

DRILLING DEFORMATION

When cores are split, many show signs of significant sediment disturbance, including the downward-concave appearance of originally horizontal bands, haphazard mixing of lumps of different lithologies (mainly at the tops of cores), and the near-fluid state of some sediments recovered from tens to hundreds of meters below the seafloor. Core deformation probably occurs during one of three different steps at which the core can suffer stresses sufficient to alter its physical characteristics: 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, usually a few tens of meters, and then drilling another hole.

For all ODP drill sites, a letter suffix distinguishes each hole drilled at the same site. For example, 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 DSDP (Sites 1 through 624) but prevents ambiguity between site- and hole-number designations.

The cored interval is measured in meters below the seafloor. The depth interval of an individual core is the depth below the seafloor that the coring operation began to the depth that the coring operation ended. Coring intervals are determined by the maximum length of a core barrel, 9.7 m. The cored intervals, however, may be shorter and may not necessarily be adjacent to each other but may be separated by drilled intervals. In soft sediment, the drill string can be "washed ahead" with 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 space between the drill pipe and wall of the hole. The presence of thin, hard rock layers can result in "spotty" sampling of these resistant layers within the washed interval.

¹ Ciesielski, P. F., Kristoffersen, Y., et al., 1988. *Proc. ODP, Init. Repts.*, 114: College Station, TX (Ocean Drilling Program).

² Shipboard Scientific Party is as given in the list of Participants preceding the contents.

Cores taken from a hole are numbered sequentially 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 internal diameter), plus about a 0.2-m-long sample (without a plastic liner) in a core catcher. The core catcher is a device at the bottom of the core barrel that prevents the core from sliding out when the barrel is being retrieved from the hole. The sediment core, which is in the plastic liner, is then cut into 1.5-m-long sections that are numbered serially from the top of the sediment core (Fig. 1); the routine for handling hard rocks is described in the "Basement Rocks" section (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 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 then 1.5-m-long sections are numbered sequentially, starting with Section 1 at the top. As many sections as needed are created 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.

Samples are designated by distance 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 "114-

699A-2R-2, 98-100 cm" means that a sample was taken between 98 and 100 cm from the top of Section 2 of rotary-drilled Core 2, from the first hole drilled at Site 699 during Leg 114. A sample from the core catcher of this core might be designated "114-699A-2R, CC (8-9 cm)."

The depth below the seafloor for a sample numbered, for example, "114-699A-2R-2, 8-10 cm" is the sum of the depth to the top of the cored interval for Core 2 (in this example, 8.6 m, equivalent to the length of Core 1), plus the 1.5 m included in Section 1, plus the 8 cm below the top of Section 2. The sample in question is therefore located at 10.18 m below seafloor (mbsf), which, in principle, is the sample subseafloor depth (however, sample requests should refer to a specific interval within a core section rather than sub-bottom depths in meters).

All ODP core and sample identifiers indicate core type. The following abbreviations are used: R = rotary barrel; H = advanced hydraulic piston core (APC); P = pressure core barrel; X = extended core barrel (XCB); B = drill-bit recovery; C = center-bit recovery; I = *in-situ* water sample; S = sidewall sample; W = wash core recovery; N = Navidrill core; and M = miscellaneous material. Only APC, XCB, rotary, and wash cores were drilled on ODP Leg 114.

Core Handling

As soon as a core was retrieved on deck during Leg 114, a sample was taken from the core catcher and given to the paleontological laboratory for an initial age assessment.

The core was then placed on the long horizontal rack on the catwalk, and gas samples were taken by piercing the core liner and withdrawing gas into a vacuum-tube sampler. Voids within the core were sought as sites for 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. Next, the core was marked into section lengths, each section was labeled, and the core was cut into sections. Interstitial-water (IW), organic geochemistry (OG), and physical-properties (PP) whole-round samples were then taken. Each section was sealed at the top and bottom by gluing on color-coded plastic caps, blue to identify the top of a section and clear for the bottom. A red cap was placed on section ends from which an IW or OG sample had been taken. The caps were attached to the liner by coating the end of the liner and the inside rim of the end cap with acetone, and the caps were taped to the liners.

The cores were then carried into the laboratory, where the sections were again labeled, using an engraver to mark the full designation of the section. The length of core in each section and the core-catcher sample were measured to the nearest centimeter; this information was logged into the shipboard core-log data-base program.

The cores were then allowed to warm to room temperature (approximately 4 hr) before they were split. During this time, the whole-round sections were run through the Gamma-Ray Attenuation Porosity Evaluator (GRAPE) for estimating bulk density and porosity (see the following text; Boyce, 1976) and the pass-through magnetic susceptibility meter (see the following text). After the core temperature had equilibrated, thermal conductivity measurements were made immediately before the cores were split.

Cores of relatively soft material were split lengthwise into "working" and "archive" halves. The softer cores were split with a wire or saw, depending on the degree of induration. Harder cores were split with a band saw or diamond saw. As many cores on Leg 114 were split with a wire from the top to bottom, younger material could possibly have been transported down the split face of each core section. Thus, one should be

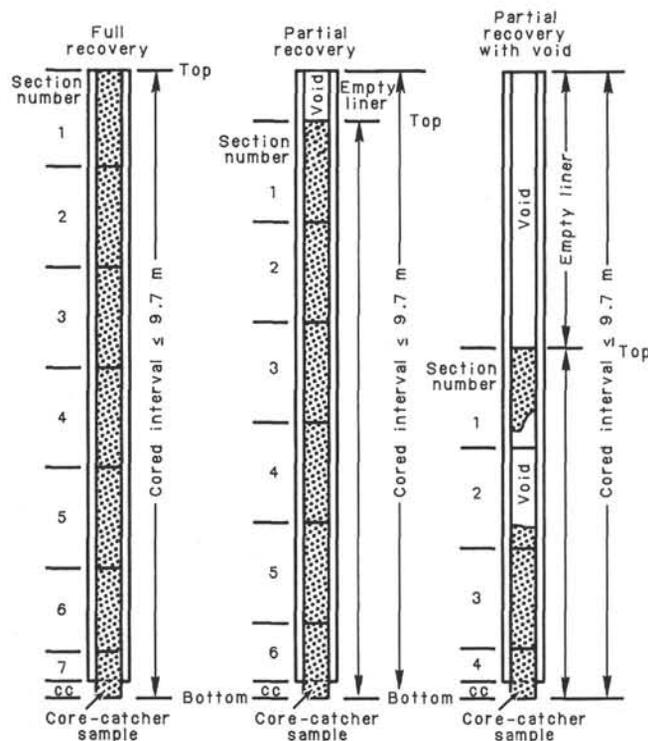


Figure 1. Diagram showing procedure for cutting and labeling core sections.

aware that the very near-surface part of the split core could be contaminated.

The working half was sampled for both shipboard and shore-based laboratory studies. Each extracted sample was logged into the sampling computer program by location and the name of the investigator receiving the sample. Records of all removed samples are kept by the Curator at ODP. The extracted samples were sealed in plastic vials or bags and labeled. Samples were routinely taken for shipboard analysis of sonic velocity by the Hamilton Frame method, for water content by gravimetric analysis, for percent calcium carbonate (carbonate bomb), and for other purposes. Many of these data are reported in the site chapters.

The archive half was described visually. Smear slides were made from samples taken from the archive half and were supplemented by thin sections taken from the working half. The archive half was then measured using the pass-through cryogenic magnetometer and photographed with both black-and-white and color film, a whole core at a time.

Both halves were then put into labeled plastic tubes, sealed, and transferred to cold-storage space aboard the drilling vessel. Leg 114 cores were transferred from the ship by refrigerated vans to cold storage at the East Coast Repository at Lamont-Doherty Geological Observatory, Palisades, New York.

CORE-DESCRIPTION FORMS ("BARREL SHEETS")

The core description forms (Fig. 2), or "barrel sheets," summarize the data obtained during shipboard analysis of each core. The following discussion explains the ODP conventions used in compiling each part of the core description form and the exceptions to these procedures adopted by Leg 114 scientists.

Core Designation

Cores are designated using site, hole, and core number and type as previously discussed (see "Numbering of Sites, Holes, Cores, and Samples" section). In addition, the cored interval is specified in terms of meters below sea level (mbsl) and mbsf. On Leg 114, these depths were based on the drill-pipe measurement, as reported by the SEDCO coring technician and the ODP operations superintendent.

Age Data

Microfossil abundance, preservation, and zone assignment, as determined by the shipboard paleontologists, appear on the core description form under the heading "Biostratigraphy Zone/Fossil Character." The geologic age determined from the paleontological results appears in the "Time-Rock Unit" column.

On Leg 114, planktonic foraminifers, calcareous nannofossils, and diatoms provided most of the age determinations, although radiolarians and benthic foraminifers were also useful age markers. Detailed information on the zonations and terms used report abundance and preservation appear in the "Biostratigraphy" section (this chapter).

Paleomagnetic, Physical-Property, and Chemical Data

Columns are provided on the core description form to record paleomagnetic results, location of physical-properties samples (density, porosity, velocity, and thermal conductivity), and chemical data (percentage of CaCO₃ determined using the carbonate bomb). Additional information on shipboard procedures for collecting these types of data appears in the "Paleomagnetism," "Physical Properties," and "Inorganic Geochemistry" sections (this chapter).

Graphic Lithology Column

The lithological classification scheme presented here is represented graphically on the core description forms using the symbols illustrated in Figure 3. Modifications and additions made to the graphic lithology representation scheme that were recommended by the JOIDES Sedimentary Petrology and Physical Properties Panel are discussed in the "Lithostratigraphy" section (this chapter).

Sediment and Sedimentary Rock Core Description Forms

Drilling Disturbance

Recovered rocks, particularly soft sediments, may be slightly to extremely disturbed, and the conditions of disturbance must be indicated on the core description form. The symbols for the six disturbance categories used for soft and firm sediments (Fig. 4) are recorded in the "Drilling Disturbance" column on the core description form. The disturbance categories are defined as follows:

1. Slightly disturbed: bedding contacts are slightly bent.
2. Moderately disturbed: bedding contacts have undergone extreme bowing and firm sediment is fractured.
3. Very disturbed: bedding is completely disturbed or homogenized by drilling, sometimes showing symmetrical diapirlike structure.
4. Soupy: intervals are water-saturated and have lost all aspects of original bedding.
5. Biscuitied: sediment is firm and broken into chunks 5 to 10 cm long.
6. Brecciated: indurated sediment is broken by the drilling process into angular fragments, perhaps along preexisting fractures.

Sedimentary Structures

The locations 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 4 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 sediment were determined by comparison with the Geological Society of America Rock-Color Chart (Munsell Soil Color Charts, 1971). Colors were determined immediately after the cores were split and while they were still wet.

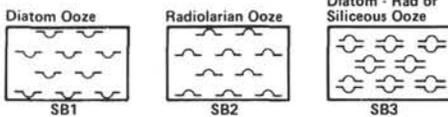
Lithology

Lithologies are recorded on the core description form by one or more of the symbols shown in Figure 3. The symbols in a group, such as CB1 or SB5, correspond to end-members of the sediment compositional range, such as nannofossil ooze or radiolarite. For sediments that are mixtures of siliciclastic and biogenic sediments, the symbol for the minor constituent is on the left side of the column, the symbol for the major constituent is on the right side, and the abundances of the constituents approximately equal the percentage of the width of the graphic column that each symbol occupies. For example, the left 20% of the column may have a diatom ooze symbol (SB1), whereas the right 80% may have a clay symbol (T1), indicating sediment composed of 80% clay and 20% diatoms.

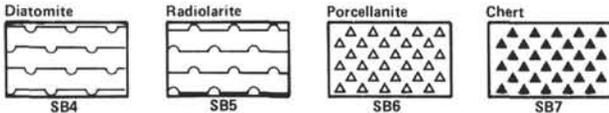
Smear slide, thin-section, and X-ray diffraction compositions, as well as carbonate and organic carbon contents together

PELAGIC SEDIMENTS

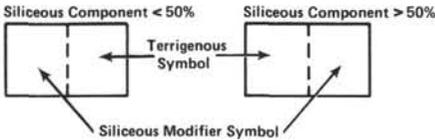
Siliceous Biogenic Sediments
PELAGIC SILICEOUS BIOGENIC - SOFT



PELAGIC SILICEOUS BIOGENIC - HARD



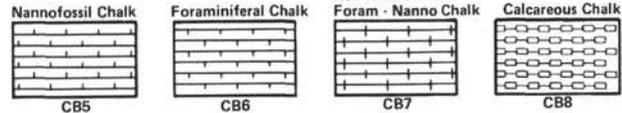
TRANSITIONAL BIOGENIC SILICEOUS SEDIMENTS



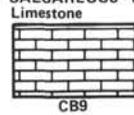
Calcareous Biogenic Sediments
PELAGIC BIOGENIC CALCAREOUS - SOFT



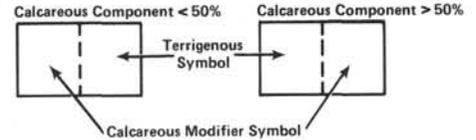
PELAGIC BIOGENIC CALCAREOUS - FIRM



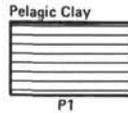
PELAGIC BIOGENIC CALCAREOUS - HARD



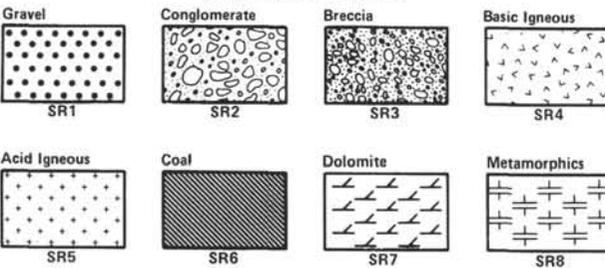
TRANSITIONAL BIOGENIC CALCAREOUS SEDIMENTS



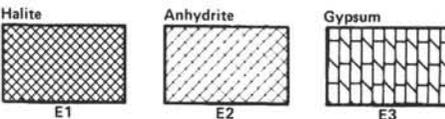
Non-Biogenic Sediments



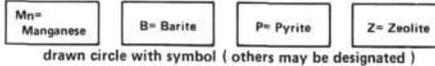
SPECIAL ROCK TYPES



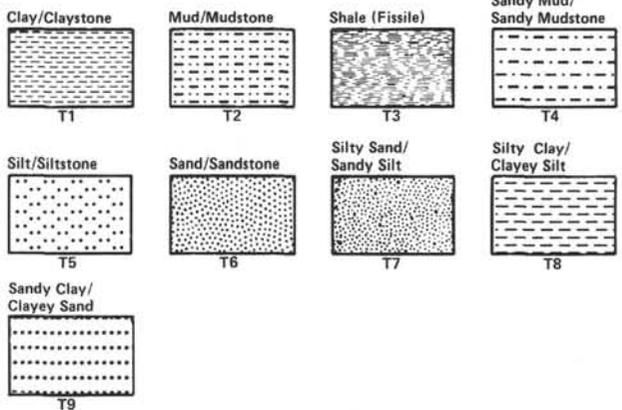
EVAPORITES



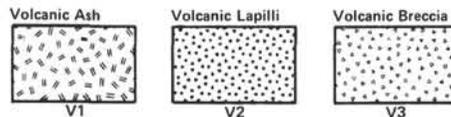
Concretions



TERRIGENOUS SEDIMENTS



VOLCANOGENIC SEDIMENTS



ADDITIONAL SYMBOLS

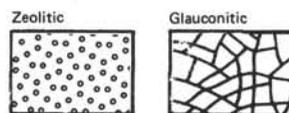


Figure 3. Key to symbols used in "Graphic Lithology" column on the core description form shown in Figure 2.

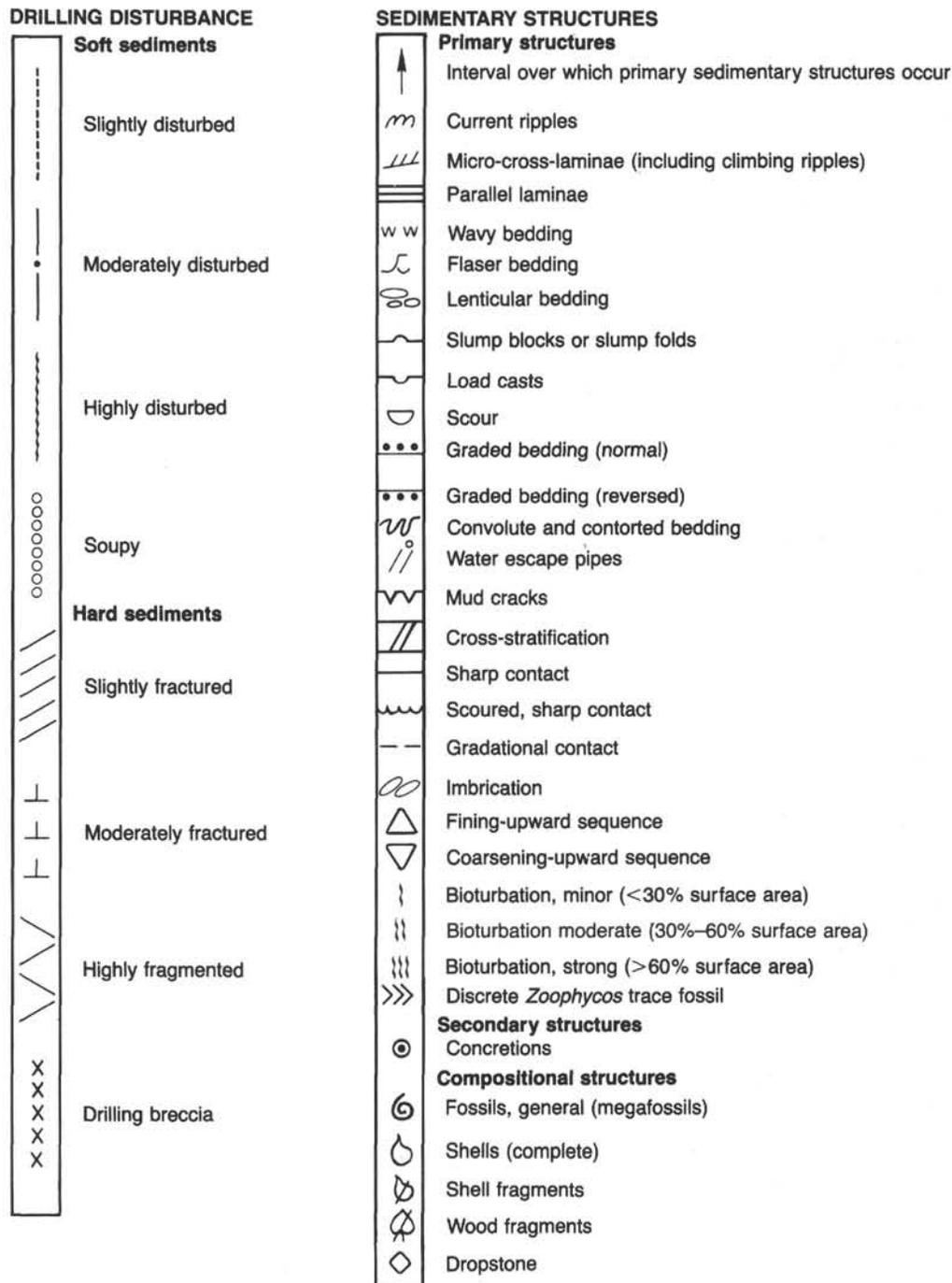


Figure 4. Standard symbols for drilling disturbance and sedimentary structures observed in sediments recovered during Leg 114. These symbols are used on the core description form (Fig. 2).

with the location by section and centimeter interval of all samples, are listed below the core description. In addition, the locations of the samples in the cores are indicated by an asterisk (*) in the "Samples" column on the core description forms.

BASEMENT-ROCK HANDLING AND CORE DESCRIPTION FORMS

Igneous rocks were split, using a rock saw with a diamond blade, into archive and working halves. The archive halves were described and the working halves were sampled aboard ship. Each piece of rock was numbered sequentially from the top of each core section, beginning with the number 1. Pieces were labeled on the rounded, unsawed surface. Pieces that could be fit-

ted together before splitting were given the same number, but were lettered consecutively downsection, as 1A, 1B, 1C, and so on. Spacers were placed between pieces with different numbers but not between those with different letters and the same number. In general, spacers are placed at interpreted drilling gaps (no recovery). The stratigraphic orientation is known for all pieces that are cylindrical in the liner and are greater in length than the diameter of the liner; on these pieces, arrows were drawn pointing to the top of the core section. Care was taken to ensure that correct stratigraphic orientation was preserved through every step of the sawing and labeling process.

Special description forms are used for igneous and metamorphic rocks because igneous rock representation on standard sed-

iment core description forms would be too compressed to provide adequate information for potential sampling. Graphic representation of each 1.5-m core section is shown on these forms, along with summary hand-specimen and thin-section descriptions (Fig. 5).

LITHOLOGIC CLASSIFICATION OF SEDIMENTS

After careful evaluation of existing schemes for classification of oceanic sediments, the sedimentology group on Leg 114 decided to adopt a slight modification of the system proposed by Dean et al. (1985). This system represents a refinement of the "official" JOIDES classification and is similar to the system described by Kaharoeddin et al. (1982) for use at the Antarctic Marine Geology Research Facility of Florida State University. It is also similar to the system proposed by J. M. Mazzullo, A. W. Meyer, and R. Kidd (unpubl. data). Certain features of Mazzullo et al.'s classification were adopted by Leg 114 scientists for use with neritic sediments.

The system of Dean et al. is briefly described in the following paragraphs. A more detailed description of the classification can be found in the original publication (Dean et al., 1985).

The basic framework of the classification is the three-component system of calcareous-biogenic, siliceous-biogenic, and nonbiogenic components. Estimates of the percentages of these main components are based on smear slide analyses, using broad boundaries of 10%, 25%, and 50%. Assignment of a specific name follows a set of rules:

1. The main name of the sediment is determined from the component (or group of components) that is >50% (e.g., siliceous ooze).
2. A component between 25% and 50% is a major modifier of the name (e.g., silty, diatom, etc.).
3. A component between 10% and 25% is a minor modifier of the name (i.e., "-bearing").

Steps in using the classification are as follows:

1. If the terrigenous components constitute more than 50% of the sediment, the sediment is a clay, silt, or whatever (see below for classification of terrigenous sediments). If biogenic components are more than 50%, the main name of the sediment is *ooze*.
2. The sediment name is amended by the name(s) of the dominant biogenic component(s) (siliceous or calcareous) (e.g., nannofossil ooze).
3. The major and minor modifiers precede the main name in order of increasing abundance. The least important component is the first modifier; the most abundant component name is immediately before main name (e.g., diatom nannofossil ooze, clay-bearing diatom ooze).

Examples of three-component classifications with complete names (established following the preceding three steps) are shown in Figures 6A-6C.

Induration

The main name of a sediment is modified to reflect induration. The following terms are used to indicate induration of biogenous sediments:

	Calcareous	Siliceous
Soft:	Ooze	Ooze
Firm:	Chalk	Diatomite/radiolarite
Hard:	Limestone	Porcellanite (dull, porous) Chert (lustrous, indurated)

Terrigenous Sediments

If the sediment has more than 50% terrigenous components, the main name is determined by use of a three-component (sand-silt-clay) classification system, as shown in Figure 7. This system is not the one used by Dean et al. (1985, fig. 6), but is a simplification following the practice of Leg 113 (see "Explanatory Notes" chapter; Barker, Kennett, et al., 1988), in order to facilitate comparison of the results of Legs 113 and 114.

If terrigenous material is less than 50% of the sediment and merits major- or minor-qualifier status, the same terminology is employed as for biogenic sediments, except that the terms "muddy" or "mud-bearing" are used without qualifiers (i.e., there are no "silty-muddy," "silty-mud-bearing," or similar terms).

Volcanogenic Sediments

Volcanogenic sediments, usually consisting of glass, feldspar, pyroxene, volcanic-lithic fragments, or secondary minerals such as palagonite or zeolites, are treated by the preceding rules. For instance:

- 10%–25% ash: volcanic ash-bearing
- 26%–50% ash: volcanic ash (plus major name)
- >50%: volcanic ash

Lithified analogs are tuff-bearing, tuffaceous, and tuff.

Other components are classified following the same procedure. For example, modifiers for ferromanganese nodules are "ferromanganese-bearing" and "ferromanganic." For zeolites, the terms are "zeolite-bearing" and "zeolitic."

Sediment components that are present in amounts of <10%, but are deemed to be particularly important, are accounted for in the sediment name (e.g., "organic-carbon-rich"). In all such cases, however, the terms must be defined and the amounts quantified.

BIOSTRATIGRAPHY

Calcareous Nannofossils

Preservation

Estimates of preservation are, by their nature, subjective and imprecise. The following guidelines have been applied to the study of calcareous nannofossils from Leg 114.

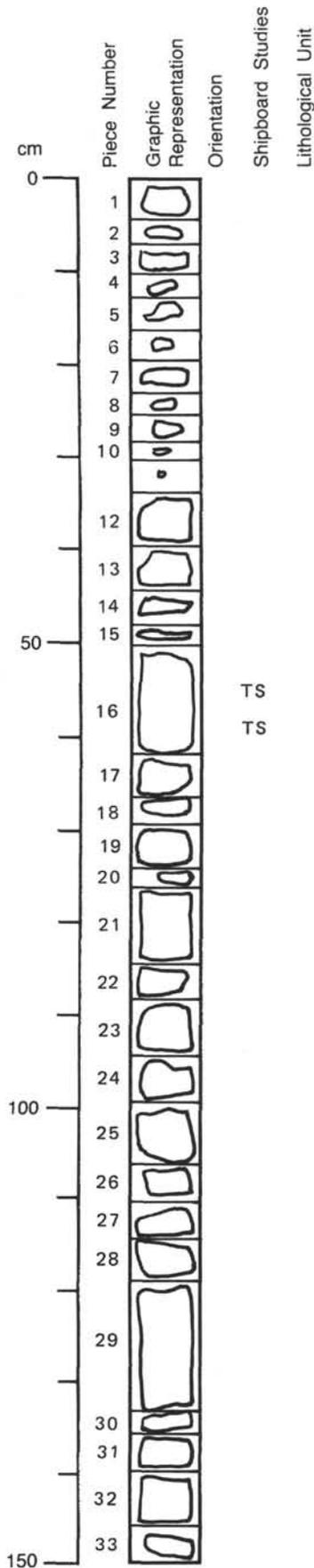
- Poor: severe overgrowth of discoasters and placoliths with secondary calcite (assemblage biased in solution-resistant forms)
- Moderate: some overgrowth and/or dissolution of placoliths and discoasters
- Good: well preserved, with only minor signs of dissolution and/or overgrowth

Sample Preparation

Smear slide preparations of all samples were made with the following procedure: a small piece of sediment is smeared onto a glass slide with a drop of water using a flat toothpick. Mounting medium and a cover glass are then applied.

Biostratigraphic Methods

The most widely used Cenozoic calcareous nannofossil zonal schemes (Martini, 1971; Bukry, 1973, 1975) are only partially applicable to the sedimentary sequences of the subantarctic South Atlantic. Progressive deterioration of the climate through the Cenozoic led to increased provincialism among the highly stenothermal calcareous nannoplankton. These algae respond quickly to changes in the thermal structure of the water masses. This is



114-698A-24R-1

UNIT 1: CHERT

Piece 1

COLOR: Gray (N7).

UNIT 2: SPARSELY PLAGIOCLASE(?) PHYRIC (FELDSPATHOID-PHYRIC?) BASALT

Pieces 2-33

GROUNDMASS: Fine-grained plagioclase and augite.

PHENOCRYSTS: Feldspar or feldspathoid, 1-3 mm.

COLOR: Greenish gray (5BG 6/1).

VESICLES: Rare, 2-4 mm, some open, some filled with serpentinite and calcite.

ALTERATION: Moderately altered and serpentinized alkali basalt.

SMEAR SLIDE SUMMARY (%):

TS 1, 146
 TS (Dominant lithology)

COMPOSITION:

Mica 90
 Accessory minerals:
 Spinel Tr
 Magnetite
 (opaques) 10

NOTE: Smear slide is from material scraped from side of barrel between Pieces 32 and 33.

PHYSICAL PROPERTIES:

1, 93
 ϕ (%) = 12.26
 ρ_g (g/cm³) = 3.10

Figure 5. Core description form used for the description of igneous rocks.

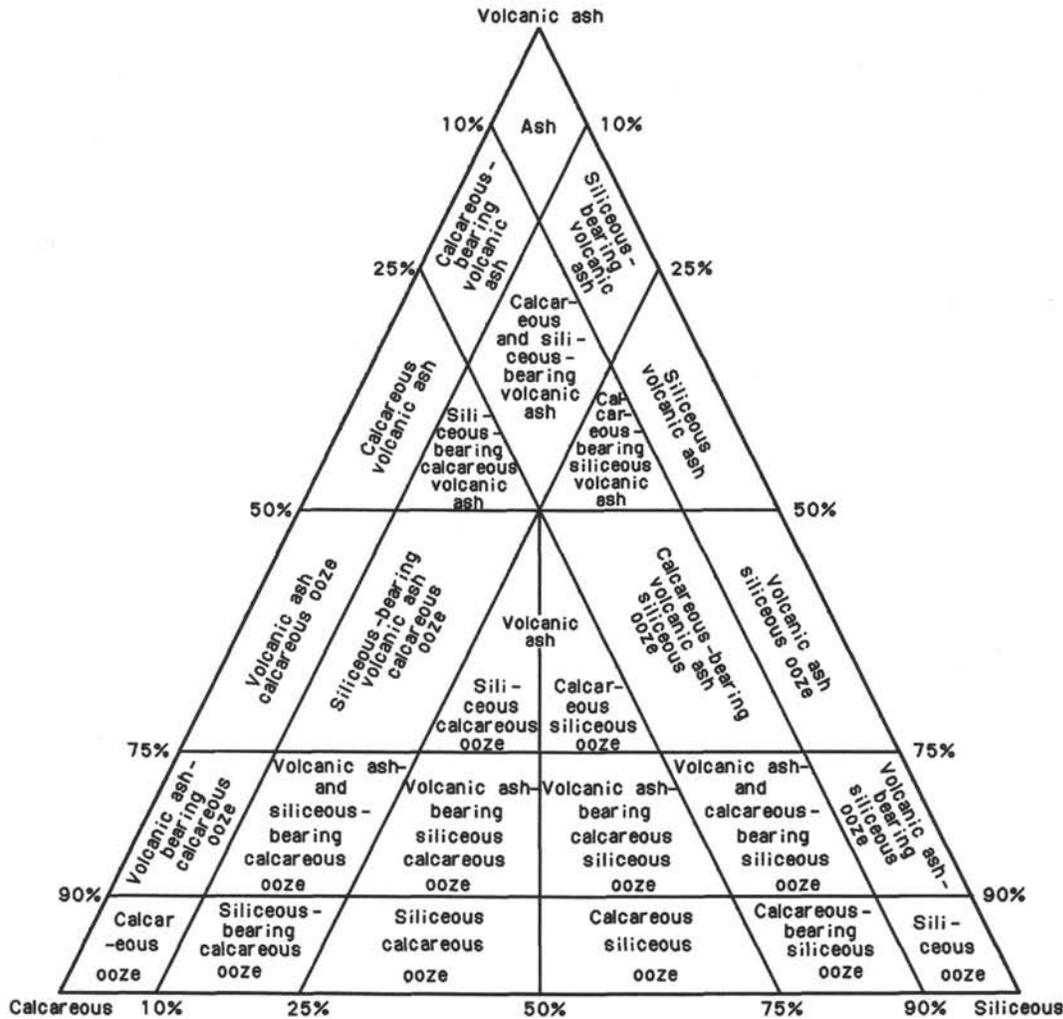


Figure 6. Classification schemes used to name sediments recovered on Leg 114 (adapted from Dean et al., 1985).

seen dramatically in the subantarctic regions, where low diversity, endemic species, and poor preservation prevent recognition of most of the biostratigraphic datums used to subdivide strata of low latitudes.

Where age-diagnostic species are present, they are often too rare to be used to define biostratigraphic events reliably. Their stratigraphic ranges can be curtailed locally by changes of the climate. In some instances, however, they may have longer stratigraphic ranges in these high latitudes than they do in low latitudes.

The aim of the present investigation is to relate paleoclimatic, paleogeographic, sedimentologic, and geochemical events to a standard time scale, using nanofossils. The problems outlined above dictate different methods for dating the strata in the subantarctic with nanofossils than those generally employed in fossiliferous, low-latitude sequences. In the latter, most of the species used by Martini (1971) and Bukry (1973, 1975) are present. Their occurrences and co-occurrences are used to recognize zones in the sedimentary sequences penetrated. The first and last occurrences of such species are used to define zonal boundaries; direct correlation to magnetostratigraphy transforms such biostratigraphic events into a biochronologic datums. This provides numeric ages for geologic events.

This method was applicable to only a limited number of events. Most of the ages assigned to the strata in this study are

derived by a different procedure. In the absence of Cenozoic marker species, secondary or auxiliary biostratigraphic markers, not included in the lower latitude zonal schemes, were used. Their stratigraphic ranges have been established in numerous different studies, and those given in a recent summary (Perch-Nielsen, 1985) were adopted for the present investigation. Perch-Nielsen (1985) related these stratigraphic ranges to the Martini (1971) and Bukry (1973, 1975) zones. The occurrences and co-occurrences of these species in the samples analyzed allowed their assignment of a range of ages. These ages were expressed in terms of Martini's (1971) zones to allow precise correlations to the geochronology and chronostratigraphy of Berggren et al. (1985a, 1985b).

A local zonation scheme developed for use in the subantarctic South Atlantic by Wise (1983) and Wise and Constans (1976) from examination of the nanofossils recovered by DSDP Legs 36 and 71 was found to be applicable to the Oligocene sections penetrated. Application is restricted to the Oligocene sequence because of the incomplete stratigraphic record in the holes on which the zonation is based.

In the Cretaceous sections penetrated by Holes 699A and 700B, the nanofossil zonation of Sissingh (1977) was applied. This scheme was developed in the mid- to high latitudes of the northern hemisphere but appears to be applicable to the Maestrichtian sections of the subantarctic. Below the Maestrichtian,

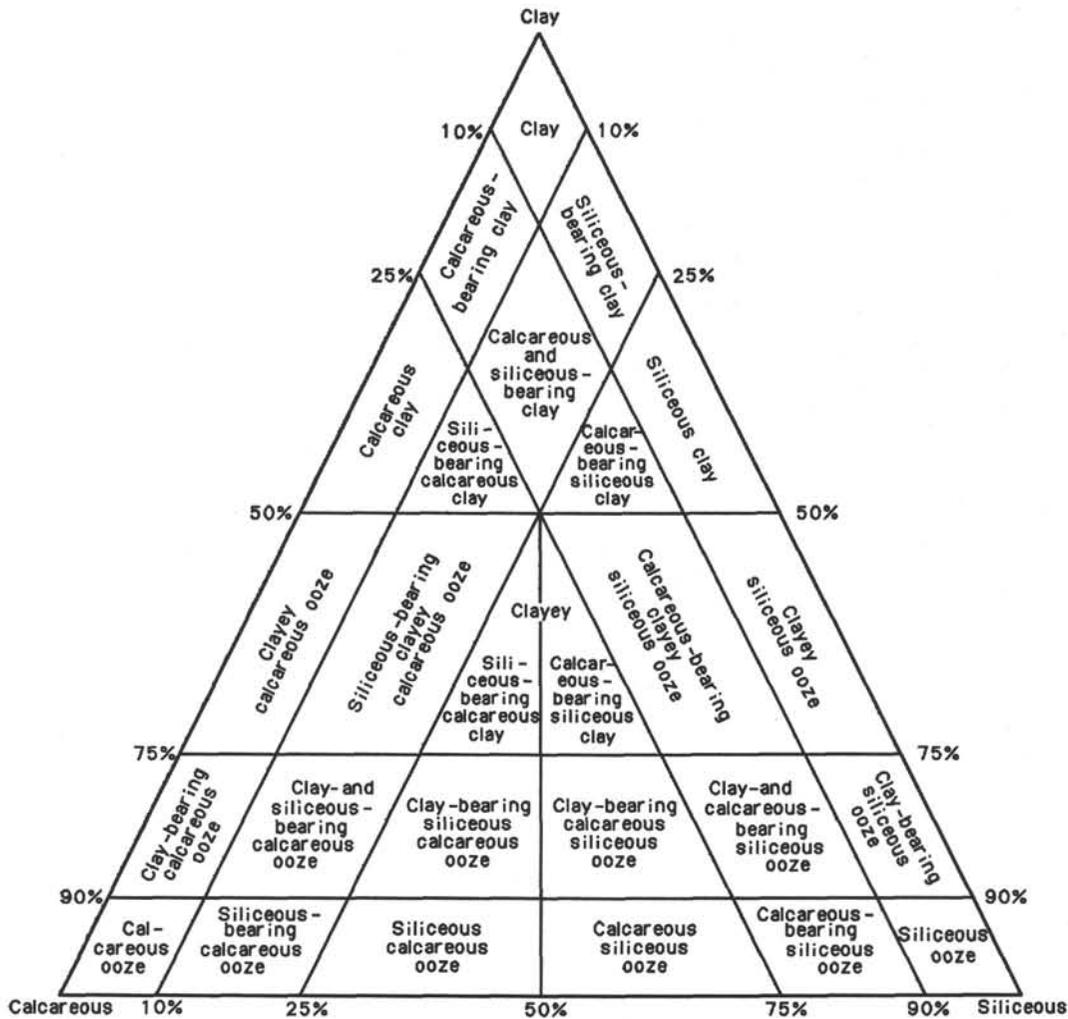


Figure 6 (continued).

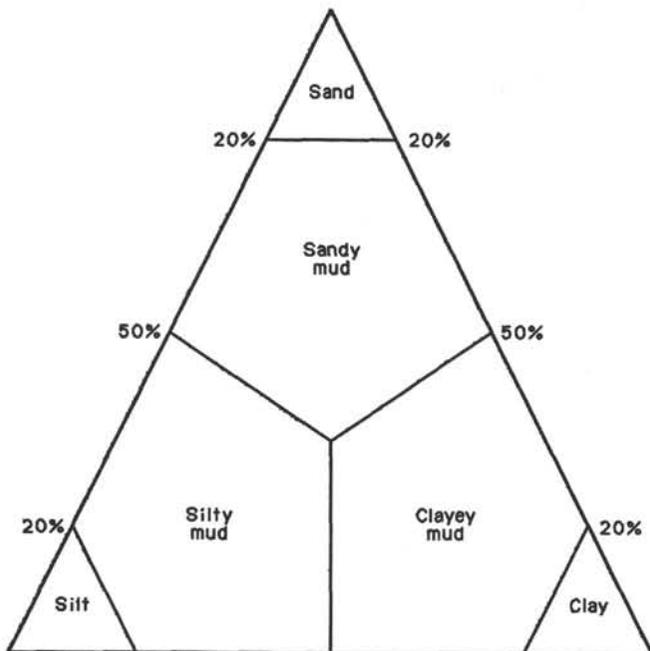


Figure 7. Classification scheme used to name terrigenous sediments.

leomagnetic record in such a way that it is possible to compare paleoclimatic, paleogeographic, and sedimentologic events in bioprovinces of different latitudes. However, most of the marker species used by Berggren et al. (1985a) were of warm-water preference and are absent in the areas investigated during Leg 114. Consequently, it is difficult or impossible to apply the standard zonation to high-latitude sequences without the use of secondary or auxiliary markers and control from paleomagnetic data or other fossil group events.

The temperate zonal scheme proposed by Jenkins (1985) has tentatively been used, but some of Jenkins' marker species are absent or may have a different stratigraphic range in comparison to New Zealand. The preliminary zonation adopted for the Tertiary (when possible) incorporates elements of the zonations of both Berggren et al. (1985a) and Jenkins (1985), the latter of which is not calibrated to paleomagnetic data. For the Cretaceous the zonal scheme based on planktonic foraminifer events (Caron, 1985) can be applied only to some intervals. In the other intervals, age assignments are linked to the identified nanofossil and paleomagnetic stratigraphies.

The Neogene has not been subdivided into zones because only a few marker species of both the standard and Jenkins (1985) zonations were found. A local biozonation can be established by calibrating the planktonic foraminifer events with diatoms and paleomagnetic data.

Onshore examination of core samples has allowed for a better correlation of the Paleogene stratigraphic intervals to the

standard zonation scheme. A few of the marker species used by Berggren et al. (1985a) have been found, together with alternative species known to have their ranges within the standard P zones in other southern hemisphere areas.

The ages assigned to the samples are related to the P zones and to the calcareous nannofossil zonation of Martini (1971), based primarily on correlation of different latitude schemes reported by Bolli et al. (1985), McGowran (1986), and Pujol and Sigal (1979). However, because several biozonal boundaries can not be defined and some of the P zones are not recognized, short hiatuses cannot be detected.

Some events, common to every sequence, could be tied to the P zones by means of correlations between planktonic foraminifers first and last occurrences and paleomagnetic data such as the LAD of Planorotalites (lower part of P11) and first appearance datum (FAD) of *Globigerinatheka index* (upper part of P11). A local biozonation for the Paleogene was constructed based on the distribution of some phylogenetically related, generally dissolution-resistant endemic forms, such as *Acarinina primitiva*, *Globigerinatheka senni*, *G. index*, *Subbotina linaperta*, *S. angiporoides*, "*Globigerina*" *labiacrassata*, "*Globigerina*" *brazieri*, and "*Globigerina*" *woodi woodi*, listed in chronologic order from oldest to youngest.

The occurrence of tropical-type planktonic foraminifers indicates extratropical excursions and can be used to recognize "warm spikes" at high latitudes, which are isochronous and therefore, correlatable. The *Morozovella crater* Acme Zone, for instance, has been identified at every site straddling the early to middle Eocene boundary. For the low-latitude planktonic foraminifers, the term occurrence (O) has been used instead of appearance (A) because their range at high latitudes, in most cases, seems to be ecologically, rather than evolutionary, controlled.

Benthic Foraminifers

Sample Preparation

Foraminifer samples were soaked in a hydrogen peroxide solution (3%) and washed through a 63- μ m sieve with a Calgon solution. Several samples were boiled in sodium carbonate solution prior to wet-sieving. Samples were rinsed with methanol and dried under heat lamps.

Biostratigraphic Methods

Relative abundances of benthic foraminifers were made from the greater than 149- μ m size fraction. Paleobathymetric estimates were based on van Morkhoven et al. (1986) and Tjalsma and Lohmann (1983).

Radiolarians

Sample Preparation

Leg 114 core-catcher samples were processed using a standard method employed in the study of radiolarians, silicoflagellates, ebridians, and archaeomonads. A small (approximately 15 g) sample was treated first with dilute HCl (~10%) to dissolve the calcium carbonate components of the sediment, followed by the addition of hydrogen peroxide (H₂O₂) to dissolve organic matter. The entire treatment was made on a hot plate for about 1 hr to accelerate these chemical reactions. After decantations using deionized water were repeated two or three times, the residues were sieved through 63- μ m screen. One strewn slide was made from each fraction, with a 22 × 40 mm cover slip and Canada balsam as mounting medium.

Abundance and Preservation

By systematically traversing the entire smear slide of each fraction separately with a mechanical stage, the relative abundances of radiolarians and silicoflagellates plus ebridians in a sample were ranked as follows:

Rare: 1–10 specimens
 Few: 11–20 specimens
 Common: 21–50 specimens
 Abundant: over 51 specimens

For the relative abundance of an individual taxon within an assemblage, the following ranking was used:

Rare: 1%–5% of the population
 Few: 6%–10% of the population
 Common: 11%–25% of the population
 Abundant: over 26% of the population

Upon the complete examination of a respective smear slide, the state of microfossil preservation of the sample was expressed as follows:

Poor: noticeable number of fragments or broken specimens in the slide
 Moderate: some fragments or incomplete specimens
 Good: most of the specimens are complete

Biostratigraphic Methods

The zonal schemes of Hays and Opdyke (1967) from the Antarctic, Chen (1975) from Leg 28 of the Pacific sector of Antarctic, and biostratigraphic datums of Weaver (1983) from Leg 71 in the subantarctic Atlantic were consulted as the main references for analysis of Leg 114 Neogene radiolarians. A warm-water assemblage of Sanfilippo et al.'s (1985) low-latitude zonation was used for part of the upper Miocene section of Site 704 and part of the Eocene section of Site 698. No zonation that was applicable to the entire subantarctic region was available at the time of the cruise for the Paleogene and Cretaceous sections.

In the case of the silicoflagellates, their biostratigraphic occurrence was compared with the zonations of Busen and Wise (1977) from Leg 36, Shaw and Ciesielski (1983) from Leg 71 of the subantarctic Atlantic, and Ciesielski (1975) from Leg 28 of the Pacific sector of the Antarctic.

As for both ebridians and archaeomonads, because no biostratigraphic zonation exists for the area, the occurrence of taxa was referred to publications of Ling (1973) from the North Pacific and of Perch-Nielsen (1975) from Leg 29 of the Pacific sector of the Antarctic.

Diatoms

Sample Preparation

Smear slides and slides of the HCl- and H₂O₂ insoluble residues were analyzed during Leg 114 for their diatom abundances and species. In intervals for which rare large species have been declared stratigraphic marker species, as for example near the Eocene/Oligocene boundary (*Rylandsia inaequiradiata*), the >63- μ m fraction of the HCl- and H₂O₂ insoluble residues was additionally examined.

Hyrax was used as a mounting medium. The slides were examined at magnifications of 1000× and 400×.

Abundance and Preservation

Abundances of species in the diatom assemblages were recorded using the following categories:

- Single: (< 1%)
- Rare: (> 1%)
- Few: (> 5%)
- Common: (> 20%)
- Abundant: (> 50%)

Estimates of diatom preservation for this shipboard analysis can only be very rough and subjective using the abundance of dissolution-resistant species within the assemblages and the degree of fragmentation of the valves. A more precise and more objective classification might be achieved during the shore-based laboratory studies.

Biostratigraphic Methods

Two quite different diatom zonation schemes have been proposed within the past 4 yr for the Oligocene and Eocene (Gombos and Ciesielski, 1982; Fenner, 1984).

For the Neogene of the subantarctic region a diatom zonation was introduced by McCollum (1975). This zonation was modified by Weaver and Gombos (1981) and Ciesielski (1983). For the upper Neogene many datums have been correlated against the paleomagnetic record. Following is a list of the datums generally found in the subantarctic region and their absolute age estimates by comparison with the paleomagnetic stratigraphy in the same holes. These are thought to be useful for plotting the age-depth curves for each site. The ages of the datums are taken from McCollum (1975), Burckle et al. (1978), Weaver and Gombos (1981), and Ciesielski (1983). For the early Miocene paleomagnetic control is missing, and the ages given were obtained by extrapolation (Barron, 1985).

LAD	<i>Hemidiscus karstenii</i>	0.19 m.y.
LAD	<i>Actinocyclus ingens</i>	0.62 m.y.
FAD	<i>Coscinodiscus elliptipora</i>	1.5 m.y.
LAD	<i>Rhizosolenia barboi</i>	1.6 m.y.
LAD	<i>Coscinodiscus kolbei</i>	1.9 m.y.
LAD	<i>Coscinodiscus vulnificus</i>	2.2 m.y.
LAD	<i>Cosmidiscus insignis</i>	2.5 m.y.
LAD	<i>Nitzschia weaveri</i>	2.64 m.y.
LAD	<i>Nitzschia interfrigidaria</i>	2.8 m.y.
FAD	<i>Coscinodiscus vulnificus</i>	3.14 m.y.
FAD	<i>Nitzschia weaveri</i>	3.88 m.y.
FAD	<i>Nitzschia interfrigidaria</i>	4.02 m.y.
FAD	<i>Nitzschia angulata</i>	4.2 m.y.
LAD	<i>Denticulopsis hustedtii</i>	4.5 m.y.
LAD	<i>Denticulopsis lauta</i>	8.5–8.7 m.y.
LAD	<i>Denticulopsis dimorpha</i>	8.7 m.y.
LAD	<i>Nitzschia denticuloides</i>	10.5–11.2 m.y.
FAD	<i>Denticulopsis dimorpha</i>	~ 12.35 m.y.
LAD	<i>Nitzschia grossepunctata</i>	14–14.5 m.y.
LAD	<i>Coscinodiscus rhombicus</i>	~ 18.5 m.y.
LAD	<i>Bogorovia veniamini</i>	~ 19.5 m.y.
LAD	<i>Rocella gelida</i>	~ 21.5 m.y.

The applicability of the preceding zonal schemes and the correctness of the ages of the datums will be further tested by post-cruise studies. It is hoped that Leg 114 will provide new datums calibrated by the paleomagnetic time scale through the Neogene and Paleogene.

INORGANIC GEOCHEMISTRY

Pore Waters

Interstitial-water samples were collected routinely and analyzed aboard ship for pH, alkalinity, calcium, magnesium, sul-

fate, silica, fluoride, salinity, and chloride. Splits of all samples were preserved for shore-based determinations of potassium, lithium, strontium, strontium isotopes, and germanium. Attempts were made to measure potassium aboard ship without success. All procedures follow the methods given in Gieskes and Peretsman (1986) unless stated otherwise in this chapter or the individual site chapters (this volume).

A Metrohm 605 pH-meter was used to measure pH immediately in conjunction with the alkalinity measurements. Each sample was then titrated with 0.1 N HCl and the end point calculated from a Gran plot. Alkalinities were standardized against IAPSO (International Association of Physical Science Organizations) standard seawater.

Salinity was determined from refractive indices measured with an AO Scientific Instruments hand-held optical refractometer and reported in per mil (g/kg) total dissolved salts. Sulfate concentrations were measured on highly diluted aliquots of each sample with a Dionex 2120i Ion Chromatograph. Standards were prepared by dilution of IAPSO standard seawater.

Chloride was determined by titration with silver nitrate to a potassium chromate end point. Standardization was against IAPSO.

Calcium was determined by a modification of the EGTA titration using GHA as an indicator. The indicator is extracted into butanol near the end point. A titration for total divalents is performed with EDTA to an Eriochrome Black-T end point. Both methods are standardized using IAPSO, and the calculations for calcium and magnesium were performed as suggested in Gieskes and Peretsman ("Corrected Ca and Mg"; 1986).

Dissolved silica was determined by a modification of the procedure used by P. Froelich. The detailed procedure, patterned after that used by ODP, is appended to this chapter.

Fluoride was determined by fluoride ion-specific combination electrode (Orion model #96-09) by the method of Froelich et al. (1983); 0.5 mL of sample was mixed with 0.5 mL TISAB IV and allowed to equilibrate for 15 min before reading. Calibration was against a series of fluoride-spiked IAPSO solutions. The slope of the response was perfectly Nernstian and was rechecked thoroughly only at the beginning of the leg and again at the end. Drift was compensated for by maintaining the electrode in a large volume of IAPSO water plus TISAB and adjusting the (EMF)₀ accordingly.

Several tests were performed to check for artifacts of the temperature of squeezing. These are explained in detail in each site report.

ORGANIC GEOCHEMISTRY AND SEDIMENT CARBONATE CONTENTS

The following organic-geochemical measurements were performed during Leg 114:

Total organic carbon (TOC) and inorganic carbon (carbonate; IC) were determined with a Coulometrics Carbon Analyzer by difference on combustion and by direct measurement of CO₂ liberated upon acidification. TOC consists of all organic carbon and inorganic carbon liberated to CO₂ during heating in a pure oxygen atmosphere. CO₂ is then measured by coulometry. IC was determined by reacting samples with acid, with the CO₂ again measured by coulometry. Percent calcium carbonate was calculated from %IC. Percent organic carbon was taken as the difference between TOC and IC. This procedure is not capable of accurately detecting organic carbon in samples containing less than 0.1% C_{org}.

No Rock-Eval measurements were made. Headspace determinations of volatile hydrocarbon gases were made routinely on almost all cores. Even though no values in excess of background levels were encountered during the leg, the data are reported for completeness.

Determination of Dissolved Silica in Leg 114 Pore Waters: Modifications to Standard ODP Procedures

We adopted several modifications to standard ODP techniques for the determination of dissolved silica in pore waters. These changes result in several minor methodological improvements: (1) the shelf stability of the molybdate reagent is enhanced, (2) preparation of the working solution reagents is simplified, (3) the necessity for salinity matching (or corrections) between standards (in deionized water) and samples (seawater) is eliminated, and (4) precision and accuracy of the procedure are improved by ensuring that the sample is added to the molybdate, rather than vice versa.

The following modifications refer to the dissolved silica procedure reported by Gieskes and Peretsman (1986; p. 37–40). This entire section on silica is reproduced here with the Leg 114 modifications.

Introduction

Determination of silica in pore waters of marine sediments depends upon (1) the production of a silicomolybdate complex and (2) the reduction of this complex to give a blue color. The modified method is adapted from the work of Strickland (1952), Mullin and Riley (1955), Strickland and Parsons (1968), Parsons et al. (1984), and Fanning and Pilson (1973), plus the results of work in P. Froelich's lab.

Stock Reagents

All reagents are prepared with deionized, silica-free water.

1. Molybdate stock reagent: dissolve 16.0 g ammonium molybdate— $(\text{NH}_4)_6\text{Mo}_7\text{O}_{24}\cdot 4\text{H}_2\text{O}$ —(preferably fine white crystalline) in about 700 mL of deionized water using a 1000-mL volumetric flask. After it has completely dissolved, dilute to 1000 mL with deionized water. Store in a clear polyethylene bottle out of light, but do not refrigerate. Discard if a white precipitate develops in the bottom of the bottle or if the solution turns faintly bluish.

2. Stock HCl reagent: measure 48 mL of concentrated HCl (12 N) into a graduated cylinder. Pour about 800 mL of deionized water into a 1-L volumetric flask, and add the HCl. Allow to cool and make to 1 L. Store in a polyethylene bottle. Stable indefinitely.

NOTE: Unacidified molybdate is very stable and will not precipitate from solution for many months.

3. Stock metol-sulfite solution: dissolve 6.0 g anhydrous sodium sulfite (Na_2SO_3) in about 300 mL of deionized water in a 500-mL volumetric flask. Add 10 g metol (p-methylaminophenol sulfate), and then add deionized water to make to 500 mL. When the metol has dissolved, filter the solution through a No. 1 Whatman filter paper into a clean, dark glass bottle with a glass-stoppered top. Store in the refrigerator. This solution deteriorates rapidly on contact with air and must be maintained airtight when not in use. It is normally prepared fresh at least once a month.

4. Stock oxalic acid solution: dissolve 60 g of analytical reagent quality oxalic acid dihydrate ($\text{COOH}_2\cdot 2\text{H}_2\text{O}$) in 1000 mL deionized water, and store in a polyethylene bottle. The solution will remain stable indefinitely.

5. Stock sulfuric acid reagent: slowly pour 300 mL of concentrated, analytical reagent quality sulfuric acid into about 500 mL of deionized water in a 1-L volumetric flask. Cool to room temperature, make to 1 L, and store in a polyethylene bottle. The solution will remain stable indefinitely.

Working Solutions

Working solutions are prepared immediately before use.

1. Molybdate working solution: mix equal parts of dilute stock HCl reagent and molybdate stock reagent. This solution is stable for 6–12 hr. Store in a polyethylene bottle.

2. Reducing working solution: mix equal volumes of metol-sulfite stock reagent, oxalic acid stock reagent, and sulfuric acid stock reagent, adding the sulfuric acid last. This solution is stable for 4–6 hr. Do not store; prepare for immediate use. The solution must be allowed to come to room temperature before use (20 min).

Synthetic Seawater

Dissolve 25 g sodium chloride (NaCl) and 8 g magnesium sulfate heptahydrate ($\text{MgSO}_4\cdot 7\text{H}_2\text{O}$) in 1 L of deionized water and store in a polyethylene bottle. The silica content of this solution should not exceed 1–2 $\mu\text{m/L}$.

Standards

1. Primary silicate standard: sodium fluorosilicate. Place a small quantity of Na_2SiF_6 in an open plastic vial in a vacuum desiccator overnight to remove excess water. Do not heat or fuse.

Dissolve 0.9403 g Na_2SiF_6 in deionized water in a 1-L volumetric flask. Dissolution is slow and cannot be rushed, so allow at least 30 min. Use low-conductivity water. The concentration of this standard is 5000 μM . Store in two 500-mL polyethylene bottles. This standard is stable for 6–12 months. It should be kept out of light but never refrigerated.

2. Secondary standards: working standards are prepared from the primary standard by diluting it with synthetic seawater. When making dilutions, use synthetic seawater and store in polyethylene containers. These standards are stable for several weeks. Using a 50-mL volumetric flask, add the primary standard and then bring to 50 mL with synthetic seawater so that the concentration of the zero standard (μM) is 100 times the volume (mL) of primary standard (e.g., 2 mL of primary standard would produce 200 μM of zero standard, 4 mL of primary standard would produce 400 μM of zero standard, and so on). The highest standard should not exceed 2000 μM .

NOTE: These standards do not have the same salinities. However, in the following procedure, samples and standards are all diluted by 20 fold; thus, all standards, blanks, and samples end up with salinities between 1 and 2 per mil. This small difference in salinity causes a negligible salt error.

Procedure

1. Have all reagents prepared. Label 5- or 10-mL plastic vials and caps. Add to the vials accurately in the following order (parentetical values are for the 5-mL vials):

- 2.375 mL (1.900 mL) deionized water
- 1.000 mL (0.800 mL) molybdate working solution, swirl to mix
- 0.125 mL (0.100 mL) of sample standard or blank, swirl to mix.

Start the timer. After exactly 20 min (± 30 s), add 1.500 mL (1.200 mL) of the reducing working solution. Swirl to mix; do not shake. Cap the vials.

2. After 12 hr, but before 24 hr, have elapsed read the absorbance in 1-cm cells in a spectrophotometer peaked at 812 mm.

NOTE: Always run several blanks. Blanks are always composed of the same batch of deionized water used to do the dilutions.

Always run the zero standard, which is not the same as the blanks. The zero standard is included in the calibration curve. The reagent blank absorbance is subtracted from the sample absorbance before multiplying by the calibration factor.

Do not add molybdate to the sample, but add the sample to the molybdate (or to the diluted molybdate).

There is no temperature effect provided all solutions are at room temperature.

Timing is critical. In batch mode with a 20-min limit for the first reaction, one person can react about 40 vials at a rate of one every 30 s.

PALEOMAGNETICS

The magnetic experiments made in the shipboard paleomagnetic laboratory can be subdivided into three complementary parts:

1. Measurement of the natural remanent magnetization (NRM), carried out on split-core sections at 5-cm intervals using the three-axis pass-through cryogenic magnetometer. These measurements provided the values of declination, inclination, and magnetization intensity for the measured intervals.

2. Progressive demagnetization of pilot samples in ac fields up to 100 mT to remove secondary components of magnetization. The pilot samples were measured with the Molspin spinner magnetometer, and the appropriate ac peak field value for demagnetization was determined from inspection of magnetization intensity and vector demagnetization plots. Samples were then demagnetized routinely at the optimum ac peak field value and measured using a special holder placed on the core handler of the cryogenic magnetometer (eight samples were measured in one pass through the sensing region) or using the Molspin spinner magnetometer.

3. Low-field magnetic susceptibility measurements using the Bartington whole-core and discrete sample sensors. Whole-core measurements were made at 5-cm intervals at the same stratigraphic levels used for the split-core NRM measurements. The magnetic susceptibility provides an indication of downhole variations in the concentration of magnetic material.

Magnetostratigraphy

Time scales are syntheses of three independently varying aspects: correlation, calibration, and terminology. We have chosen the time scale of Berggren et al. (1985a, 1985b) as our working model as it is the most complete synthesis available. The calibration of the Berggren et al. (1985a, 1985b) time scale is based on an interpretation of radiometric dates tied into the magnetic polarity pattern and as such, provides reasonable estimates of absolute ages of biostratigraphic events. The accuracy of the dates is probably about 10%, whereas the precision of correlation is much better.

The terminology of the magnetic time scale has experienced dramatic changes and is still in a state of flux. The first magnetic time scale, derived from a worldwide distribution of basalts, was divided into "epochs" (Cox et al., 1963), later named Brunhes, Matuyama, and Gauss (Cox et al., 1964). Hays and Opdyke (1967) extended the epoch system, defining new time units based on the magnetostratigraphy of deep-sea sediments. The magnetic epochs were correlated to the magnetic anomaly pattern, first used by Vine and Matthews (1963) as key evidence for the process of seafloor spreading and then by later workers (e.g., Hays and Opdyke, 1967; Ryan et al., 1974). Because the term epoch has a previously defined connotation in stratigraphy, the Subcommittee on Stratigraphic Nomenclature recommended that magnetic epochs be referred to as "chrons" (Hedberg et al., 1979).

Unfortunately, the long-accepted correlation of Chron 9 to anomaly 5, proposed initially by Ryan et al. (1974), is now considered to be in error (Miller et al., 1985; Berggren et al., 1985a, 1985b). The preferred correlation is now Chron 11 to anomaly 5. Thus, the literature faces the danger of ambiguity from the use of

Miocene chron names. Following LaBrecque et al. (1983), who proposed an anomaly-based chron terminology for the Paleogene, Berggren et al. (1985b) recommend the adoption of the chron structure proposed by Cox (1982) but with the addition of a prefix letter "C." Although in their figure 6 (Neogene time scale) they use the "new-old" terminology, we will use that which is recommended in the text. By adopting an entirely new, anomaly-based chron system, we hope to simplify our magnetostratigraphic terminology.

There is a discrepancy within Berggren et al. (1985a) as to the age assigned to the early/late Oligocene boundary. Berggren et al. (1985a) indicate an age of 30.0 Ma in figure 5, whereas an age of 30.6 Ma is indicated in the text. We adhere to an age of 30.0 Ma for the early/late Oligocene boundary.

PHYSICAL PROPERTIES

Physical-property measurements were made on whole cores and on discrete core samples in order to determine the relationships between the various sediment facies recovered on Leg 114.

The Leg 114 shipboard program for physical-property sampling included the following measurements:

GRAPE

The Gamma Ray Attenuation Porosity Evaluator (GRAPE) was used routinely to log the density variations in whole-core sections. The standard procedures used for calibration are described in Boyce (1976). Because of grain density variations, porosity cannot be reliably determined from the density measurements, and because of variable drilling disturbance downcore, the absolute density values should be used for qualitative purposes only.

The GRAPE is best used to show relative, rather than absolute, density changes along the core for correlation with lithologic changes. This is illustrated by the raw GRAPE data presented in Figure 8 for Cores 114-701C-4H and 114-701C-49X.

Core 114-701C-4H showed no apparent signs of disturbance and filled the liner completely. However, the split core showed some signs of disturbance, especially in Section 114-701C-4H-6 (32.8–34.3 mbsf) and the upper portion of Section 114-701C-4H-1 (25.3–26.8 mbsf) (see core photograph following "Site 701" chapter, this volume). The GRAPE record is less coherent in these sections, and GRAPE density is slightly low. The lower 60 cm of Section 114-701C-4H-6 (33.7–34.3 mbsf) showed signs of flow, and the GRAPE record is flat and featureless for that segment. The sediments consist mostly of mud- and ash-bearing diatom ooze. Certain discrete ash layers are apparent in the GRAPE record as well, at 60–65 cm (27.4–27.45 mbsf), 70–80 cm (27.5–27.6 mbsf), and 130–150 cm (28.1–28.3 mbsf) of Section 114-701C-4H-2. These ash layers can be correlated to ash layers in adjacent holes. Thus, the GRAPE data can be used for cross-hole lithologic correlation.

Core 114-701C-49X, on the other hand, showed outward signs of some biscuiting, did not fill the liner, and would not normally have been processed using the GRAPE. However, the disturbance in Core 114-701C-49X was uniform and apparently occurred in place. Despite the disturbance, definite lithologic changes that are readily apparent in the core show up quite noticeably in the GRAPE record. For example, the changes in the mean GRAPE density level at 95 cm in Section 114-701C-49X-3 (456.75 mbsf) and at 135 cm in Section 114-701C-49X-2 (455.65 mbsf) correlate with changes in the lithology. The "staining" at 40 cm (457.7 mbsf) and 59 cm (457.89 mbsf) in Section 114-701C-49X-4 correlates with an excursion in the GRAPE density in the 40–60-cm interval. A similar zone occurs in Section 114-701C-49X-5, in the GRAPE interval from 60–90 cm (459.4–457.7 mbsf). This example illustrates the sensitivity of the GRAPE density to lithologic variations.

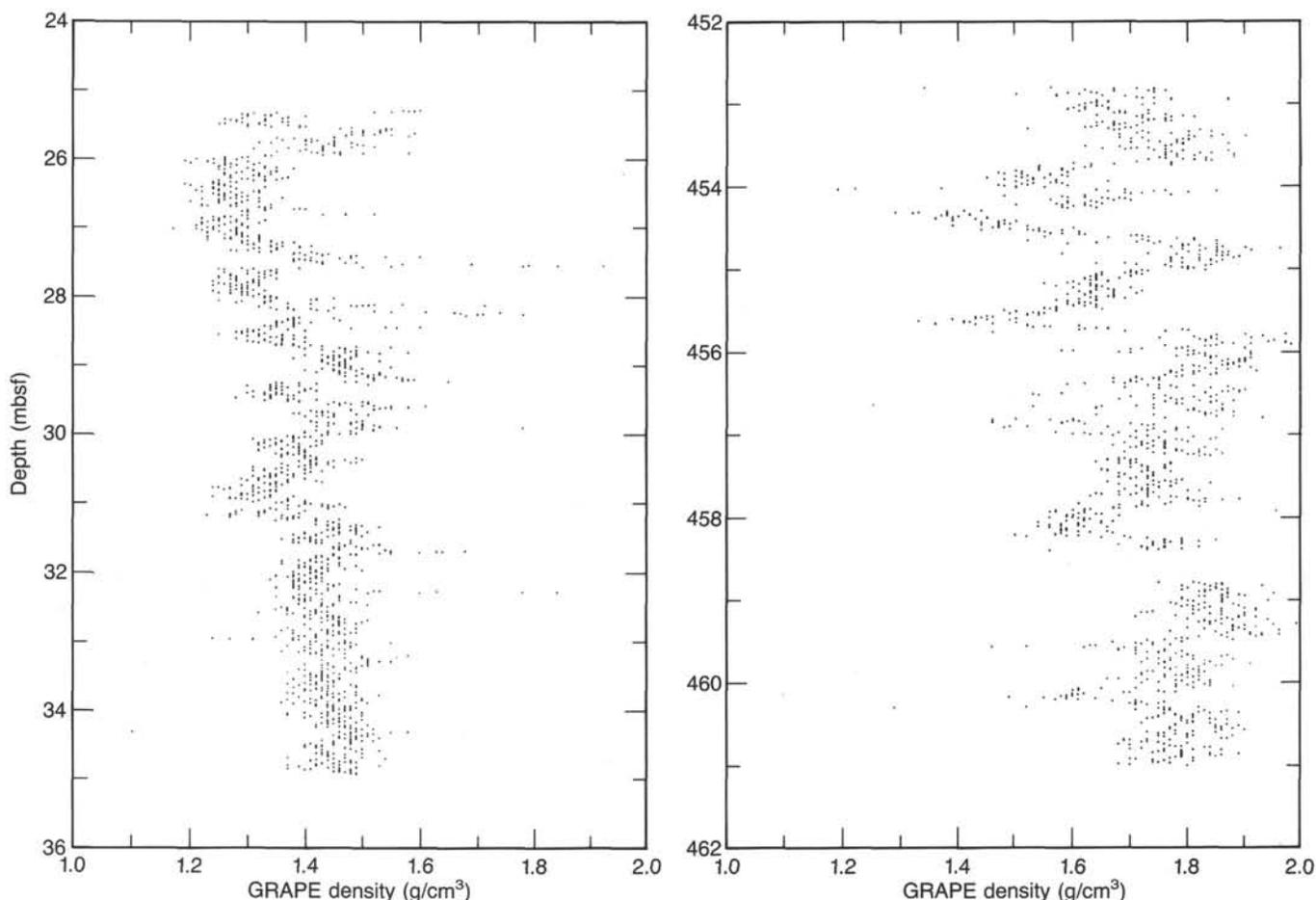


Figure 8. Plots of density measured using the GRAPE from Cores 114-701C-4H and 114-701C-49X.

P-Wave Logger

The *P*-wave logger (PWL) is a compressional- (*P*-) wave whole-core logging tool operated in conjunction with the GRAPE. The raw data were stored on diskettes and then transferred via a DEC PRO-350 personal computer to the VAX. Typical sampling intervals are 2 mm. The system and procedure are detailed in the *Initial Reports of the Proceedings of Leg 108* (Ruddiman, Sarnthein, et al., 1988). As with the GRAPE system, the PWL velocities are best used as indicators of lithologic change and for cross-hole correlation. The absolute velocities tend to be 20 to 100 m/s lower than *P*-wave velocities obtained from Hamilton Frame measurements. This discrepancy might be due to a higher content of gas within the liner; the gas is released upon splitting of liner. PWL data recovery was good in sediments recovered with the APC technique because the sediments completely filled the liner. Diminished data recovery for the PWL (see, for example, Fig. 19, "Site 703" chapter, this volume) occurs in XCB cores, where biscuiting of sediments and unfilled liners lead to severe disturbance of measurements. The GRAPE and PWL are best used together as qualitative lithologic correlation tools.

Hamilton Frame Velocity

Compressional-wave velocity measurements were also made on split cores within the liner and on discrete, indurated samples without the liner. The calibrating and operating procedure was conducted in a manner similar to that described in Boyce (1976). No correction factor was applied to the velocities; the calibration velocities agreed with accepted values within the errors estimated for the procedure, ± 50 m/s, after removal of time delays

caused by the liner, if present, and the cable. Tests indicated that measurements were generally repeatable to within ± 20 m/s, and in one case to within ± 5 m/s (Samples 114-703A-40X-3, 88-90 cm, and 114-703A-40X-3, 90-92 cm).

Index Properties

Index properties include the gravimetric parameters of porosity, water content, bulk density (both wet and dry), and grain density. Samples of 5 to 10 cm³ in precalibrated aluminum containers were taken routinely from each section of the freshly split cores from the first hole of each site and from every other section in the subsequent holes for cross-hole correlation. Wet and dry weights were determined aboard ship using a Scitech electronic balance to a precision of ± 0.01 g, repeatable to within ± 0.04 g. Sample volumes were determined for both wet and dry samples using the Penta Pycnometer to a precision of 10⁻⁴ cm³, repeatable to within 0.05 cm³. The samples were oven dried at 100°C for 24 hr. The index properties, including porosity, were then computed from the weights and volumes as outlined by Boyce (1976). For Site 701 and subsequent sites, the porosity was computed using the equation given by Hamilton (1971). Samples taken for other purposes will also be analyzed for water content, and the data sets will be merged.

Water content is the wet water content, with a maximum value of 100%. Thus, we have a logical pair composed of the porosity and the water content, each of which expresses the fluid fraction as a percent of the total volume, in the case of porosity, or the total weight, in the case of water content. The dry water content, on the other hand, expresses the fluid weight as a

percent of the dry weight, and should logically be paired with the void ratio that expresses the fluid volume as a fraction of the dry volume.

Vane Shear Measurements

Vane-shear-strength measurements were made using the hand-held Torvane apparatus for Site 698. Measurements for subsequent Sites 699 through 704 were made using the motorized vane shear system using a procedure similar to that outlined by Boyce (1977).

Thermal Conductivity

Needle-probe measurements of thermal conductivity (Von Herzen and Maxwell, 1959) were made at least once per core and more frequently, if possible, on whole-core sections. Measurements were controlled by the Thermcon unit. Cores were allowed to equilibrate for at least 3 hr in the core laboratory. Measurement time was 4 min. Acceptable results were achieved from the calibration runs, which were performed when possible. Thermal conductivity values are expressed in standard SI units of watts/meter/kelvin (W/m/K).

DOWNHOLE MEASUREMENTS

Downhole logging measurements determine directly changes in *in-situ* physical and chemical properties of the formation along the length of the borehole. Three different Schlumberger logging tool strings were available on Leg 114: the seismic-stratigraphic combination (sonic velocity, resistivity, gamma-ray, and caliper; SDT/DIPH/GR/CALI), the geochemical combination (induced gamma-ray spectroscopy, aluminum clay tool, and natural gamma-ray spectrometry; GST/ACT/NGT), and the lithoporosity combination (lithodensity, neutron porosity, natural gamma-ray spectrometry, and caliper; LDT/CNL/NGT/CALI). Not all of the three tool strings were used at each of the three sites logged. A detailed description of the physical principles and properties of these parameters are given in a number of publications (e.g., Schlumberger, 1972; Lamont-Doherty Borehole Research, 1985; Serra, 1984). The following is a summary description of the parameters measured.

Sonic

The Schlumberger borehole-compensated (BHC) sonic tool used on Leg 114 is a dual-transmitter, dual-receiver short-spacing tool providing measurements of interval traveltimes and full waveform recordings at 3- and 5-ft (0.91- and 1.52-m) spacings from the transmitter. The transmitter/receiver pairs are geometrically arranged to compensate for tool tilt and borehole size variations. The full waveform train is recorded at each receiver and the *P*-wave arrival is then detected by a threshold/expected arrival time algorithm. An interval transit time is calculated for the difference in arrival time between the two receivers, 2 ft (0.61 m) apart. One automatic compressional-wave arrival pick is recorded. Compressional-wave velocities are computed from interval traveltime and constitute measurements of the *in-situ* velocities. The full waveform data has not yet been analyzed.

Natural Gamma Ray

Two natural gamma-ray logs are usually recorded; the natural gamma spectrometry (NGT) and gamma-ray (GR) logs. The GR log is a total count gamma-ray log that monitors the overall amount of natural gamma radiation emitted from the three major radioactive elements that commonly occur in the formation: potassium (⁴⁰K), uranium (U decay series), and thorium (Th decay series). The NGT tool uses gamma spectrometry technique for quantitative determination of potassium, uranium, and thorium in formations encountered in a borehole. Four logs are acquired with this tool: the total count (spectral) gamma-ray (SGR,

same as the GR log) log that monitors the total radioactivity from the three radioactive elements, the potassium log (wt% K), the uranium log (equivalent uranium in ppm), and the thorium log (equivalent thorium in ppm). Concentrations of these radioactive elements are characteristic of specific environments, and their recognition can contribute significantly to reconstruction of depositional environment. For instance, uranium concentrations in carbonates may indicate horizons enriched in phosphates and/or organic material. Reducing environments, which favor uranium enrichment, are often associated with calm water conditions. Uranium also tends to accumulate in faults or fractures; thus, uranium concentration can indicate fracture zones or calm depositional environment conditions. The main application of the NGT logs is lithologic identification. Thorium and potassium concentrations and their ratios can indicate the presence of micaceous clay minerals, which can provide an estimate of the clay content in carbonate sediments. Th and K logs may also be used in determining the type of clays minerals present in the formation.

Resistivity

Resistivity tools used on Leg 114 were a new, digital phasor, dual induction (DIPH) tool and an analog dual induction (DIL) tool. The DIPH is essentially an improvement on the DIL; it measures higher resistivities than those normally recorded by the DIL and has better borehole compensation. Both the DIPH and the DIL provide three resistivity logs, each with a different depth of investigation. The spherically focused log (SFL) has a shallow depth of penetration into the formation (10–13 cm), the medium induction log (IMPH or ILM) penetrates about 60–120 cm, and the deep induction log (IDPH or ILD) has a depth of penetration between 3 and 3.6 m. Resistivity variations within carbonate sediments are mainly a function of temperature, porosity, and salinity of the pore fluids because the conducting medium is mainly pore water. The presence of clay minerals, however, decreases the resistivity of the formation. Because resistivities primarily reflect porosity changes in the formation, apparent porosities can be determined from the resistivity logs using Archie's (1942) law. The porosities are only approximate because variations in borehole diameter and clay content affect the apparent resistivities. In the Leg 114 site chapters, the resistivities were not corrected for the borehole diameter effects or changes in the salinity of the formation. However, the caliper log was used to qualitatively monitor the effects of changes in borehole diameter on the resistivities. Conductivities are computed as the reciprocal of resistivity and are presented in the site chapters.

Induced Gamma-Ray Spectroscopy

The induced gamma-ray spectroscopy (GST) tool is a neutron-activation tool. A pulsed neutron accelerator bombards the adjacent formation with high-energy neutrons and then measures the time-varying energy spectrum of the gamma rays produced by the bombardment. Each element has a "characteristic" spectral response to the neutron bombardment. The presence of six elements is inferred from the GST: silicon (Si), calcium (Ca), iron (Fe), chlorine (Cl), hydrogen (H), and sulfur (S). This tool does not provide a quantitative elemental composition but rather the relative proportions of the six elements (Ca, Cl, Si, Fe, H, and S), which sum to equal one. The raw count rates for each element (elemental yields) therefore provide a qualitative variation in elemental composition along the borehole. Research is currently underway to quantify these measurements. Interpretation of the GST data consists mainly of using ratios of the relative elemental proportions for lithologic identification, porosity estimates, and determinations of the salinity of the formation fluid. Four elemental-yield ratios were rou-

tinely determined and used in the interpretation of the Leg 114 GST data. The lithology indicator ratio (LIR), the ratio of counts of silicon to the sum of silicon plus calcium, was used as a semiquantitative indicator of the relative abundance of quartz and biogenic silica to calcite. The presence of clay minerals, however, complicates the interpretation of the LIR ratio. The iron indicator ratio (IIR), the ratio of iron counts to the summed silicon plus calcium counts, can be a good measure of the total iron concentration along the borehole, provided that there are no significant variations in aluminum in the clays. The porosity indicator ratio (PIR) is the ratio of hydrogen counts to the sum of silicon plus calcium counts. The PIR measures indirectly the total amount of free water (pore spaces) plus bound water (in clay minerals) by detecting hydrogen abundance. The salinity indicator ratio (SIR), the ratio of chlorine counts to hydrogen counts, is essentially a chlorinity indicator ratio. Because bound water in clays contains hydrogen and may contain a significant and variable amount of chlorine, the SIR ratio should be used with caution. The best application is in formations lacking clay minerals.

A major advantage of the GST tool is that it works through drill pipe. When logging through pipe, however, the iron counts will be affected by the varying thickness and/or varying iron content of the pipe, and careful data reduction is required if one is to interpret the IIR ratio with confidence. A major disadvantage of the GST is that multiple passes at a slow logging speed (150–200 m/hr) generally are required to accurately characterize the energy spectrum. On Leg 114, the GST was run through open hole and through pipe. Because of time constraints, only single passes were run in combination with the aluminum clay tool (ACT) and the NGT; this affected the statistics built into the interpretation. The ACT has a Californium (Cf) source that primarily activates aluminum (Al) and manganese (Mn). The concentrations of Al and Mn are determined from the measured induced gamma-ray activity. If properly calibrated, absolute elemental concentrations of Al (wt%) and relative variations in Mn are determined. The combination of Al, Fe, and K may be used to determine the percentage of clay minerals in sediment.

Density

The lithodensity tool (LDT, also known as gamma-gamma density) uses two detectors. The short-spacing detector is much more sensitive to the density of the material immediately adjacent to the face of the probe. The density computed from the near detector is used to correct, or to "compensate," the density computed from the far detector for effects of tool standoff resulting from mud cake or borehole rugosity. The LDT tool measures the back-scattered gamma rays emitted by a Cesium (^{137}C) source, and two energy windows (low and high) are analyzed for the far detector. Gamma rays with energies less than 1.01 MeV interact with atoms in the formation mainly by Compton scattering and through photoelectric effect. Gamma rays with energies of 150 keV and higher are used in the density computation because they are subject mainly to the Compton scattering process, on which the density computation is based. The bulk density of the formation is determined from the Compton scattered gamma rays, which are a function of the electron density of the rock and its matrix. The low-energy gamma rays (below 0.06 MeV) are subject to photoelectric absorption. Therefore, the low-energy window is used to monitor photoelectric effects. The LDT log uses the ratio of the low- to high-energy windows to compute the photoelectric index (Pe). Because photoelectric absorption is mainly a function of the atomic number Z , Pe is used as a lithology indicator. The depth of investigation of the LDT is usually less than 10 cm.

Neutron Porosity

The neutron tool (CNL) uses a chemical radioactive source to excite the formation with neutrons. Neutrons with both thermal and epithermal energies are captured by the nuclei in the formation, and each capture is accompanied by gamma-ray emission with energy dependent on the atom. The CNL measures the hydrogen index of the formation by determining the amount of neutrons by hydrogen atoms. Porosity is then inferred from the hydrogen index assuming 100% water saturation. The CNL tool used on Leg 114 has two detectors, near and far, again to compensate for variations in borehole size. Assuming water saturation in a hydrocarbon-free environment, the CNL measures the total water content of the formation, including pore water and bound water in clay minerals. "True" formation porosity can be determined from the CNL if clay minerals are lacking in the formation. The depth of investigation of the tool is less than 30 cm.

Caliper and Tension Logs

Other auxiliary parameters measured include measurements of the hole diameter and cable tension during a logging run. The hole diameter is measured with a caliper (MCD or CALI) consisting of a three-arm bowspring device. Caliper measurements are primarily used for correcting log responses that are sensitive to hole size. The tension measurements also monitor the hole conditions and the performance of the heave compensation device.

Log Processing

During logging, incoming data were monitored in real time on an oscilloscope and simultaneously recorded digitally on tape in the Schlumberger logging unit. The Schlumberger tape format records data at 800 bpi and cannot be directly read on the 1600-bpi tape drive used with the Masscomp computer system in the shipboard downhole logging laboratory. Therefore, after logging, the Schlumberger tape was copied from 800- to 1600-bpi tape, and then read by the Masscomp and reformatted to Terralog log-interpretation format. The Terralog log-interpretation package is an interactive system with various log processing, interpretation, and display options. Preliminary log interpretations were carried out aboard the *JOIDES Resolution*, and more detailed analyses will be done at the Borehole Research Laboratory of Lamont-Doherty Geological Observatory and by the Borehole Geophysics Research Group of the Geological Survey of Canada.

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