2. EXPLANATORY NOTES[1]

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RESPONSIBILITIES FOR AUTHORSHIP

The authors of the three site chapters are the shipboard party collectively, ultimate responsibility lying with the two chief scientists and the DSDP staff representative. Chapters 3, 4, and 5 present data and discussions of the holes drilled. All site chapters follow the same general outline (authors' names in parentheses).

Site summary data
Background and objectives (Karig, Kagami)
Operations (Kagami)
Sedimentology (Cadet, Charvet, Coulbourn, Fujioka, Leggett, Lundberg, Matsumoto, Smith, Stein, Taira)
Structural geology (Lundberg, Karig)
Biostratigraphy (Akiba, Lagoe, Lang, Lombari)
Sediment accumulation rates (Coulbourn, Akiba, Cadet, Lombari)
Inorganic geochemistry (Matsumoto, Stein)
Organic geochemistry (Machihara, Mukhopadhyay, Stein)
Physical properties (Bray, Karig)
Paleomagnetics (Niitsuma)
Heat flow (Kinoshita)
Logging (Karig)
Correlation of drilling results and seismic profiles (Kagami)
Summary and conclusions (Karig)
References

The interpretations of individual authors have been retained in the section for which they were responsible. Therefore, conflicting interpretations within a particular section and between an individual section and a summary are sometimes apparent. Authors of special-topic chapters and the synthesis chapters are given at the beginning of each chapter.

SURVEY AND DRILLING DATA

The survey data used for specific site selections are given in each site chapter. On passage between sites, continuous observations were made of depth, magnetic field, and sub-bottom structure. We used a precision echo sounder, seismic profiler, and magnetometer to make short surveys on *Glomar Challenger* before dropping the beacon.

Depths were continuously recorded underway on a Gifft precision graphic recorder. The depths were read on the basis of an assumed 1463 m/s sounding velocity. The sea depth (in meters) at each site was corrected (1) according to the tables of Matthews (1939) and (2) for the depth of the bull transducer (6 m) below sea level. In addition, any depths referred to the drilling platform have been calculated on the assumption that this level is 10 m above the water line.

The seismic-profiling system consisted of two Bolt air guns, a Scripps-designed hydrophone array, Bolt amplifiers, two bandpass filters, and two EDO recorders, usually recording at two different filter settings.

Drilling Characteristics

Because water circulation down the hole is open, cuttings are lost onto the sea bed and cannot be examined. The only available information about sedimentary stratification between cores, other than from seismic data, is provided by 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 to penetrate. A number of other variable factors, however, determine the rate of penetration, so it is not possible to relate penetration rate directly to the hardness of the layers. Among these, the parameters of bit weight and revolutions per minute are recorded on the drilling recorder.

Drilling Deformation

When the cores were split, many showed signs that the sediment had been disturbed since its deposition. Such signs were the concave-downward appearance of originally plane bands, the haphazard mixing of lumps of different lithologies, and the near-fluid state of some sediments recovered from tens or hundreds of meters below the sea bed. It seems reasonable to suppose that this deformation came about during or after the cutting of the core. Three different stages during which the core may suffer stresses sufficient to alter its physical characteristics are (1) cutting, (2) retrieval (with accompanying changes in pressure and temperature), and (3) core handling on board.

SHIPBOARD SCIENTIFIC PROCEDURES

Numbering of Sites, Holes, Cores, Sections, and Samples

DSDP drill sites are numbered consecutively from the first site drilled by *Glomar Challenger* in 1968. Site numbers are different from hole numbers. A site number refers to one or more holes drilled while the ship was positioned over one acoustic beacon. These holes could be within a radius as great as 900 m from the beacon. Several holes may be drilled at a single site by pulling the

[1] Kagami, H., Karig, D. E., Coulbourn, W. T., et al., *Init. Repts. DSDP*, 87: Washington (U.S. Govt. Printing Office).

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drill pipe above the seafloor (out of one hole), moving the ship 100 m or more from the previous hole, and then drilling another hole.

A letter suffix distinguishes additional holes drilled at the same site. The first hole takes only the site number; the second takes the site number with suffix A; the third takes the site number with suffix B, and so forth. It is important, for sampling purposes, to distinguish the holes drilled at a site, because recovered sediments or rocks from different holes usually do not come from equivalent positions in the stratigraphic column.

The cored interval is measured in meters below the seafloor. The depth interval of an individual core is the depth below seafloor that the coring operation began to the depth that the coring operation ended. Each coring interval is generally 9.5 m long, which is the nominal length of a core barrel; however, the coring interval may be shorter. "Cored intervals" are not necessarily 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; however, if thin, hard rock layers are present, it is possible to retain samples of these resistant layers within the washed interval and thus have a core longer than 9.5 m.

Cores taken from a hole are numbered serially from the top of the hole downward. Core numbers and their associated cored interval in meters below the seafloor are normally unique for a hole; however, problems may arise if an interval is cored twice. When this occurs, the core number is assigned a suffix, such as "S" for supplementary (the designation "S" has been used in previous legs as a prefix to the core number for sidewall core samples).

Full recovery for a single core is normally 9.28 m of sediment or rock in a plastic liner (6.6 cm inner diameter), plus about a 0.2-m sample (without a plastic liner) in the core catcher. The core catcher is a device at the bottom of the core barrel; it 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 cut into 1.5-m sections and numbered serially from the top of the sediment core (Fig. 1). When full recovery is obtained, the sections are numbered from 1 through 7, the last section possibly being shorter than 1.5 m. The core catcher sample is placed below the last section when the core is described; it is labeled core catcher (CC) and treated as a separate section (for sediments only).

When recovery is less than 100%, 1.5-m sections are numbered serially, starting with Section 1 at the top. There will be as many sections as are needed to accommodate the length of the core recovered (Fig. 1); for example, 3 m of core sample in plastic liners will be divided into two 1.5-m sections. The last section may be shorter than the normal 1.5 m.

When recovery is less than 100%, the original stratigraphic position of the sediment in the cored interval is unknown; we attribute the top of the recovered sediment to the top of the cored interval. The purposes of this convention are convenience in data handling and consistency. If recovery is less than 100%, if the core is fragmented, and if shipboard scientists believe that the fragments were not originally contiguous, the sections are numbered serially and the intervening sections are noted as void, whether the fragments as found were contiguous or not.

Samples are designated by distances in centimeters from the top of each section to the top and bottom of the sample in that section. A full identification number for a sample consists of the following information: leg, site, hole, core, section, and interval in centimeters from the top of the section. For example, the sample identification number "87-582B-30-3, 98–100 cm" describes a sample taken between 98 and 100 cm from the top of Section 3 of Core 30, from the third hole drilled at Site 582 during Leg 87. A sample from the core catcher of this core is designated "87-582B-30,CC (8–9 cm)."

The depth below the seafloor for a sample numbered "87-582B-30-3, 98–100 cm" is the sum of the depth to the top of the cored interval for Core 30 (327.9 m) and the 3 m included in Sections 1 and 2 (each 1.5 m long) and the 98 cm below the top of Section 3. The sample in question is located at 331.88 m sub-bottom, which in principle is the sample depth below the seafloor (sample requests should refer to a specific interval within a core section, rather than the depth below seafloor).

Center-bit cores are designated as X cores; one of these was taken at Hole 582B in an effort to clear the bit of any plug present. Because the sediment retrieved in the process cannot be assigned to any definite sub-bottom interval, the core is merely listed in sequence.

Conventions regarding the cataloging of the cores recovered by the hydraulic piston corer (HPC) are the same as those for the rotary cores, except that sediment can extrude from the top of the core liner, a common occurrence in the gassy sediments of the Leg 87A study area. Section 0 contains that sediment and, unlike the normal 1.5-m section, is no longer than the length of sediment recovered. This system differs from the labeling scheme used on Legs 1 through 45, which had a designation called "zero section", but did not have a "number 7 section."

Handling of Cores

A core is normally cut into 1.5-m sections, sealed, and labeled on the rig floor; the sections are then brought into the core laboratory for processing. The following determinations are normally made before the sections are split: gas analysis, thermal-conductivity analysis (soft sediment only), and continuous wet-bulk density determinations using the gamma ray attenuation porosity evaluator (GRAPE).

The cores are then split longitudinally into working and archive halves, either by wire cutter, or by supersaw. The contrast in appearance between cores cut by the two methods can be significant. Samples extracted from the working half include those for measurement of sonic velocity by the Hamilton Frame method, measurement of wet-bulk density by a GRAPE technique, carbon-carbonate analysis, measurement of calcium-carbon-

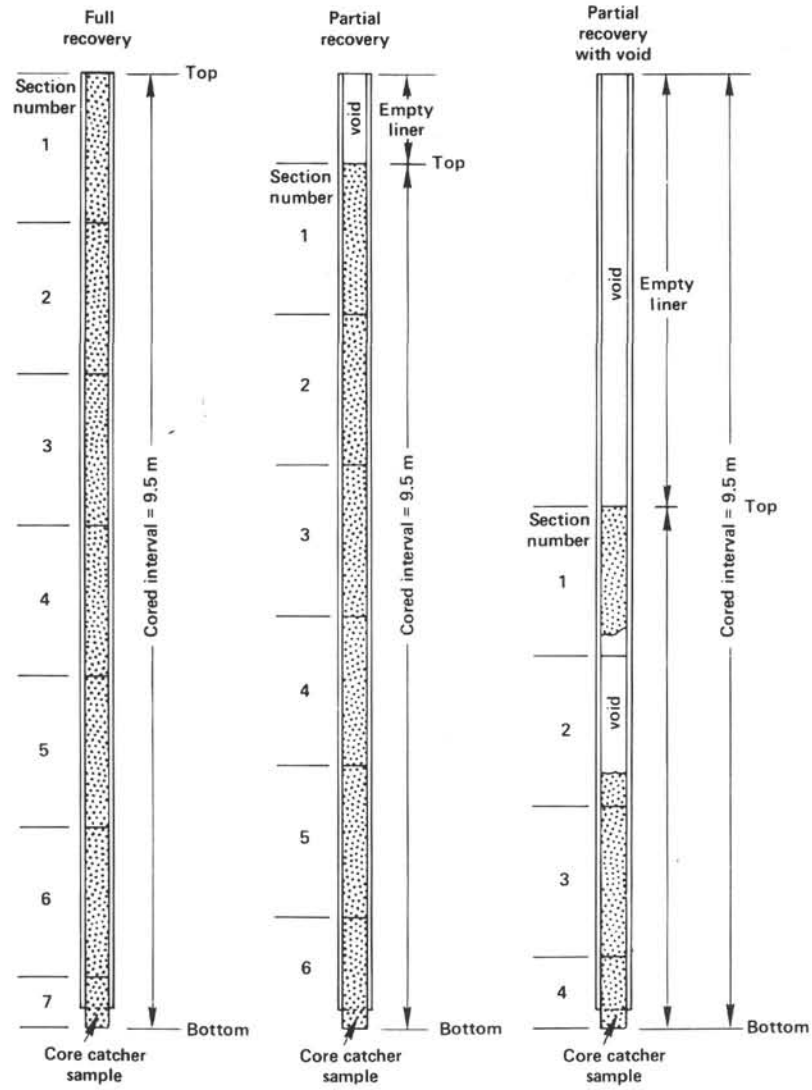

Figure 1. Cutting and labeling procedure for core sections.

ate percentage (carbonate bomb), geochemical analysis, paleontologic studies, and other studies. When sufficiently firm, the archive half is washed on the cut surface to emphasize the sedimentary features. The color, texture, structure, and composition of the various lithologies within a section are described on standard visual core description sheets (one per section), and any unusual features are noted. During Leg 87, a smear slide is made, usually from the first section of each core at 50 cm if the core is uniform. Two or more smear slides are often made for each area of distinct lithology in the core section. The smear slides are examined by petrographic microscope, and then the archive half of the core section is photographed.

After the cores are sampled and described, they are maintained in cold storage aboard *Glomar Challenger* until transferred to the DSDP repository. Core sections that are removed for organic-geochemistry study are frozen immediately on board and kept frozen. All Leg 87 cores and frozen cores are presently (1985) stored at the DSDP West Coast Repository (Scripps Institution of Oceanography).

Rock and sediment obtained from core catchers and not used in the initial examination are retained in core liners for subsequent work. Sometimes significant pebbles from the core are extracted and stored separately in labeled containers. Sometimes the liners contain only sediment-laden water; this usually is collected in a bucket and allowed to settle, the residue being stored in freezer boxes.

Visual core descriptions, smear-slide descriptions, carbonate-bomb (percent $CaCO_3$) determinations (all done on board) provide the data for the core descriptions in this volume. This information is summarized and sample locations in the core are indicated on the core description sheets (Fig. 2).

Core Description Forms for Sediments and Sedimentary Rocks

Drilling Disturbance

Recovered rocks, particularly soft sediments, may be extremely disturbed. This mechanical disturbance is a result of the coring technique, which uses a 25-cm-di-

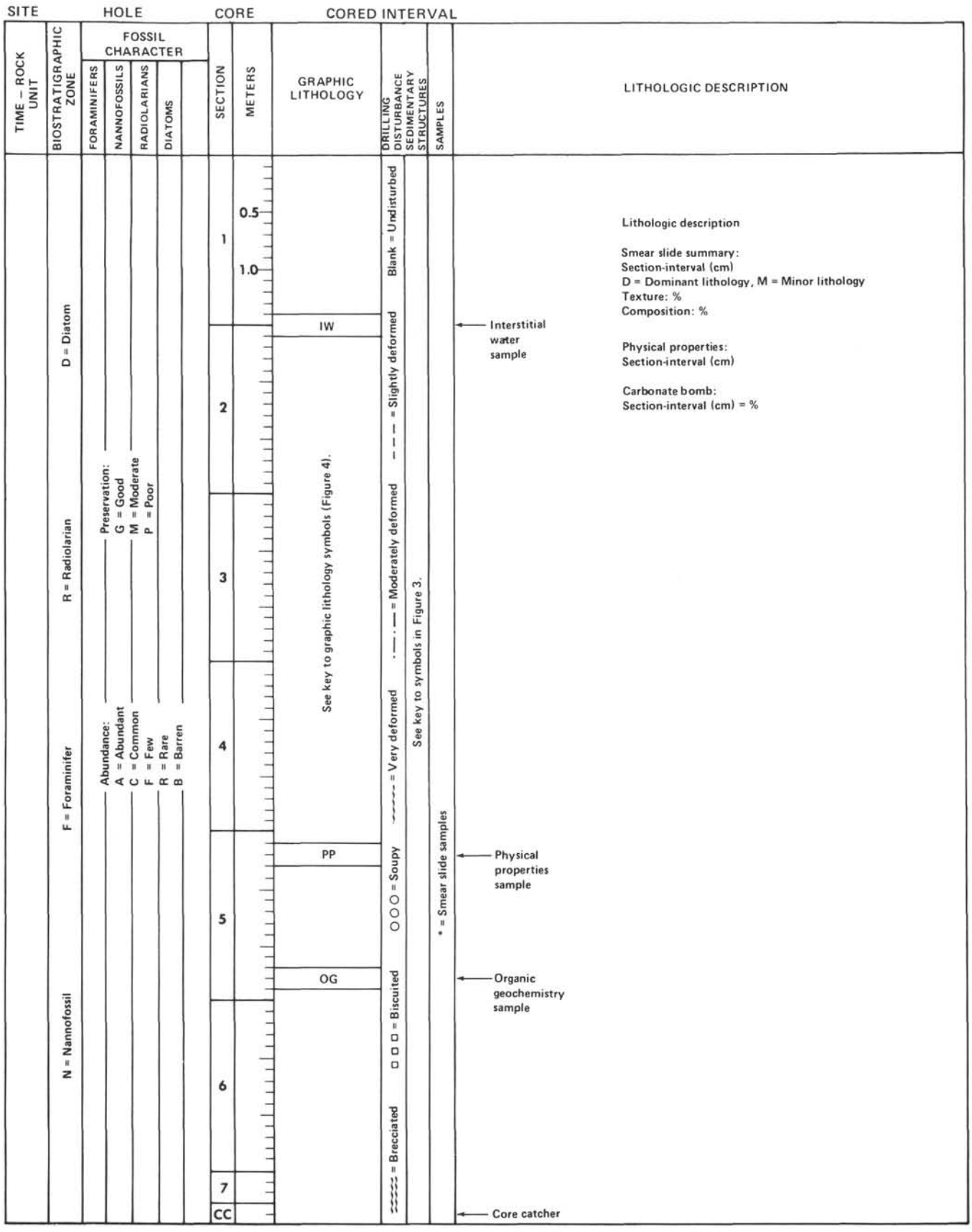

Figure 2. Sample core form for description of sediment (barrel sheet).

ameter bit with a 6 cm-diameter opening for the core sample. Symbols for the six disturbance categories used for soft and firm sediment are shown in Figure 2 and are entered in coded form in the column labeled "Drilling disturbance."

The disturbance categories are defined as follows:

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

Sedimentary Structures

In the soft, and even in some harder, sedimentary cores, it may be extremely difficult to distinguish between natural structures and structures created by the coring process. Thus, the description of sedimentary structures is optional. Locations and types of structures appear as graphic symbols in the "Sedimentary structures" column on the core description form (Fig. 2). Figure 3 displays the key for these symbols.

Color

Colors of the core samples are determined with the Geological Society of America Rock-Color Chart. Colors are determined immediately after the cores are split and while cores are wet.

Lithology

The "graphic lithology" column on the core description form is based on the lithologies, and the sediment is represented by a single pattern or by a grouping of two or more symbols (Fig. 4). The symbols in a grouping correspond to end members of sedimentary compositional ranges, such as clay or nannofossil ooze. The symbol for the terrigenous constituent appears on the right-hand side of the column, the symbol for the biogenic constituent(s) on the left-hand side of the column. The abundance of any component approximately equals the percentage of the width of the "Graphic lithology" column its symbol occupies. For example, the left 20% of the column may have a diatom ooze symbol, whereas the right 80% may have a silty, clay symbol, indicating sediment composed of 20% diatoms and 80% mud.

Because of the difference in the length-to-width ratio between the actual sediment core and the Graphic lithologic column, it is not possible to reproduce structures as they appeared in the core; in the graphic representation they are highly flattened and distorted. The same is true for rock fragments or pebbles in the cores. As a result, the locations of pebbles are shown by a solid square and the depth of small "patches" of ash or other lithologic changes are given by triangular inset of the appropriate lithologic symbol on the right side of the lithologic column (Figs. 2 and 3). This convention applies also to beds thinner than 10 cm. Voids less than 10 cm are not shown.

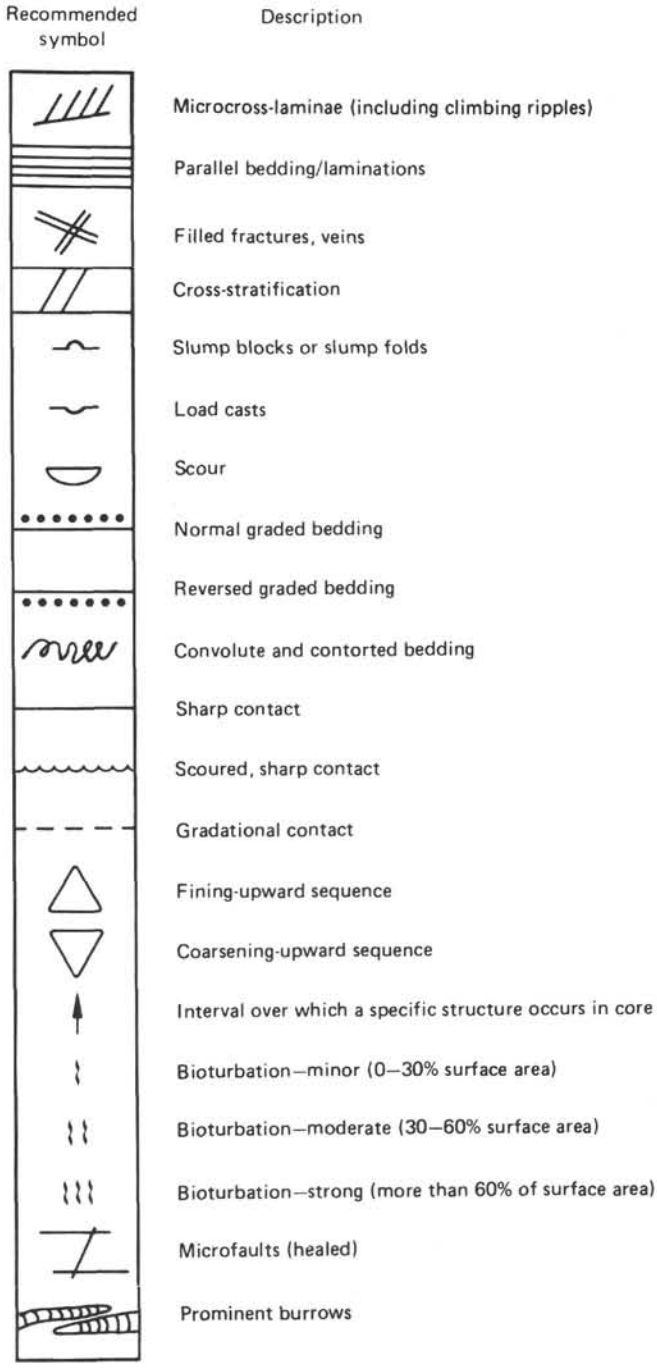

Figure 3. Symbols of sedimentary structures used on core description forms (sediment).

Smear-slide (or thin-section) compositions, carbonate content (percent $CaCO_3$), and organic carbon content determined on board are listed below the core description; the two numbers separated by a hyphen refer to the section and centimeter interval, respectively, of the sample. The locations of these samples in the core

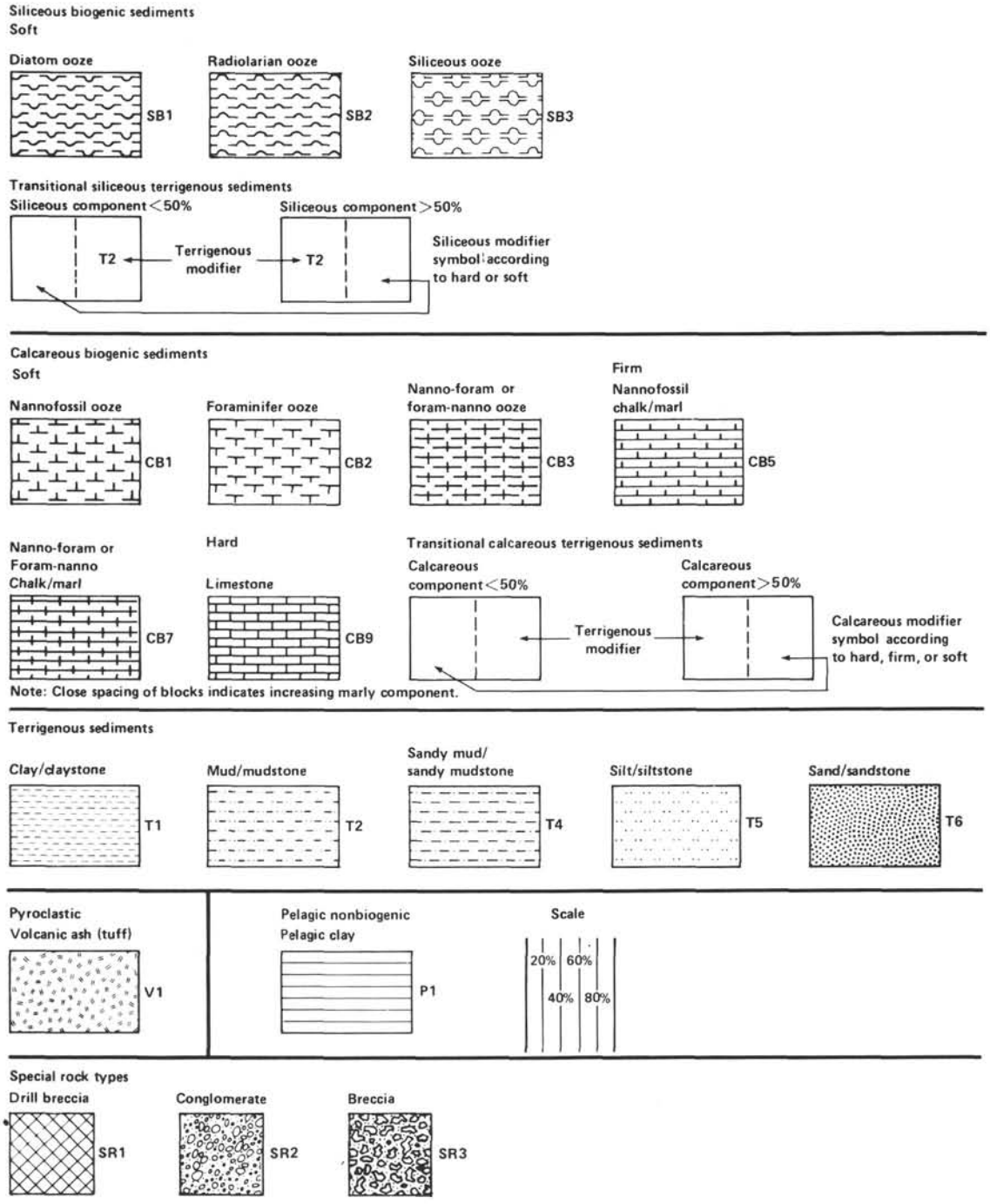

Figure 4. Symbols used in graphic lithology columns of core description forms (sediment).

and a key to the codes used to identify these samples are given in the "Samples" column (Fig. 2). Locations and intervals of organic geochemistry (OG), interstitial water (IW), and physical property (PP) samples are given in the "Graphic lithology" column.

Lithologic Classification of Sediments

The basic classification system used here was devised by the JOIDES Panel on Sedimentary Petrology and Physical Properties (SPPP) and adopted for use by the JOIDES Planning Committee in March 1974. Leg 87 shipboard scientists have modified this classification because of the dominant hemipelagic nature of the sediments recovered and the difficulty in accurately determining silt/clay ratios in smear slides.

This classification is descriptive rather than generic, and divisions between different types of sediment are somewhat arbitrary. We treat lithologic types not covered in this classification as a separate category termed Special Rock Types. A brief outline of the conventions and descriptive data used to construct this classification follows (see Fig. 5).

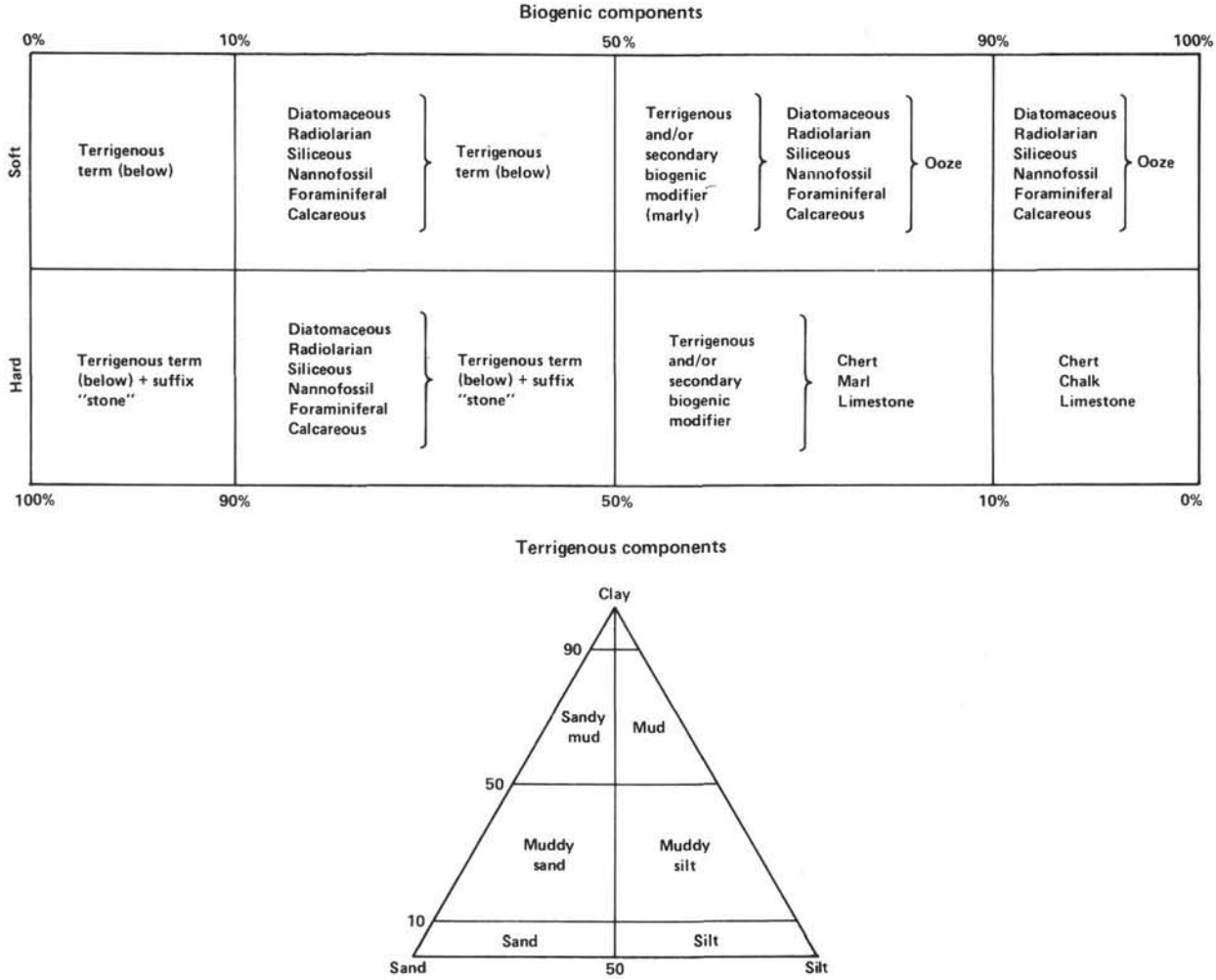

Figure 5. Textural classification of clastic sediments.

Conventions and Descriptive Data

Composition and Texture

In this classification, composition and texture are the only criteria used to define the type of sediment or sedimentary rock. Composition is more important for describing sediments deposited in the open ocean, and texture becomes significant for hemipelagic and nearshore sediments. These data come principally from visual analyses of smear slides with a petrographic microscope. They are estimates of abundance of and size of the components on a slide and may differ somewhat from more accurate analyses of grain size, carbonate content, and mineralogy presented in related shore-based studies. From past experience, we find quantitative estimates of distinctive minor components to be accurate to within 1 to 2%, but for major constituents accuracy is poorer, ±10%. All smear-slide estimates are done on board.

When applicable, one or several modifiers are used to name the type of sediment encountered. In all cases the dominant component appears last in the name; minor components precede, with the least common constituent listed first. Minor constituents occurring in amounts less than 10% are not included in the name. This convention also holds for zeolites, iron and manganese micronodules, and other evidence (such as fish bones) that indicates very slow sedimentation rates or nondeposition. Often these minerals are conspicuous even though greatly diluted. If deemed important, as graded beds and *Chondrites* were on Leg 87, minor constituents are sometimes included in the name of the sediment or mentioned in the lithologic description.

Induration of Sediments

We recognize three classes of induration or lithification for all sediments.

1. Calcareous sediments and sedimentary rocks (categories after Gealy et al., 1971). (1) soft = ooze; has little strength and is readily deformed under pressure of finger or broad blade of spatula; (2) firm = chalk; is partially lithified and readily scratched with fingernail or edge of spatula; (3) hard = limestone, dolostone; is well lithified and cemented, resistant or impossible to scratch with fingernail or edge of spatula.

2. The three classes of induration for transitional carbonates, siliceous, pelagic, and terrigenous sediments are as follows: (1) soft = may be split with wire cutter; (2) firm = is partially lithified but fingertip pressure leaves

an indentation; (3) hard = cannot be compressed with fingertip pressure.

Types of Sediment and Compositional Boundaries

Pelagic Clay

Pelagic clay is principally an authigenic pelagic deposit that accumulates at very slow rates. The class has often been termed brown clay or red clay, but because these terms are confusing we did not use them.

1. The boundary of pelagic clay with terrigenous sediments occurs where authigenic components (Fe/Mn micronodules, zeolites), fish debris, and other microfossil constituents reach 10% in smear slides, indicating pelagic clay. Because the accumulation rates of pelagic clay and terrigenous sediments are very different, transitional deposits are exceptional.
2. The boundary of pelagic clay with siliceous biogenic sediments occurs where siliceous remains make up 30% of the sediment.
3. The boundary of pelagic clay with calcareous biogenic sediment is uncommon. Generally, this facies passes from pelagic clay through siliceous ooze to calcareous ooze, with one important exception: at the base of many ocean sections, black, brown, or red clays occur directly on basalt, overlain by or grading up into calcareous sediments. Most of the basal clayey sediments are rich in iron, manganese, and other metallic trace elements.

Pelagic Siliceous Biogenic Sediment

Pelagic siliceous biogenic sediment is distinguished from pelagic clay by having more than 30% siliceous microfossils. Siliceous biogenic sediments are distinguished from calcareous biogenic sediments by a calcium carbonate content of less than 30%. These sediment types were rarely encountered on Leg 87.

For a pelagic biogenic siliceous sediment with ~30–100% siliceous fossils, the following terminology is used: (1) soft: siliceous ooze (radiolarian ooze or diatomaceous ooze, depending on the dominant fossil component); (2) hard: radiolarite, diatomite, chert, or porcellanite; (3) compositional qualifiers: diatoms and radiolarians may be the principal components, thus one or two qualifiers may be used. The order of the two qualifiers in the terms is dependent on the dominant fossil type. The most dominant component is listed last and the minor component listed first.

Pelagic Biogenic Calcareous Sediment

Pelagic calcareous sediment is distinguished by a biogenic $CaCO_3$ content in excess of 30%. There are two classes: (1) pelagic biogenic calcareous sediments that contain 60 to 100% biogenic $CaCO_3$ and (2) transitional biogenic calcareous sediments that contain 30 to 60% $CaCO_3$. These sediment types were not encountered on Leg 87.

For the pelagic biogenic calcareous sediment with 60 to 100% $CaCO_3$, the following terminology is used: (1) soft for calcareous ooze; (2) firm for chalk; (3) hard and cemented for limestone; (4) compositional qualifiers (if nannofossils and foraminifers are the principal components, then one or two qualifiers may be used).

The transitional biogenic calcareous sediments with 30 to 60% $CaCO_3$ are termed marl or marlstone, depending on whether they are soft or hard.

Terrigenous Sediment

Terrigenous sediments are distinguished by a terrigenous component in excess of 30% and by siliceous and authigenic components each less than 10%. These are the most common sediment types encountered on Leg 87.

Sediments in this category are subdivided into textural groups by smear-slide estimation or grain-size analysis on the basis of the relative proportions of sand, silt, and clay. The size limits are those defined by Wentworth (1922). Textural classification follows the triangular diagram (Fig. 5).

The transition between pelagic and terrigenous sediments is termed hemipelagic. This is the dominant type of sediment encountered during continental margin drilling and is treated separately.

Hemipelagic Sediment

Hemipelagic sediments are distinguished by a terrigenous component in excess of 30%, a total nonbiogenic component in excess of 40%, and a biogenic silica content in excess of 10%. Besides the terrigenous component, hemipelagic sediments are usually rich in biogenic silica (usually diatoms, because of coastal upwelling) and volcanic ash (predominantly along active margins). The classification of these sediments by dominant components can be represented by a triangle in which the peak and each corner represent 100% of a specific component: 100% clay at the peak, and 100% silt and 100% sand at the corners of the base. The percentage of silt and clay used in the diagram (Fig. 5) refers only to terrigenous components. Authigenic minerals, ash, and biogenic particles are not included.

For biogenic opal contents greater than 10%, the dominant siliceous biogenic component should be used in the name. We have used the term siliceous in the diagram (Fig. 5), but when other identifiable biogenic siliceous components dominate, terms such as radiolarians, radiolarite, or spicular may be used.

Components such as sand, diatoms, radiolarians, spicules, and ash may be used as qualifiers to the original sediment description if their abundance is 10 to 30% of the sediment. Within the textural group and the component group, the modifiers are listed in order of increasing sedimentary abundance.

Volcanogenic Sediment

Pyroclastic rocks are described according to the textural and compositional scheme of Wentworth and Williams (1932). The textural groups are: more than 32 mm—volcanic breccia, 32 to 4 mm—volcanic lapilli, and less than 4 mm—volcanic ash (tuff when indurated). The composition of these pyroclastic rocks are described as vitric (glass), crystalline, or lithic.

Sediments rich in ash are described in the following manner:

Ash (%)	Soft sediment	Indurated
0–10	Mud	Mudstone
10–30	Vitric mud	Vitric mudstone
30–60	Muddy ash	Tuffite
>60	Ash	Tuff

Qualifiers

In general, sediments containing various constituents in the 10 to 30% range may be identified in the name of sediment (e.g., vitric diatomaceous mud or vitric muddy diatomaceous ooze). If more than one such qualifier is used, they are listed in order of increasing abundance in the sediment.

Biostratigraphy and Basis for Age Determination

Microfossil zonation of sediments cored on Leg 87 is constructed to varying degrees on the basis of the following references:

Foraminifers. Foraminiferal zones are based on Berggren and Van Couvering (1974), Blow (1969), Keller (1979a, b, 1980), Thompson (1980), Saito and others (1981).

Nannofossils. Bukry's (1973, 1975) zonation is used primarily; zone boundaries in the Pleistocene are modified on the basis of recent work done by Gartner (1977) and Čepek and Wind (1979).

Radiolarians. Zonation for radiolarians is based on Kling (1981) and Reynolds (1980).

The schemes for these zonations are shown in each of the site chapters in this volume (Fig. 14, Site 582; Fig. 17, Site 583; and Fig. 22, Site 584).

The following letters are used on core description sheets to indicate fossil abundance.

A = abundant (flood, many species and specimens)
C = common (many species, easy to make age assignment)
R = rare (enough for age assignment)
T = trace (few species and specimens, not enough for age assignment)
B = barren

Letters used to designate fossil preservation are as follows.

E = excellent (no dissolution or abrasion)
G = good (very little dissolution or abrasion)
M = moderate (dissolution and/or abrasion and/or recrystallization very noticeable)
P = poor (substantial or very strong evidence of dissolution and/or abrasion and/or recrystallization)

Shipboard Geochemical Measurements

Carbonate Bomb

Percent $CaCO_3$ was also determined on board ship by the carbonate bomb technique (Müller and Gastner, 1971). In this simple procedure, a sample is powdered and treated with HCl in a closed cylinder. Any resulting CO_2 pressure is proportional to the $CaCO_3$ content of the sample. Application of the calibration factor to the manometer reading ($\times 100$) yields percent $CaCO_3$. Percent error can be as low as 1% for sediments high in $CaCO_3$, and in general an accuracy of ~ 2 to 5% can be obtained.

These data are presented on the core description sheets. The sample interval is designated by two numbers: the section number followed by the top of the sample interval. For example, a sample from Section 584-1-2, 11–12 cm, with 90% calcium carbonate will be represented on the core-description sheet as "2-11 (90%)."

Other Geochemical Analyses

On-board analyses for carbon-carbonate, pH, alkalinity, salinity, calcium, magnesium, and chlorinity are conducted routinely.

A limited number of carbon-carbonate analyses are made using a LECO WR-12 Carbon Analyzer. Sample preparation includes drying, grinding (with a Diamonite mortar and pestle), and weighing-out of two samples (0.1 g each). One of these is analyzed for total carbon after wetting with deionized water and drying. The other, analyzed for organic carbon, is acidified to remove the acid-soluble components, dried, and analyzed. Reproducibility tests are not run, but the total carbon and organic carbon analyses should be near $\pm 4\%$ (relative) and the carbonate near $\pm 2\%$ (absolute).

Interstitial waters are routinely analyzed for pH, alkalinity, salinity, calcium, magnesium, and chlorinity. Sediments are squeezed using a stainless steel press; the water collects in plastic syringes and is then filtered through 0.45-μm, 1-in. millipore filters. Interstitial waters collected with the *in situ* water sampler are filtered through 0.4-μm, 13-mm filters before analysis.

A Corning Model 130 pH meter and a Markson combination electrode were used to determine pH. The pH meter is calibrated with 4.01 and 7.42 buffer standards; all readings are originally in millivolts and later are converted to pH. All pH measurements are made in conjunction with alkalinity measurements.

Alkalinities are determined potentiametrically. Samples (5–10 ml) are first tested for pH, then titrated with 0.1 N HCl. Near the end point, acid is added in 0.01-ml or 0.005-ml increments, and the millivolt readings are noted for each increment. The exact end point is then calculated by the Gran Factor method (Gieskes and Rogers, 1973).

Salinity is calculated from the fluid refractive index, as measured by a Goldberg optical refractometer, using this expression:

$$\text{Salinity (‰)} = 0.55 \times \Delta N$$

where ΔN is the refractive index multiplied by 10^4. The refractometer's calibration is checked periodically using IAPSO standard seawater and deionized water.

Calcium is determined by titrating a 0.5-ml sample with EGTA (a complexing agent); GHA is used as an indicator. To sharpen the end point, the calcium-GHA complex is extracted into a layer of butanol. No correction is made for strontium, which is also included in the result.

Magnesium is determined by titrating a buffered 0.5-ml sample to an Ereochrome Black-T end point, using EDTA (sodium salt) as a titrant. This method analyzes all alkaline earths, including calcium, strontium, and magnesium; concentrations are obtained by subtracting the calcium (which includes strontium) from this analysis.

Chlorinity is determined by titrating a 0.1-ml sample (diluted with 1 ml of deionized water) with silver nitrate to a potassium chromate end point.

Methods and equipment are checked and standardized at each site using IAPSO standard seawater. As a further check, a surface seawater sample is also analyzed and archived. In addition, this sample is used to test for possible drill-water contamination of the interstitial water samples.

Physical Properties—Procedures

A thorough discussion of measurement procedures for physical properties is presented by Boyce (1976), including descriptions of equipment methods, errors, correction factors, and problems related to coring disturbance. Only a brief review of methods employed on Leg 87 is given here.

Velocity

Compressional-wave velocity was measured on the Hamilton Frame Velocimeter by timing a 400-kHz pulse between two transducers and measuring the distance across the sample with a dial gauge. Measurements were made at laboratory temperature and pressure. For consolidated sediments, a piece was removed from the core and trimmed carefully to form two parallel surfaces to ensure good contact with the transducer heads. Water was used to make good acoustical contact between the sample and the transducers.

Calibration measurements of the velocimeter were made through lucite, aluminum, and brass standards of varying thicknesses to obtain a calibration constant for each of three μs/cm settings on the DSDP Tektronix 485 oscilloscope used to make the traveltime measurements. This calibration constant reflects the position picked by the operator as representing the first break from horizontal of the sonic signal. Data from the calibrations remained constant throughout the duration of Leg 87.

An OYO Corporation Model-5217A sonic viewer was also utilized to measure the shear-wave sonic velocity. The device is based on the same principle as that of the Hamilton Frame for compressional sonic-wave measurements. The shear wave is energized with 33-kHz sinusoidal electric power, and the signal received after the specimen is passed through is digitized and stacked until the enhanced signal forms an amplitude prominent enough to be interpreted.

GRAPE

The gamma-ray attenuation and porosity evaluator (GRAPE) was used to determine wet-bulk density based on the attenuation of gamma rays by the sample. Boyce (1976) discusses the theoretical aspects in detail. During Leg 87, the GRAPE was used in two modes: (1) continuous GRAPE, in which most sections of the core were irradiated; continuous "corrected" wet-bulk density (relative to quartz) was plotted on an analog graph; and (2) 2-minute GRAPE, in which the gamma count through a small piece of the core was measured for 2 minutes, followed by a similar count through air and/or a quartz standard.

Continuous GRAPE

Before each core was passed through the device, an aluminum standard was measured. An equivalent density of 2.60 Mg/m^3 was assigned to the 6.61-cm (diameter) aluminum standard analog record and a density of 1.0 Mg/m^3 to the 2.54-cm (diameter) aluminum standard analog record. Linear interpolation of the GRAPE analog data between these values yielded an "empirical" wet-bulk density of the sediment sample in the core (ρ_{bcz}). If the sample completely filled the core, then $\rho_{bc} = \rho_{bcz}$, where ρ_{bc} = "corrected" wet-bulk density (relative to quartz). Then

$$\rho_b = \frac{(\rho_{bc} - \rho_{fc})(\rho_g - \rho_f)}{(\rho_{gc} - \rho_{fc})} + \rho_f,$$

where ρ_g = true grain density ($\sim$2.65 Mg/m^3 for sediments); ρ_{gc} = corrected grain density ($\sim$2.7 Mg/m^3 for sediment); ρ_f = true fluid density ($\sim$1.025 Mg/m^3); ρ_{fc} = corrected fluid density ($\sim$1.125 Mg/m^3); and ρ_b = true wet-bulk density.

Given the above values,

$$\rho_b = 1.066(\rho_{bc} - 1.125) + 1.025. \quad (1)$$

Shipboard reduction of analog GRAPE records involved selection of high-density portions of each core section on the analog record, and calculation of true wet-bulk density (ρ_b) by formula (1). These calculations were subsequently corrected for independently determined true grain densities. The porosity ϕ is obtained by

$$\phi(\%) = \frac{\rho_g - \rho_b}{\rho_g - \rho_f} \times 100.$$

Two-Minute GRAPE

For 2-minute GRAPE calculations,

$$\rho_{bc} = \frac{\ln(I_o/I)}{d\ \mu qtz},$$

where I_o = 2-minute gamma count through air, I = 2-minute gamma count through the sample, d = gamma-ray path length through the sample, and μqtz =

quartz attenuation coefficient determined daily by measuring through a quartz standard. Then, as in the continuous GRAPE calculation (assuming a 2.65 Mg/m^3 grain density),

$$\rho_b = 1.066\ (\rho_{bc} - 1.125) + 1.025$$

and

$$\phi(\%) = \frac{100(2.65 - \rho_b)}{1.675}.$$

Boyce (1976) estimates ±5% accuracy for continuous GRAPE data and ±2% for 2-minute GRAPE data. In practice, we found that the error on Leg 87 seemed to be higher, partly because of the highly disturbed nature of many of the cores and partly because of errors in gamma-ray travel-path determinations caused by the extremely friable nature of the sediments. However, good agreement exists between the GRAPE data and gravimetric methods.

Samples for the 2-minute GRAPE counts were also used for gravimetric methods. One of three different sampling techniques was used depending on the stiffness and the fissibility of the sediments and rocks. In soft sediments, Boyce cylinders were inserted and cut from the split cores to produce the most undisturbed sample possible. The upper and lower sample surfaces were gradually trimmed flush with the cylinder to minimize sediment remolding. The resulting disturbance was small enough to have a negligible effect either on the GRAPE counts or on the gravimetric analysis. In harder sediments, when cylinders could no longer be inserted without causing severe deformation or cracking, 10–20-cm^3 slices were removed using razor blades. Parallel surfaces were trimmed on four sides to allow GRAPE counts both perpendicular and parallel to bedding. When increased induration allowed, minicores were cut from the drilling biscuits and coherent sections. Again, the surfaces were carefully trimmed.

Gravimetric Technique: Boyce Cylinder, Chunk, and Minicore

Following the 2-minute GRAPE counts, the samples prepared as described above were used for water content and porosity determinations. No salt corrections were applied in any of these techniques. Drying and weighing equipment on board *Glomar Challenger* were used for these measurements.

$$\text{Water content (\% wet wt.)} = 100 \times \frac{[(\text{wt. wet sediment}) - (\text{wt. dry sediment})]}{(\text{wt. wet sediment})}$$

For porosity determinations, a grain density of 2.65 Mg/m^3 and a water density of 1.03 Mg/m^3 were assumed.

$$\text{Porosity (\%)} = 100 \times \frac{\text{vol. evaporated water}}{\text{vol. wet sediment}}$$

$$= 100 \times \frac{[(\text{wt. evaporated water})/(1.03\ Mg/m^3)]}{\left[\frac{(\text{wt. dry sediment})}{(2.65\ Mg/m^3)} + \frac{(\text{wt. evaporated water})}{(1.03\ Mg/m^3)}\right]}$$

The porosity calculations were subsequently corrected for independently determined true grain densities.

Shear Strength

A Soiltest Torvane, a Soiltest CL700 pocket penetrometer, and a Wykeham-Farrance laboratory vane shear apparatus were used on board to determine the undrained shear strength of clayey sediments. The Torvane was hand-rotated at a rate designated to reach failure in about 10 s with constant loading. Repeated determinations yielded results that were generally reproducible to ±15%. Measurements were made in the least disturbed sections of the split core. Measurements were discontinued when cracking of the sediments was observed, indicating failure by fracturing rather than by shear.

The pocket penetrometer was used to determine unconfined compressive strength of clayey sediments by insertion of a calibrated piston into the split cores. Shear strength was obtained as follows:

$$S = 2c$$

$$\tau_f = c = \tfrac{1}{2}\ S$$

where: S = unconfined compressive strength and $\tau_f = c$ = cohesive shear strength of clay at failure. Measurements were made on the least disturbed sections of the split core with the penetrometer axis parallel to bedding. Effort was made to perform each test at a uniform loading rate. Surface cracking was rare during test, so the penetrometer could be used to its maximum capacity at 216 kPa.

The Wykeham-Farrance vane apparatus was used at all Leg 87 sites. Measurements were made only on undisturbed sections of the split core with the vane axis parallel to bedding. A 1.28-cm vane was inserted 0.8 cm into the (half) core and was rotated by a motor at 89°/minute. Resistance springs were selected so that shearing occurred between 30 and 110° stress. Shear strength is calculated as:

$$\tau_f = c = \left[\frac{2t}{\pi d^2 h\left(1 + \frac{2}{3n}\right)}\right] \text{(maximum degree spring stress)},$$

where $\tau_f = c$ = cohesion and shear strength of clay at failure, t = spring torque factor in (g·cm)/degree, d = diameter of vane blades, and h = height of vane blades. Subsequent to failure, the vane was rotated through two complete revolutions within the sediment, the sediment was allowed to set for 10 minutes, and the test was repeated to determine the remolded shear strength.

Heat Flow and Thermal Conductivity

Heat Flow

Detection of *in situ* bottom-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. *In situ* temperatures were measured by inserting a thermistor sensor head into the sediment. It is mounted either at the tip of a cutting shoe of the hydraulic piston corer or in a spear head of the Barnes water sampler. Temperature data, actually resistance readings of the thermistor, are digitized and stored in a random-access-memory (RAM) chip controlled by a crystal-timer–driven central processing unit (CPU) and retrieved through a shipboard CPU-controlled microcomputer system. Both measuring systems were used successfully, depending on which coring tool was utilized. Each system is named for its place of origin: the Tokyo University type and the Woods Hole type. Cross-correlation measurements demonstrate a reasonable consistency of the data obtained by both devices.

Needle Probe Measurements of Thermal Conductivity

In the needle probe apparatus, the heater and temperature sensor are contained in a very fine needle, approximately 1 mm in diameter and 6 cm long. The needle can be inserted directly into soft sediment. In such sediments the needle is usually inserted into the end of the core half parallel to the axis of the core. A wait of about 30 minutes for equilibration precedes the 4-minute measurement period.

In harder sediments both halves of a small core section are used to make a sandwich around the probe. A groove is scraped in the face of one core-half to accept the probe. The preparation of samples for this type of measurement is time-consuming and requires use of part of the archive half of the core.

Conductivity is determined from the relation that applies for a line source in an infinite medium:

$$K = \frac{A I^2 \ln(t_2/t_1)}{T_2 - T_1} - B,$$

where K = thermal conductivity, I = current flowing in the heater wire, t_1 and t_2 = two times during the measurement period, T_2 and T_1 = temperatures at times t_2 and t_1, and A and B are constants. For the needle probe device, B = 0 and A is determined directly from probe parameters.

The temperature data are recorded either on a strip-chart recorder or on a paper tape punched through a CPU-controlled analog-to-digital conversion circuit. For quick shipboard reading of the punched data tape, a teletype is attached to the paleomagnetic spinner.

Paleomagnetic Techniques

Remanent magnetization of sediment and rock samples is measured with a Digico balanced fluxgate rock magnetometer, calibrated frequently with a shipboard standard. Error direction of remanent magnetization is less than 4°. The noise level is $2.3 \pm 1.1 \times 10^{-7}$ emu/cm^3.

A Schoenstedt A.C. geophysical specimen demagnetizer (Model GSD-1) is used for alternating field (AF) demagnetization of the samples. With this single-axis system demagnetizer, every sample is demagnetized three times, once about each of the three orthogonal axes.

Samples for paleomagnetic analysis are taken from unconsolidated and semiconsolidated sediments in the upper parts of the cores by inserting plastic 2.5-cm cubes into the split sections. In more lithified samples from deeper levels, cylindrical samples of 2.5-cm diameter are taken from the split core sections with a diamond corer ("minicore drill"). An orientation is marked with an arrow in the uphole direction on every sample before removal from the split core section. When inclined bedding is encountered, the inclination of the bedding plane is carefully measured against the plane along which the core is split.

PHOTOGRAPHY

Sets of color and black-and-white negatives of whole cores are available for consultation. In addition, negatives in black and white for closeup documentation of special structures are presently (1985) archived at DSDP. They will ultimately be transferred to archives at Ocean Drilling Program, Texas A&M University, College Station, Texas 77843.

OBTAINING SAMPLES

Investigators who desire to obtain samples should refer to the DSDP-NSF Sample Distribution Policy (see prefatory material for this volume). Requests must be as specific as possible; include site, core, section, interval within a section, and volume of sample required.

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