Storms, M. A., Natland, J. H., et al., 1991
Proceedings of the Ocean Drilling Program, Initial Reports, Vol. 132

2. EXPLANATORY NOTES[1]

Shipboard Scientific Party[2]

INTRODUCTION

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* volume of the Leg 132 *Proceedings of the Ocean Drilling Program*. Methods used by various investigators for shore-based analysis of Leg 132 data will be detailed in the individual scientific contributions published in the *Scientific Results* volume.

Authorship of Site Chapters

The separate sections of the site chapters were written by the following shipboard personnel (authors are listed in alphabetical order, no seniority is necessarily implied):

Site Summary: Natland
Background and Objectives: Natland
Operations: Natland, Storms
Lithostratigraphy: Brass, Van Waasbergen
Biostratigraphy: Premoli-Silva, Sliter
Paleomagnetics: Rack
Basement Lithology and Geochemistry: Brown, Natland
Physical Properties: Rack

Following the text of each site chapter are summary core descriptions ("barrel sheets" or igneous rock visual core descriptions) and photographs of each core.

Use of Ma vs. m.y.

1. Ma is used in an age sense and replaces m.y.B.P. (million years Before Present), e.g., 35–40 Ma.
2. m.y. is used as a quantity in sentences such as, "... for 5 m.y. in the early Miocene."

Leg 132 Special Procedures

Special procedures used during Leg 132 are indicated in bracketed sentences or paragraphs in subsequent sections.

Drilling Characteristics

Information concerning sedimentary stratification in uncored or unrecovered intervals may be inferred from seismic data, wireline-logging results, and from an examination of the behavior of the drill string as observed and recorded on the drilling platform. Typically, the harder a layer, the slower and more difficult it is to penetrate. A number of other factors may determine the rate of penetration, so it is not always possible to relate the 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 concave-downward 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 cutting, retrieval (with accompanying changes in pressure and temperature), and core handling on deck. A detailed discussion of slump-like drilling disturbance is given in the "Core Description" section of this chapter.

Shipboard Scientific Procedures

Numbering of Sites, Holes, Cores, and Samples

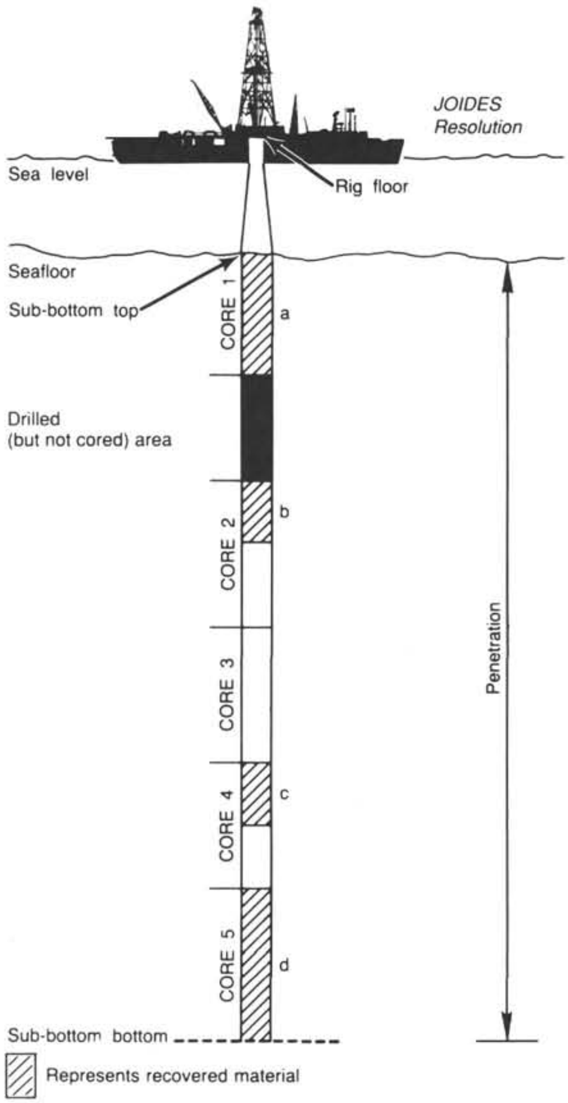
ODP drill sites are numbered consecutively, and refer to one or more holes drilled while the ship was positioned over one acoustic beacon. Multiple holes may be drilled at a single site by pulling the drill pipe above the seafloor (out of the hole), moving the ship some distance from the previous hole, 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 drilled is assigned the site number modified by the suffix A, the second hole takes the site number and suffix B, and so forth. Note that this procedure differs slightly from that used by DSDP (Sites 1 through 624), but prevents ambiguity between site- and hole-number designations. It is important to distinguish among 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 seafloor (mbsf). The depth interval assigned to an individual core begins with the depth below the seafloor that the coring operation began, and extends to the depth that the coring operation ended (see Fig. 1). For example, each coring interval is generally up to 9.5 m long, which is the capacity of a core barrel. Coring intervals may be shorter and may not necessarily be adjacent if separated by drilled intervals. In soft sediments, the drill string can be "washed ahead" with the core barrel in place, without recovering sediments. This is achieved by pumping water down the pipe at high pressure to wash the sediment out of the way of the bit and up the annulus between the drill pipe and the wall of the hole. If thin, hard, rock layers are present, then it is possible to get "spotty" sampling of these resistant layers within the washed interval, and thus to have a cored interval greater than 9.5 m. In drilling hard rock, a center bit may replace the core barrel if it is necessary to drill without core recovery.

Cores taken from a hole are numbered serially from the top of the hole downward. Core numbers and their associated cored intervals in meters below seafloor usually are unique in a given hole; however, this may not be true if an interval must be cored

[1] Storms, M. A., Natland, J. H., et al., 1991. *Proc. ODP, Init. Repts,* 132: College Station, TX (Ocean Drilling Program).
[2] Shipboard Scientific Party is as given in the list of participants preceding the contents.



BOTTOM FELT: distance from rig floor to seafloor

TOTAL DEPTH: distance from rig floor to bottom of hole (sub-bottom bottom)

PENETRATION: distance from seafloor to bottom of hole (sub-bottom bottom)

NUMBER OF CORES: total of all cores recorded, including cores with no recovery

TOTAL LENGTH OF CORED SECTION: distance from sub-bottom top to sub-bottom bottom minus drilled (but not cored) areas in between

TOTAL CORE RECOVERED: total from adding a, b, c, and d in diagram

CORE RECOVERY (%): equals TOTAL CORE RECOVERED divided by TOTAL LENGTH OF CORED SECTION times 100

Figure 1. Coring and depth intervals.

twice, because of caving of cuttings or other hole problems. Maximum full recovery for a single core is 9.5 m of rock or sediment contained in a plastic liner (6.6 cm internal diameter) plus about 0.2 m (without a plastic liner) in the core catcher (Fig. 2). The narrow design of the Diamond Coring System (DCS) slim-line tubing resulted in a reduced internal plastic core-liner diameter of approximately 5.6 cm (2.2 in.). The core catcher is a device at the bottom of the core barrel which prevents the core from sliding out when the barrel is being retrieved from the hole. In certain situations (e.g., when coring gas-charged sediments which expand while being brought on deck) recovery may exceed the 9.5 m maximum.

A recovered core is divided into 1.5 m sections which are numbered serially from the top (Fig. 2). When full recovery is obtained, the sections are numbered from 1 through 7, with the last section possibly being shorter than 1.5 m (rarely, an unusually long core may require more than 7 sections). When less than full recovery is obtained, there will be as many sections as needed to accommodate the length of the core recovered; for example, 4 m of core would be divided into two 1.5 m sections and one 1 m section. If cores are fragmented (recovery less than 100%), sections are numbered serially and intervening sections are noted as void, whether shipboard scientists believe that the fragments were contiguous *in-situ* or not. In rare cases a section less than 1.5 m may be cut in order to preserve features of interest (e.g., lithological contacts).

By convention, material recovered from the core catcher is placed below the last section when the core is described, and labeled core catcher (CC); in sedimentary cores, it is treated as a separate section. The core catcher is placed at the top of the cored interval in cases where material is only recovered in the core catcher. However, information supplied by the drillers or by other sources may allow for more precise interpretation as to the correct position of core catcher material within an incompletely recovered cored interval.

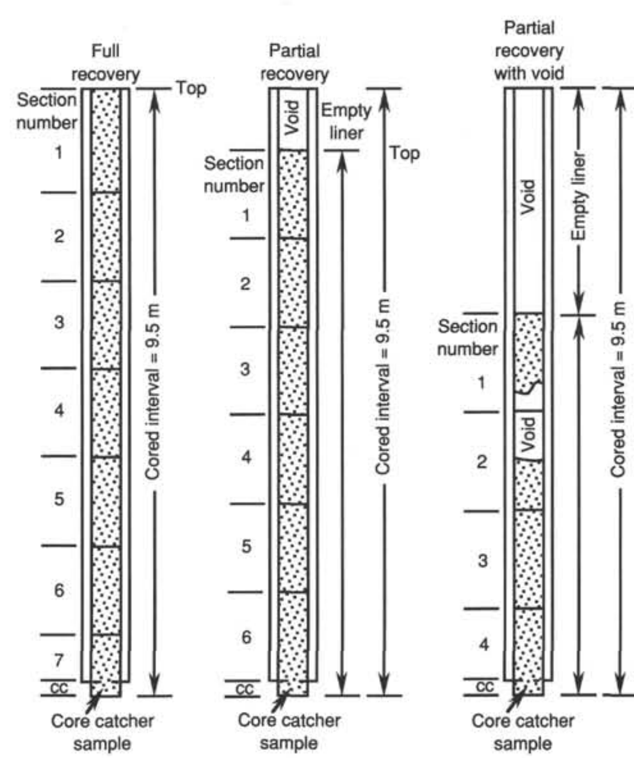


Figure 2. Examples of numbered core sections.

Special core handling conventions for DCS cored rocks on Leg 132 are as follows: The recovered rocks were first oriented by an igneous petrologist, then split with a diamond saw and placed into 0.75 m core sections for description and sampling. The visual core descriptions were used to describe each of the 0.75 m core sections, which were then photographed using a modified format for these shorter than normal sections. Standard procedures for describing the rocks then were employed.

In each 0.75 m section, rocks were numbered serially. Each piece was assigned a number. Fragments of a single piece were assigned a single number, and individual fragments were identified alphabetically. Core-catcher samples were placed at the bottom of the last section and treated as part of the last section, rather than separately. Scientists completing visual core descriptions described each lithologic unit, noting core and section boundaries only as physical reference points.

When, as is usually the case, the recovered core is shorter than the cored interval, the top of the core is equated with the top of the cored interval by convention, in order to achieve consistency in handling analytical data derived from the cores. Samples removed from the cores are designated by distance measured in centimeters from the top of the section to the top and bottom of each sample removed from that section. In curated hard rock sections, sturdy plastic spacers are placed between pieces which did not fit together in order to protect them from damage in transit and in storage; therefore, the centimeter interval noted for a hard rock sample has no direct relationship to that sample's depth within the cored interval, but is only a physical reference to the location of the sample within the curated core.

A full identification number for a sample consists of the following information: leg, site, hole, core number, core type, section number, piece number (for hard rock), and interval in centimeters measured from the top of section. For example, a sample identification of "132-810C-3H-1, 10–12 cm" would be interpreted as representing a sample removed from the interval between 10 and 12 cm below the top of Section 1, Core 3 (H designates that this core was taken during hydraulic piston coring) of Hole 810C during Leg 132.

All ODP core and sample identifiers indicate core type. The following abbreviations are used: R = Rotary Core Barrel (RCB); H = Hydraulic Piston Core (HPC; also referred to as APC, or Advanced Hydraulic Piston Core); P = Pressure Core Sampler; 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; Z = Diamond Coring System (DCS) Core, and M = miscellaneous material. APC, XCB, RCB, and DCS cores were cut on Leg 132.

Core Handling

Sediments

As soon as a core is retrieved on deck, a sample is taken from the core catcher and given to the paleontological laboratory for an initial age assessment. The core is then placed on the long horizontal rack, and gas samples may be taken by piercing the core liner and withdrawing gas into a vacuum-tube. Voids within the core are sought as sites for gas sampling. Some of the gas samples are stored for shore-based study, but others are analyzed immediately as part of the shipboard safety and pollution-prevention program. Next, the core is marked into section lengths, each section is labeled, and the core is cut into sections. [Interstitial-water (IW) and organic geochemistry (OG) samples were taken from the geriatric core at Hole 810A. The entire shipboard scientific party, after consulting with the ODP curator, decided that organic geochemistry and interstitial water samples would not be taken at Hole 810C. However, some headspace gas samples were scraped from the ends of cut sections on the catwalk, and sealed in glass vials for light hydrocarbon analysis.] Each section is then 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 yellow cap is placed on the section ends from which a whole-round sample has been removed, and the sample code (e.g., IW) is written on the yellow cap. The caps are usually attached to the liner by coating the end of the liner and the inside rim of the cap with acetone; the caps then are taped to the liners.

The cores are then carried into the laboratory, where the sections are again labeled, using an engraver to permanently mark the full designation of the section. The length of the core in each section and the core-catcher sample are measured to the nearest centimeter; this information is logged into the shipboard CORE-LOG database program.

Whole-round sections from APC and XCB cores are normally run through the Multisensor Track (MST). The MST includes the GRAPE (gamma ray attenuation porosity evaluator) and *P*-wave logger devices, which measure bulk density, porosity, and sonic velocity, and also includes a meter which determines the volume magnetic susceptibility. At this point, whole-round samples for physical properties (PP) and structural analysis are taken. In well-lithified sedimentary cores, the core liner is split, and the top half removed so that the whole-round core can be observed before choosing the samples. Relatively soft sedimentary cores are equilibrated to room temperature (approximately 3 hr) before passing through the MST.

Cores of soft material are split lengthwise into working and archive halves. The softer cores are split with a wire or saw, depending on the degree of induration. Harder cores are split with a band saw or diamond saw. The wire-cut cores are split from the bottom to top, so investigators should be aware that older material could have been transported up the core on the split face of each section.

The working half of the core is sampled for both shipboard and shore-based laboratory studies. Each extracted sample is logged into the sampling computer database program by the 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 are sealed in plastic vials or bags and labeled. Samples are routinely taken for shipboard physical property analysis. Selected physical properties samples are subsequently used for calcium carbonate (coulometric) analysis and the data are reported in the site chapters with the physical properties data.

The archive half is described visually. Smear slides are made from samples taken from the archive half, and are supplemented by thin sections taken from the working half. Most archive sections are run through the cryogenic magnetometer. The archive half is then photographed with both black-and-white and color film, a whole core at a time. Close-up photographs (black-and-white) are taken of particular features for illustrations in the summary of each site, as requested by individual scientists.

Both halves of the core are then put into labeled plastic tubes, sealed, and transferred to cold-storage space aboard the drilling vessel. At the end of the leg, the cores are transferred from the ship in refrigerated air-freight containers to cold storage at the Gulf Coast Repository at the Ocean Drilling Program, Texas A&M University, College Station, TX.

Igneous and Metamorphic Rocks

Igneous and metamorphic rock cores are handled differently from sedimentary cores. Once on deck, the core-catcher is placed at the bottom of the core liner and total core recovery is calculated by shunting the rock pieces together and measuring to the nearest centimeter; this information is logged into the shipboard core-log database program. [The core was then cut into 0.75 m long sections and transferred into the lab.]

The contents of each section are transferred into 1.5 m long (0.75 m long for DCS cores) sections of split core liner, where the bottom of oriented pieces (i.e., pieces that clearly could not have rotated top to bottom about a horizontal axis in the liner) are marked with a red wax pencil. This is to ensure that orientation is not lost during the splitting and labeling process. The core is then split into archive and working halves. A plastic spacer is used to separate individual pieces and/or reconstructed groups of pieces in the core liner. These spacers may represent a substantial interval of no recovery. Each piece is numbered sequentially from the top of each section, beginning with number 1; reconstructed groups of pieces are assigned the same number, but are lettered consecutively. Pieces are labeled only on external surfaces. If the piece is oriented, an arrow is added to the label pointing to the top of the section.

The working half of the hard-rock core is then sampled for shipboard laboratory studies. Records of all samples are kept by the curator at ODP. Minicore samples are routinely taken for physical properties and magnetic studies. Some of these samples are later subdivided for X-ray fluorescence (XRF) analysis and thin-sectioning, so that as many measurements as possible are made on the same pieces of rock. At least one minicore is taken per lithological unit when recovery permits, generally from the freshest areas of core. Additional thin sections, X-ray diffraction (XRD) samples, and XRF samples are selected from areas of particular interest. Samples for shore-based studies are selected in a sampling party held after drilling has ended.

The archive half is described visually, then photographed with both black-and-white and color film, one core at a time. Both halves of the core are then shrink-wrapped in plastic to prevent rock pieces from vibrating out of sequence during transit, put into labeled plastic tubes, sealed and transferred to cold-storage space aboard the drilling vessel.

VISUAL CORE DESCRIPTIONS

Sediment "Barrel Sheets"

The core-description forms (Fig. 3), or "barrel sheets," summarize the data obtained during shipboard analysis of each sediment core. The following discussion explains the ODP conventions used in compiling each part of the core-description forms and the exceptions to these procedures adopted by the Leg 132 scientific party.

Shipboard sedimentologists were responsible for visual core logging, smear-slide analyses, and thin-section descriptions of sedimentary and volcaniclastic material. Mineral-composition data were determined by X-ray diffraction, and these data augment the visual core descriptions. Data on biostratigraphy (age), geochemistry ($CaCO_3$), magnetics, and physical properties (wet bulk density and porosity) also were integrated with the sedimentologic information.

Core Designation

Core designations specify the leg, site, hole, core number, and core type, as discussed in a preceding section (see "Numbering of Sites, Holes, Cores, and Samples" section, this chapter). The cored interval is specified in terms of meters below sea level (mbsl) and meters below seafloor (mbsf). On the basis of drill-pipe measurements (dpm), which are reported by the SEDCO coring technician and the ODP operations superintendent, depths are corrected for the height of the rig floor dual elevator stool above sea level to give true water depth and correct mbsl.

Paleontological Data

Microfossil abundances, preservation, and zone assignments appear on the core-description form under the heading "Biostrat. Zone/Fossil Character." The chronostratigraphic unit, as defined by paleontological results, is shown in the "Time-Rock Unit" column. Detailed information on the zonations, together with terms used to report abundance and preservation, are presented in the "Biostratigraphy" section (this chapter).

Paleomagnetic, Physical Property, and Chemical Data

Columns on the core-description form display the results of paleomagnetic measurements (normal, reversed, or unknown polarity, shown as "N," "R," or "?," respectively), physical properties values (wet bulk density and porosity), and chemical data (percentages of $CaCO_3$ determined with the Coulometrics analyzer). Additional information on shipboard procedures for collecting these types of data appears in the "Paleomagnetism," "Physical Properties," and "Organic Geochemistry" sections (this chapter). During Leg 132, no individual samples were measured for paleomagnetic properties.

Graphic Lithology Column

The lithologies of the material recovered are illustrated graphically on the core description forms, either by a single pattern or by two or more patterns (see Fig. 4). Where an interval of sediment or sedimentary rock is a homogeneous mixture, the constituent categories are separated by a solid vertical line, and each category is represented by its own pattern. Constituents that comprise less than 25% of the sediment are not put in the graphic lithology column but, instead, are listed in the "Lithologic Description" section of the barrel sheet. In an interval composed of two or more interbedded sediment types that have quite different characteristics, the average relative abundances of the constituents are represented graphically by dashed lines that vertically divide the interval into appropriate fractions as described above.

Only intervals exceeding 10 cm can be displayed in the graphic lithology column at the scale provided. Information on finer-scale lithologic variations is included in the VCD (Visual Core Description) forms available from ODP upon request.

Sedimentary Structures

In sediment cores, natural structures can be difficult to distinguish from structures created by the coring process. Natural structures are illustrated by symbols in the "Sedimentary Structure" column of the core-description form. Figure 5 shows all of the symbols used during Leg 132 to describe the primary biogenic and physical sedimentary structures. The most common types of structures include scoured basal contacts, graded beds, cross lamination, parallel laminae, and various degrees of bioturbation.

Sediment Disturbance

Sediment disturbances that clearly result from the coring process, rather than from structural deformation, are illustrated in the "Drilling Disturbance" column on the core-description form (using the symbols shown in Fig. 5). Blank regions indicate a lack of drilling disturbance. Drilling disturbances for soft and firm sediments were categorized as follows:

1. Slightly deformed = bedding contacts are slightly bent;
2. Moderately deformed = bedding contacts show extreme bowing;
3. Highly deformed = bedding is completely disturbed and in some cases shows symmetric diapir-like or flow structures;
4. Soupy = intervals are water saturated and have lost all aspects of original bedding.

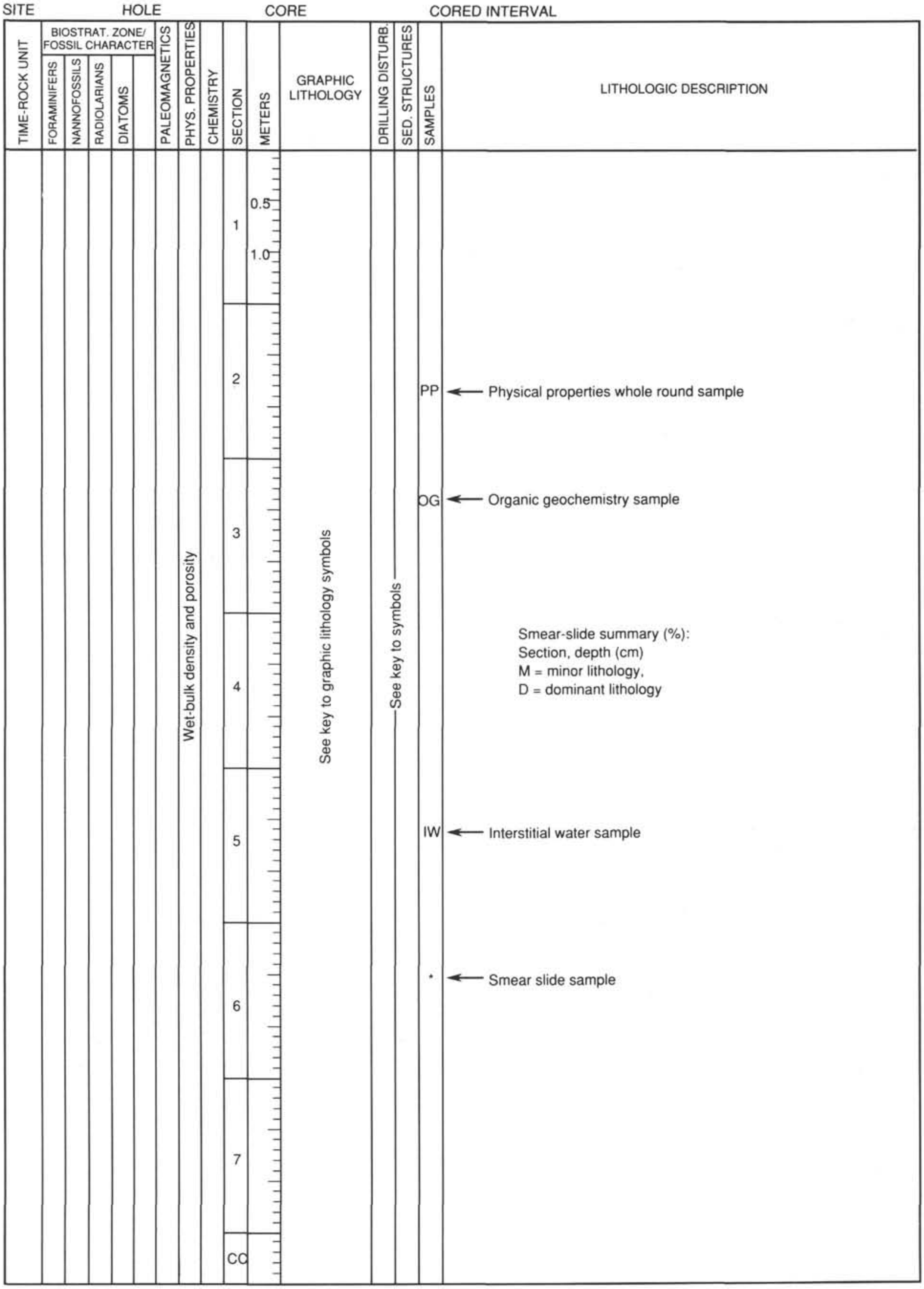


Figure 3. Core description form, or "barrel sheet," for sediments and sedimentary rocks.

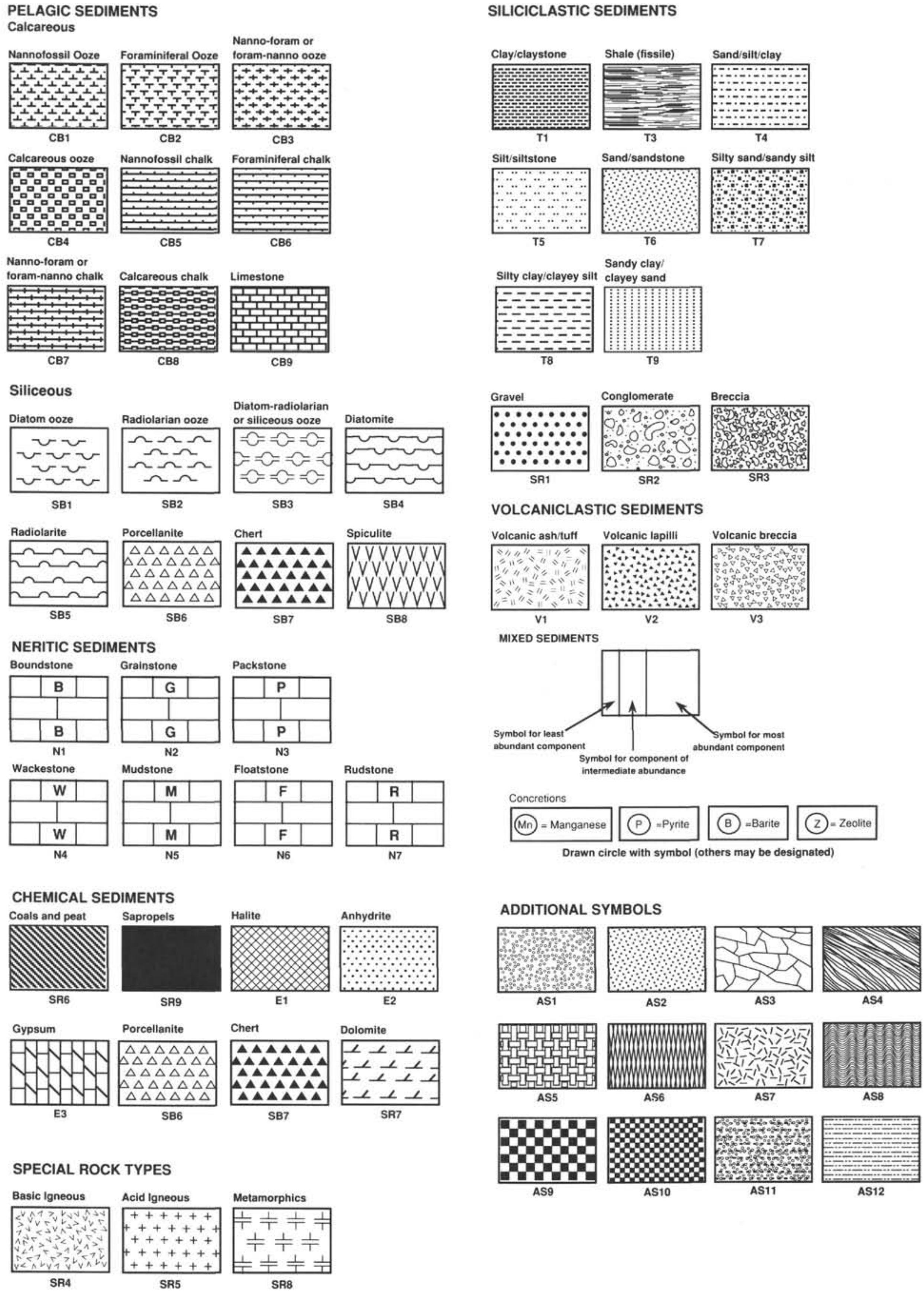


Figure 4. Lithologic symbols used in "Graphic Lithology" column of core description form, or "barrel sheet," for sediments and sedimentary rocks.

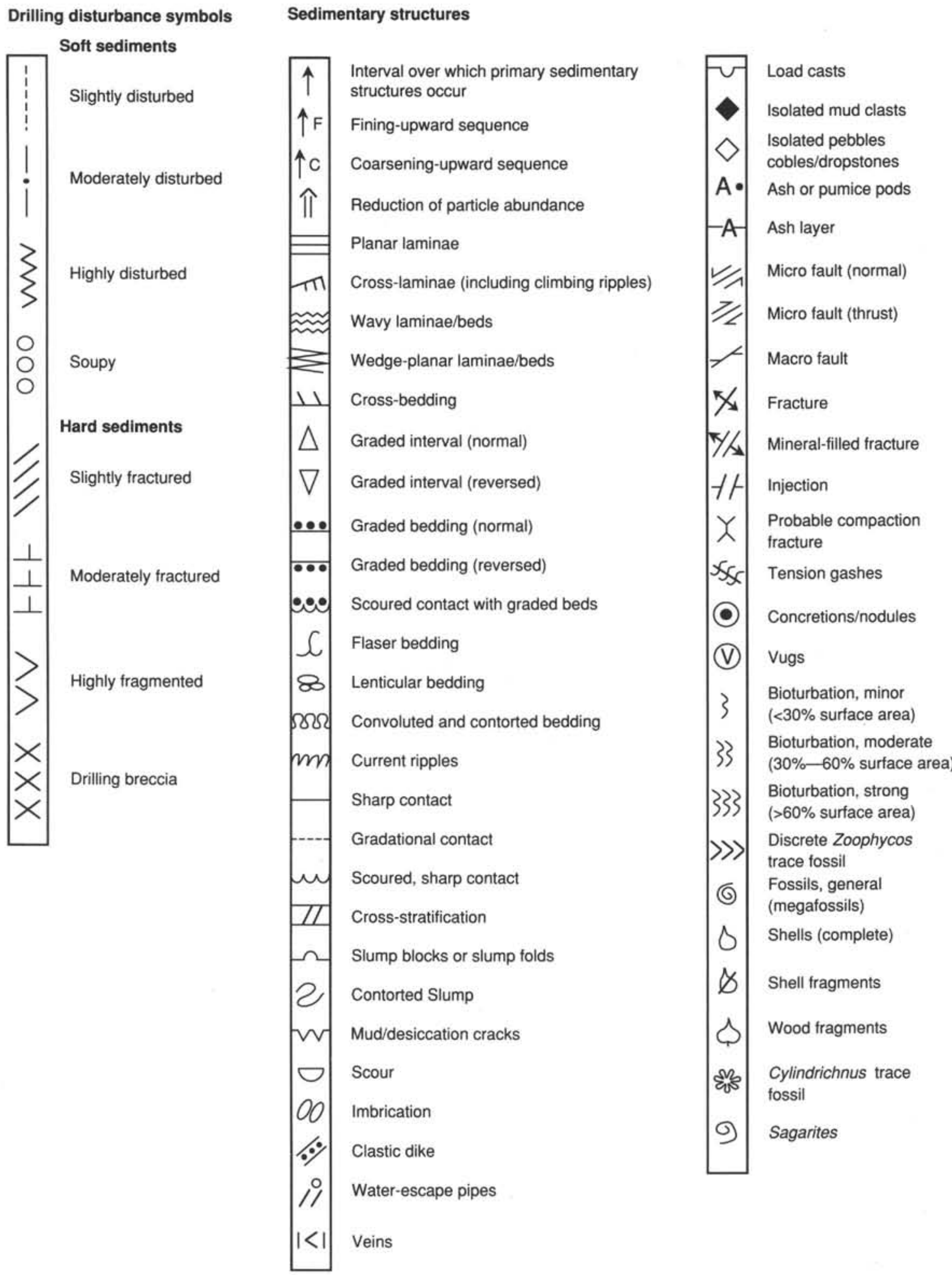


Figure 5. Symbols used in "Drilling Disturbance" and "Sedimentary Structure" columns of core description form, or "barrel sheet."

The degree of fracturing in indurated sediments and igneous rocks was described using the following categories:

1. Slightly fractured = core pieces are in place and contain little drilling slurry or breccia;

2. Moderately fragmented = core pieces are in place or partly displaced, but original orientation is preserved or recognizable (drilling slurry may surround fragments);

3. Highly fragmented = pieces are from the interval cored and probably in correct stratigraphic sequence (although they may not

represent the entire section), but original orientation is completely lost;

4. Drilling breccia = core pieces have lost their original orientation and stratigraphic position and may be mixed with drilling slurry.

Induration

Subjective criteria were used during Leg 132 to determine the induration of muddy sediments. Three classes exist for the degree of induration:

1. Soft = sediments have little strength and are readily deformed under a finger or broad blade of a spatula;
2. Firm = partly lithified sediments are readily deformed under a fingernail or the edge of a spatula blade;
3. Hard = nonfriable, cemented or compacted rocks, with the suffix "-stone" added to the name (e.g., limestone, claystone).

Color

Colors were determined qualitatively by comparison with Munsell soil-color charts (Munsell Soil Color Charts, 1971). Colors were described immediately after the cores were split because redox-associated color changes may occur when deep-sea sediments are exposed to the atmosphere. Information on core colors is given in the text of the "Lithologic Description" on the core-description forms.

Samples

The positions of samples taken from each core for shipboard analysis are indicated in the "Samples" column of the core-description form (Fig. 3). The symbol "*" indicates the locations of smear-slide samples, and the symbol "#" indicates the locations of thin-section samples. The notations "IW" and "OG" designate the locations of samples for whole-round interstitial water geochemistry and frozen organic geochemistry, respectively. Additional codes correspond to samples extracted by individual investigators. The notation "o" designates fine-grained intervals that were sampled for shipboard measurements of physical properties.

Smear Slide Summary

A table summarizing data from smear slides and thin sections appears on each core-barrel description form. These tables include information on the sample location, whether the sample represents a dominant ("D") or a minor ("M") lithology in the core, and the estimated percentage ranges of sand, silt, and clay, together with all identified components.

Lithologic Description—Text

The lithologic descriptions that appear on each core-description form (barrel sheet) consist of two parts: (1) a heading that lists all the major sediment types in the core (see "Sediment Classification" section, this chapter); and (2) a more detailed description of these sediments, including data on color, stratal thickness, specific locations of key features in the core, geometries of diagnostic sedimentary structures, and so on. Descriptions and locations of thin interbeds or minor lithologies also are included in the text.

SEDIMENTOLOGY

The sediment classification scheme for the Ocean Drilling Program (Mazzullo et al., 1987) was used during Leg 132. This classification defines two basic sediment types: (1) granular sediment and (2) chemical sediment.

Granular Sediment

Classes of Granular Sediment

Four grain types occur in granular sediments: pelagic, neritic, siliciclastic, and volcaniclastic grains; the definitions are as follows:

1. Pelagic grains are fine-grained skeletal debris produced by open-marine siliceous and calcareous microfauna and microflora (e.g., radiolarians, nannofossils) and associated organisms.
2. Neritic grains are coarse-grained calcareous skeletal fragments (e.g., bioclasts, peloids) and fine-grained calcareous grains of nonpelagic origin.
3. Siliciclastic grains comprise minerals and rock fragments that were eroded from plutonic, sedimentary, and metamorphic rocks.
4. Volcaniclastic grains include glass shards, rock fragments, and mineral crystals that were produced by volcanic processes.

Variations in the relative proportions of these four grain types define five major classes of granular sediments: (1) pelagic, (2) neritic, (3) siliciclastic, (4) volcaniclastic, and (5) mixed sediments (Fig. 6). Pelagic sediments contain >60% pelagic plus neritic grains, <40% siliciclastic plus volcaniclastic grains, and a higher proportion of pelagic than neritic grains. Neritic sediments include >60% pelagic plus neritic grains, <40% siliciclastic plus volcaniclastic grains, and a higher proportion of neritic than pelagic grains. Siliciclastic sediments are composed of >60% siliciclastic plus volcaniclastic grains, <40% pelagic plus neritic grains, and they contain a higher proportion of siliciclastic than volcaniclastic grains. Volcaniclastic sediments contain >60% siliciclastic plus volcaniclastic grains, <40% pelagic and neritic grains, and a higher proportion of volcaniclastic than siliciclastic grains. This class includes epiclastic sediments (eroded from volcanic rocks by wind, water, or ice), pyroclastic sediments (products of explosive magma degassing), and hydroclastic sediments (granulation of volcanic glass by steam explosions). Lastly, mixed sediments

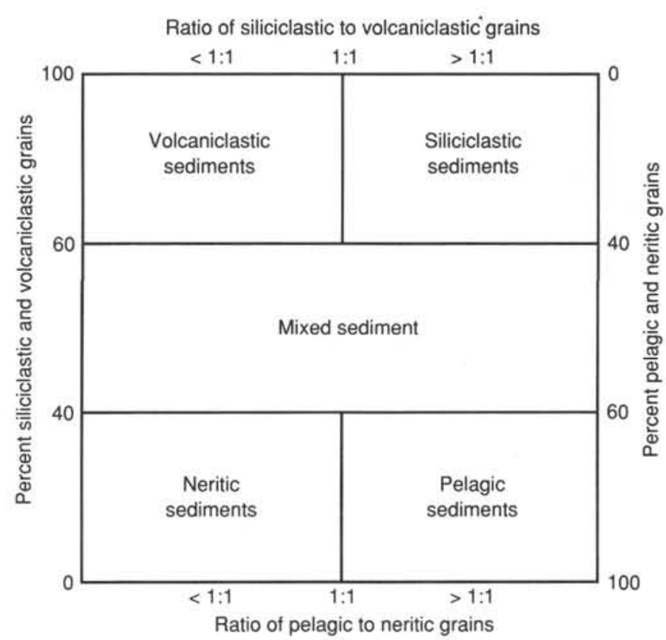


Figure 6. Diagram showing classes of granular sediment (modified from Mazzullo et al., 1987).

are composed of 40%–60% siliciclastic plus volcaniclastic grains and 40%–60% pelagic plus neritic grains.

Classification of Granular Sediment

We classified granular sediment during Leg 132 by designating a principal name and major and minor modifiers. The principal name of a granular sediment defines its granular-sediment class; the major and minor modifiers describe the texture, composition, fabric, and/or roundness of the grains themselves (Table 1).

Principal Names

Each granular-sediment class has a unique set of principal names. For pelagic sediment, the principal name describes the composition and degree of consolidation using the following terms:

1. Ooze = unconsolidated calcareous and/or siliceous pelagic sediment;
2. Chalk = firm pelagic sediment composed predominantly of calcareous pelagic grains;
3. Limestone = hard pelagic sediment composed predominantly of calcareous pelagic grains;
4. Radiolarite, diatomite, and spiculite = firm pelagic sediment composed predominantly of siliceous radiolarians, diatoms, and sponge spicules, respectively;
6. Chert = vitreous or lustrous, conchoidally fractured, highly indurated rock composed predominantly of authigenic silica.

No neritic sediments were encountered on Leg 132.

Table 1. Outline of the ODP classification scheme for granular sediment (modified from Mazzullo et al., 1987).

Sediment class	Major modifiers	Principal names	Minor modifiers
Pelagic sediment	Composition of pelagic and neritic grains present in major amounts. Texture of clastic grains present in major amounts.	Ooze Chalk Limestone Radiolarite Diatomite Spiculite Chert	Composition of pelagic and neritic grains present in minor amounts. Texture of clastic grains present in minor amounts.
Neritic sediment	Composition of neritic and pelagic grains present in major amounts. Texture of clastic grains present in major amounts.	Boundstone Grainstone Packstone Wackestone Mudstone Floatstone Rudstone	Composition of neritic and pelagic grains present in minor amounts. Texture of clastic grains present in minor amounts
Siliciclastic sediment	Composition of all grains present in major amounts. Grain fabric (gravels only). Grain shape (optional). Sediment color (optional).	Gravel Sand Silt Clay	Composition of all grains present in minor amounts. Texture and composition of siliciclastic grains present as matrix (for coarse-grained clastic sediments).
Volcaniclastic sediment	Composition of all volcaniclasts present in major amounts. Composition of all pelagic and neritic grains present in major amounts. Texture of siliciclastic grains present in major amounts.	Breccia Lapilli Ash/tuff	Composition of all volcaniclasts present in minor amounts. Composition of all neritic and pelagic grains present in minor amounts. Texture of siliciclastic grans present in minor amounts.
Mixed sediments	Composition of neritic and pelagic grains present in major amounts. Texture of clastic grains present in major amounts.	Mixed sediments	Composition of neritic and pelagic grains present in minor amounts. Texture of clastic grains present in minor amounts.

For siliciclastic sediment, the texture provides the main criterion for selection of a principal name. The Udden-Wentworth grain-size scale (Fig. 7) defines the grain-size ranges and the names of the textural groups (gravel, sand, silt, and clay) and subgroups (fine sand, coarse silt, etc.). When two or more textural groups or subgroups are present, the principal names appear in order of increasing abundance. Ten major textural categories can be defined on the basis of relative proportions of sand, silt, and clay (Fig. 8). However, in practice, distinctions between some of the categories are dubious without accurate measurements of weight percentages. This is particularly true for the boundary between silty clay and clayey silt. The suffix "-stone" is affixed to the principal names sand, silt, and clay when the sediment is

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

Figure 7. Udden-Wentworth grain-size scale (in mm) for siliciclastic sediments, together with comparable values in Phi units and standard sieve mesh sizes (from Pettijohn et al., 1973).

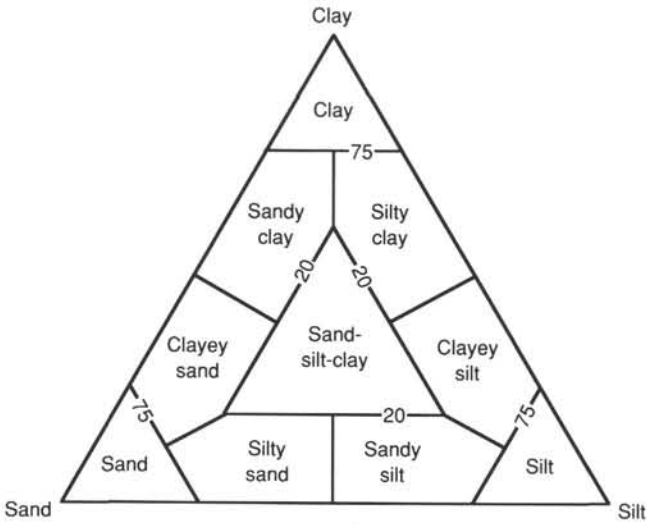


Figure 8. Triangular diagram showing classification scheme for siliciclastic sediments and sedimentary rocks. Graphic patterns for the lithologies are the same as those used on visual core description forms. Classification is modified from Shepard (1954).

lithified. The terms "conglomerate" and "breccia" are the principal names of gravels with well-rounded and angular clasts, respectively.

For volcaniclastic sediment, the principal name is also dictated by the texture. The names and ranges of three textural groups (from Fisher and Schmincke, 1984) are as follows:

1. Volcanic breccia = pyroclasts greater than 64 mm in diameter;
2. Volcanic lapilli = pyroclasts between 2 and 64 mm in diameter (when lithified, the term "lapillistone" is used);
3. Volcanic ash = pyroclasts less than 2 mm in diameter (when lithified, the term "tuff" is used).

For mixed sediment, the principal name describes the degree of consolidation, with the term "mixed sediment" used for unlithified sediment, and the term "mixed sedimentary rock" used for lithified sediment.

Major and Minor Modifiers

To describe the lithology of the granular sediment in greater detail the principal name of a granular-sediment class is preceded by major modifiers and followed by minor modifiers (Table 1). Minor modifiers are preceded by the term "with." The most common uses of major and minor modifiers are to describe the composition and textures of grain types that are present in major (greater than 25%) and minor (10%–25%) proportions. In addition, major modifiers can be used to describe grain fabric, grain shape, and sediment color.

The composition of pelagic grains can be described in greater detail with the major and minor modifiers diatom(-aceous), radiolarian, spicules(-ar), siliceous, nannofossil, foraminifer(-al), and calcareous. The terms siliceous and calcareous are used to describe sediments that are composed of siliceous or calcareous pelagic grains of uncertain origin.

The textural designations for siliciclastic grains utilize standard major and minor modifiers such as gravel(-ly), sand(-y), silt(-y), and clay(-ey). The character of siliciclastic grains can be described further by mineralogy (using modifiers such as "quartz," "feldspar," "glauconite," "mica," "kaolinite," "zeolitic," "lithic," "calcareous," "gypsiferous," or "sapropelic." We have used the terms "clayey ooze" and "calcareous clay" to describe mixed sediments in which the modifiers "clayey" and calcareous represent the less abundant major component.

The provenance of rock fragments (particularly in gravels, conglomerates, and breccias) can be described by modifiers such as volcanic, sed-lithic, meta-lithic, gneissic, and plutonic. The fabric of a sediment can be described as well using major modifiers such as grain-supported, matrix-supported, and imbricated. Generally, fabric terms are useful only when describing gravels, conglomerates, and breccias.

The composition of volcaniclastic grains is described by the major and minor modifiers "lithic" (rock fragments), "vitric" (glass and pumice), and "crystal" (mineral crystals). Modifiers can also be used to describe the compositions of the lithic grains and crystals (e.g., feldspathic or basaltic).

Chemical Sediments

Classes of Chemical Sediment

Chemical sediments are composed of minerals that formed by inorganic processes such as precipitation from solution or colloidal suspension, deposition of insoluble precipitates, or recrystallization. Chemical sediments generally have a crystalline (i.e., nongranular) texture. There are five classes of chemical sediments: (1) carbonaceous sediments,(2) evaporites, (3) silicates, (4) carbonates, and (5) metalliferous sediments.

Carbonaceous sediments contain >50% organic matter (plant and algal remains) that have been altered from its original form by carbonization, bituminization, or petrification. Examples of carbonaceous sediments include peat, coal, and sapropel (jelly-like ooze or sludge of algal remains). The evaporites are classified according to their mineralogy using terms such as halite, gypsum, and anhydrite. They may be modified by terms that describe their structure or fabric, such as massive, nodular, and nodular-mosaic. Silicates and carbonates are defined as crystalline sedimentary rocks that are nongranular and nonbiogenic in appearance. They are classified according to their mineralogy, using principal names such as chert (microcrystalline quartz), calcite, and dolomite. They should also be modified with terms which describe their crystalline (as opposed to granular) nature, such as crystalline, microcrystalline, massive, and amorphous. Metalliferous sediments are nongranular nonbiogenic sedimentary rocks that contain metal-bearing minerals such as pyrite, goethite, manganese, chamosite, and glauconite. They are classified according to their mineralogy.

Textural Analyses

Grain Size

For routine assignment of sediments to textural classes, grain sizes were estimated visually from the core material and from smear slides.

BIOSTRATIGRAPHY

Biostratigraphic data from Holes 810A and 810C are based on planktonic foraminifers and a few observations on calcareous nannofossils from smear slides prepared for lithologic descriptions. Occurrence and abundance of benthic foraminifers, other fossil groups, and inorganic components present in washed residues are also reported.

Age assignments are based mainly on core-catcher samples. Additional samples were studied when the core-catcher samples were found to be contaminated or when boundaries or unconformities were observed. Sample locations, preservation and abundance for planktonic foraminifers are indicated on the barrel sheets.

Planktonic Foraminifers

Neogene

The zonation of Blow (1979), as amended by Kennett and Srinivasan (1983), was followed. The Pliocene/Pleistocene boundary, between zones N21 and N22 is taken at the first appearance of *Globorotalia truncatulinoides*. The Miocene/Pliocene boundary, between zones N18 and N19 is based on the first appearance of *Sphaeroidinella dehiscens*, and the Oligocene/Miocene boundary is equated with the first diversification of the genus *Globigerinoides* within the range of *Paragloborotalia kugleri*. This event is close to the first appearance of *Globoquadrina dehiscens*.

Paleogene

The tropical zonation of Blow (1969) is applied to the upper Eocene-Oligocene section, and Berggren et al.'s (1985) zonation is used for the Paleocene-middle Eocene.

Cretaceous

The zonations of Caron (1985) and Sliter (1989) are combined and used for the Cretaceous. Table 2 summarizes the planktonic foraminifer datums on which the zonal schemes are based.

Methodology

Lost samples are disaggregated in a hot detergent solution, with hydrogen peroxide and Calgon added to clayey samples. Samples are washed over a 43 µm sieve, except when close to the Cretaceous/Tertiary boundary where samples are washed over a 38 µm sieve. The following categories describe the estimated frequencies of planktonic foraminifers in each sample, relative to other sand-sized particles, and of single species to total planktonic fauna:

A = Abundant (>25% of the residue);
C = Common (1%–25% of the residue);
F = Few (1%–5% of the residue);
R = Rare (<1% of the residue);
B = Barren (no foraminifers, or rare benthic foraminifers only).

The preservation of the foraminifers is described as follows:

G = Good, little or no fragmentation and/or recrystallization;
M = Moderate, some signs of dissolution (fragmentation and dissolution holes) and/or some recrystallization;
P = Poor, severe dissolution and/or recrystallization;
B = Barren, lacks planktonic foraminifers or nondiagnostic juveniles associated with benthonic foraminifers.

PALEOMAGNETICS

Natural Remanent Magnetization (NRM) and volume magnetic susceptibility (K_a) measurements were routinely performed on board the *JOIDES Resolution*. Because of secondary magnetizations acquired by the sediments and basement materials, magnetic cleaning was required to obtain the Characteristic Remanent Magnetization (ChRM) of the rock. For shipboard work, alternating field (AF) demagnetization was the only practical method for achieving this end.

Instruments

A 2-G Enterprises (model 760R) three-axis, pass-through cryogenic superconducting rock magnetometer was available for measurement of remanence on board the *JOIDES Resolution* during Leg 132. An AF demagnetizer (Model 2G600) capable of alternating fields up to 25 mT (T = tesla) is integrated with the cryogenic magnetometer. Communications between SQUID's (superconducting quantum interference device), the AF degaussing system, and the drive motor were linked through a FASTCOM4 multi-serial communications board in an IBM PC-AT compatible computer; all devices and actual measurements of core archive halves were controlled by a modified version of the Rhode Island University BASIC program. Leg 132 modifications to this program included SQUID control commands such that the magnetometer could operate at the 1× scale with flux counting for sediments and 100× for basement. The spinner magnetometer was not used in conjunction with Leg 132 studies.

The SQUID sensors in the cryogenic magnetometer measure magnetization over an interval approximately 20 cm long. Each axis has a slightly different response curve. The widths of the sensor regions imply that as much as 150 cm^3 of core contributes to the sensor signals. The large volume of core material within the sensor region permits an accurate determination of remanence for weakly magnetized samples despite the relatively high background noise related to the motion of the ship.

Sediments

Remanence measurements of sediments were performed at Site 809F by passing continuous archive-half core sections through the cryogenic magnetometer. In cores where recovery was as discrete fragments, these fragments were taped in the magnetometer holder with bedding planes perpendicular to the magnetometer "z" axis; to accommodate the size of the SQUID sensor region, samples were separated by a 10 cm gap. Depending on the lithology, measurements were taken at 2, 3, and 5 cm spacings; AF levels were also dependent on lithology but all included NRM measurements and most were concluded at 15 mT.

Basement Rocks

Basalts from Leg 132 were measured in much the same fashion as sediments. The cores recovered with the diamond coring system were archived in 75 cm sections with plastic spacers inserted between individual rock pieces. AF steps for basement lithologies were generally more closely spaced than for their sediment counterparts but, again, steps always included NRM and usually concluded with 15 mT.

Magnetic Susceptibility Measurements

Magnetic susceptibility measurements were accomplished employing a Bartington Instrument magnetic susceptibility meter (model M.S.1) with a M.S.1/CX 80 mm whole-core sensor loop set at 0.47 kHz (range 1). The susceptibility meter is on-line with the Gamma-Ray Attenuation Porosity Evaluator (GRAPE) and *P*-wave logger on the Multisensor Track (MST).

The general trend in the susceptibility data was used to characterize cored sediments. Igneous-rock susceptibility was measured using a sensor unit (type MS1B) attached to the Bartington susceptibility meter. Only those cores demonstrating sufficient volume recovery were run. Whole cores were run prior to splitting.

IGNEOUS ROCKS

Core Curation and Shipboard Sampling

Igneous rocks are split into archive and working halves using a rock saw with a diamond blade. The petrologists decide on the orientation of each cut so as to preserve unique features and/or expose important structures. The archive half is described, and samples for shipboard and shore-based analyses are removed from the working half. Each piece is numbered sequentially from the top of each section, beginning with the number 1. Pieces that can be fitted together (like a jigsaw puzzle) are assigned the same number, but are lettered consecutively (e.g., 1A, 1B, 1C, etc.). Spacers are placed between pieces with different numbers, but not

Table 2. Cretaceous planktonic foraminifer zonal schemes and biostratigraphic events used in Leg

Stage	m.y.	KS	Sliter 1989	Caron 1985	Main events
	66.5				LO *Cretaceous planktonics*
Maestrichtian		31	*A. mayaroensis*	*A. mayaroensis*	FO *Abathomphalus mayaroensis*
Maestrichtian		30	*G. gansseri*	*G. gansseri*	FO *Gansserina gansseri*
Maestrichtian		29	*G. aegyptiaca*	*G. aegyptiaca*	FO *Globotruncana aegyptiaca*
Maestrichtian		28	*G. havanensis*	*G. havanensis*	
	74.5				LO *Globotruncanita calcarata*
Campanian		27	*G. calcarata*	*G. calcarata*	FO *Globotruncanita calcarata*
Campanian		26	*G. ventricosa*	*G. ventricosa*	FO *Globotruncana ventricosa*
Campanian		25	*G. elevata*	*G. elevata*	
	84				LO *Dicarinella asymetrica*
San.		24	*D. asymetrica*	*D. asymetrica*	FO *Dicarinella asymetrica*
	87.5				
Con.		23	*D. concavata*	*D. concavata*	FO *Dicarinella concavata*
	88.5				
Tur.		22	*M. sigali*	*D. primitiva*	FO *Dicarinella primitiva*
Tur.		22	*M. sigali*	*M. sigali*	LO *Helvetoglobotruncana helvetica*
Tur.		21	*H. helvetica*	*H. helvetica*	FO *Helvetoglobotruncana helvetica*
Tur.		20	*W. archaeocretacea*	*W. archaeocretacea*	
	91				LO *Rotalipora cushmani*
Cenomanian		19	*R. cush.*: *D. algeriana*	*R. cushmani*	FO *Dicarinella algeriana*
Cenomanian		19	*R. cush.*: *R. greenhornensis*	*R. cushmani*	LO *Rotalipora reicheli*
Cenomanian		18	*R. reicheli*	*R. reicheli*	FO *Rotalipora reicheli*
Cenomanian		17	*R. brotzeni*	*R. brotzeni*	FO *Rotalipora brotzeni*
	97.5				
Albian		16	*R. appenninica*	*R. appenninica*	FO *Rotalipora appenninica*
Albian		15	*R. ticinensis*	*R. ticinensis*	FO *Rotalipora ticinensis*
Albian		14	*B. bregg.*: *R. subticinensis*	*R. subticinensis*	FO *Rotalipora subticinensis*
Albian		14	*B. bregg.*: *T. praeticinensis*	*B. breggiensis*	FO *Biticinella breggiensis*
Albian		13	*T. primula*	*T. primula*	FO *Ticinella primula*
Albian		12	*H. planispira*	*T. bejaouaensis*	
	113				
Aptian		11	*T. bejaouaensis*	*T. bejaouaensis*	FO *Ticinella bejaouaensis*
Aptian		10	*H. gorbachikae*	*H. gorbachikae*	LO *Globigerinelloides algerianus*
Aptian		9	*G. algerianus*	*G. algeriana*	FO *Globigerinelloides algerianus*
Aptian		8	*G. ferreolensis*		LO *Leupoldina cabri*
Aptian		7	*L. cabri*	*S. cabri*	FO *Leupoldina cabri*
Aptian		6	*G. blowi*	*G. blowi*	FO *Globigerinelloides blowi*
Aptian		5	*G. duboisi*	*G. blowi*	FO *Globigerinelloides duboisi*
	119				
Bar.		4	*H. similis*	*H. sigali*	FO *Hedbergella similis*
Bar.		3	*H. sigali*	*H. sigali*	FO *Hedbergella sigali*
	124				
Hau.		2	*G. hoterivica*	*G. hoterivica*	
Hau.		1	*G. spp.*	*minute planktics*	
	131				

between those with different letters and the same number. The presence of a spacer may represent a substantial interval of no recovery. Whenever the original piece is sufficiently large that the top and bottom can be distinguished before removal from the core liner (i.e., the piece could not have rotated about a horizontal axis in the liner during drilling), a red wax cross is marked on the base of each piece. [Hard rock samples cored during Leg 132 with the diamond coring system were divided into 75 cm sections.]

Before the rock is dry, sampling is carried out for shipboard physical properties, XRF, and thin-section studies. The archive half is next described in detail on the VCD form and photographed before storage. [For this engineering leg, hard rock cores are drafted from renditions made on board ship using Adobe Illustrator '88®. These were made from scans of line drawings, sketched from page-sized photographs.]

Visual Core Descriptions

Hard rocks sampled by the diamond coring system are graphically represented on VCD forms specific to igneous and metamorphic rocks (see logs for each site). Copies of the VCD forms, as well as other prime data collected during Leg 132 are available on microfilm at all three ODP repositories. The left hand column of the VCD (Fig. 9) is a graphical representation of the archive half. A horizontal line across the entire width of this column denotes a plastic spacer glued between rock pieces inside the liner. The number of each piece is also recorded, with oriented pieces indicated by the presence of an upward-pointing arrow to the right of the relevant piece. Shipboard samples and studies are indicated in the "shipboard studies" column, using the following notation:

XRF = X-ray fluorescence analysis,
TSB = Thin-section billet,
PP = Physical properties measurement.

When cores are described, checklists of the macroscopic features are used to ensure consistent and complete descriptions. The VCD form for fine-grained igneous rocks requires the following information:

1. The leg, site, hole, core number and type, and section number.
2. A graphic representation of the core, including the rock piece numbers and positions of shipboard samples.
3. Lithologic unit boundaries, based on criteria such as the occurrence of glassy and quenched margins, trends of marked grain-size variation, and changes in petrographic type and phenocryst assemblages.

The following checklist is used for fine- and medium-grained igneous rocks. For each lithologic unit defined, note the following:

(1) UNIT number (consecutive downhole), including numbers of top and bottom pieces in unit.

(2) ROCK NAME (to be filled in later).

(3) CONTACT TYPE: intrusive, discordant, depositional etc. Note the dip of the contact.

(4) PHENOCRYSTS: determine if homogeneous or heterogeneous through unit. For each phenocryst phase list the following: abundance (%), average size (in mm), shape, alteration — degree (%), type, and secondary phases, any other comments.

Now fill in ROCK NAME (item (2) above).

(5) GROUNDMASS TEXTURE: glassy, microcrystalline, fine-grained (mm), medium-grained (1–5 mm). Note any relative grain-size changes within unit from piece to piece.

(6) COLOR (dry).

(7) VESICLES: size, shape, percentage, distribution and nature of any fillings. Collect similar data for miaroles (vugs).

(8) STRUCTURE: massive, pillowed, thin or sheet-like, brecciated.

(9) ALTERATION: Type, form, distribution and degree, from fresh (<2% alteration present) to slight altered (2%–10%), moderately altered (10%–40%), highly altered (40%–80%), very highly altered (80%–95%), and completely altered (95%–100%).

(10) VEINS/FRACTURES: Type, width, orientation, % present, and nature of infillings.

When the VCD form is complete the information is then recorded in the VAX computer database HARVI. Each record is checked by the database program for consistency and printed for shipboard use. The information is reprinted here on the core description form.

Igneous rocks are classified mainly on the basis of mineralogy and texture. Basalts (fine-grained) and dolerites (medium-grained) are termed aphyric if lacking phenocrysts or if they amount to <1% of the rock. If porphyritic the rock may be sparsely phyric (phenocryst content of 1%–2%), moderately phyric (2%–10%), or highly phyric (>10%).

Thin-Section Description

Thin-section billets of basaltic rocks recovered during Leg 132 were examined to study the microcrystalline constituents in the fine-grained basalts and to confirm the identity of petrographic groups and/or alteration products. Thin sections were made from several key sites in the cores to give us an idea on the crystallization and vesiculation processes.

Petrographic descriptions together with estimates of the various mineral phases (both primary and secondary) are made on the igneous thin-section description forms, which are also entered in the VAX computer database HRTHIN.

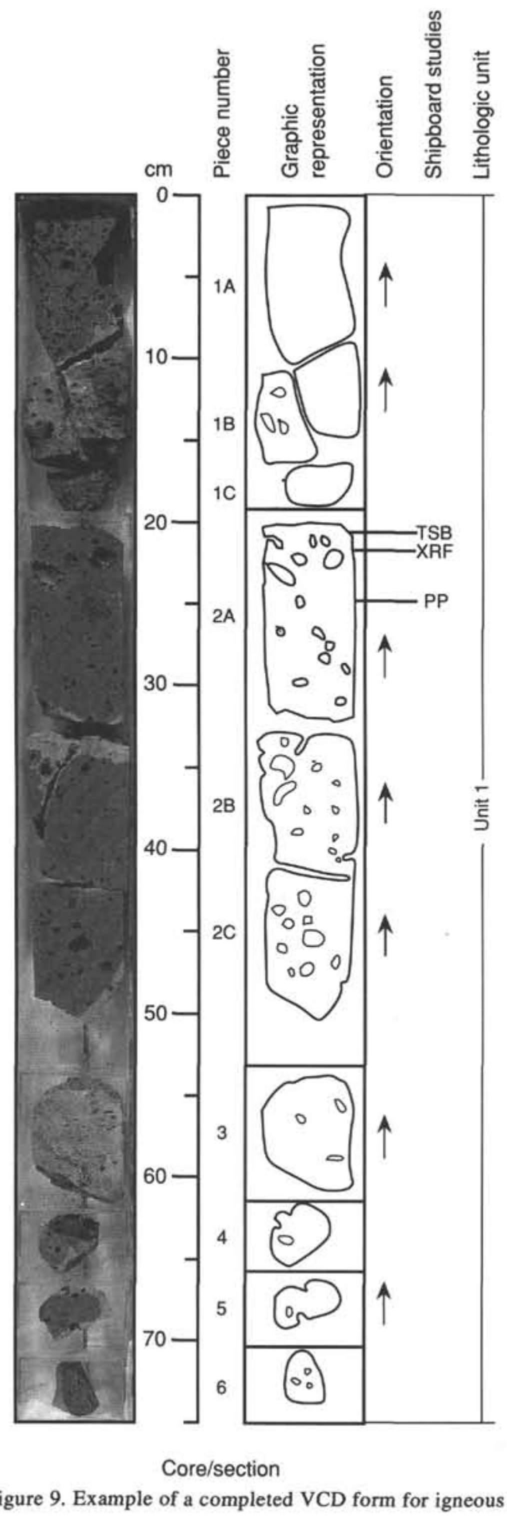
X-ray Fluorescence Analysis

Samples considered to be representative of individual lithologic units, or possibly of unusual composition, were analyzed for major oxides and selected trace elements by (XRF). The on-board XRF system is a fully automated, wavelength-dispersive, ARL 8420 spectrometer using a 3 kW rhodium X-ray tube as the excitation source for both major and trace elements. A list of analyzed elements and operating conditions are given in Table 3.

Sample preparation involves (1) crushing the sample to a powder, and (2) production of glass disks (for major element analysis) and pressed powder pellets (for trace element analysis). Initially, about 10 cm^3 of rock are removed from the core and unwanted saw marks removed by wet-grinding on a diamond impregnated disk mill. Each sample is then ultrasonically washed in distilled water and methanol for 10 min and dried at 110°C for 12 hr. Larger pieces are reduced to <1 cm diameter by crushing between two plastic disks in a hydraulic press. Powders are produced by grinding pieces in a motorized ceramic shatter box for 1–3 min to minimize contamination.

Major elements are determined on fused glass disks (Norrish and Hutton, 1969) in order to reduce matrix effects and variations in background. The disks are made by mixing 6 g of dry, lanthanum-doped (20% La_2O_3), lithium tetraborate flux (Spex #FF28-10) with 0.5 g of rock powder that has been ignited at about 1000°C in platinum-gold crucibles for 6–10 min and then poured into Pt-Au molds using a modified Claisse Fluxer apparatus. This 12:1 flux-to-sample ratio reduces matrix effects to the point where matrix corrections are unnecessary for normal basaltic to granitic compositions. Hence the relationship between X-ray intensity and concentration becomes linear and can be described by:

$$C_i = (I_i \times m_i) - b_i$$



132-809F-2Z-1

UNIT 1: APHYRIC BASALT

Pieces 1–6

CONTACTS: None.
PHENOCRYSTS: None.
GROUNDMASS: Uniformly fine grained.
VESICLES: 15–20%; <1 mm–1 cm; variable; uniform (fine); segregation vesicles, fine vesicle trails space 1–2 cm, glassy walls.
Miaroles: None.
COLOR: Dark gray.
STRUCTURE: Massive.
ALTERATION: Fresh, Piece 1B has light brown alteration, minor alteration on the surface of other pieces.
VEINS/FRACTURES: None.
ADDITIONAL COMMENTS: Piece 1A has gold saw-blade paint on the archived half. Paint has entered some vesicles. Piece 1A has an undulating diamond bit cut.

Figure 9. Example of a completed VCD form for igneous rocks.

where C_i = concentration of oxide i (wt%)
I_i = net peak X-ray intensity of oxide i
m_i = slope of calibration curve for oxide i (wt%/cps), and
b_i = apparent background concentration for oxide i (wt).

The slope m_i was calculated from a calibration curve derived from the measurement of well-analyzed reference rocks (BHVO-1, G-2, AGV-1, JGB-1, JP-1, Br, and DRN). The background b_i was determined either on blanks or derived by regression analysis from the calibration curves. Trace elements are determined on pressed-powder pellets made by mixing 6 g of fresh rock powder with 40 drops of liquid binder. This mixture is then pressed into an aluminum cap with 7 tons of pressure. A minimum of 5 g of sample ensures the pellet will be "infinitely thick" for rhodium K-series radiation. For the computation of trace element concentrations from measured X-ray intensities, an off-line calculation program based on routines from Bougault et al. (1977) and written by T.L. Grove and M. Loubet was used.

Table 3. Leg 132 XRF Analytical conditions.

Element	Line	Crystal	Detector	Collimator	Peak angle (°)	Background offset (°)	Total count time (seconds) Peak	Background
SiO_2	Kα	PET (002)	FPC	Coarse	109.14	0	40	0
TiO_2	Kα	LiF (200)	FPC	Fine	86.10	0	40	0
Al_2O_3	Kα	PET (002)	FPC	Coarse	144.66	0	100	0
Fe_2O_3*	Kα	LiF (200)	FPC	Fine	57.52	0	40	0
MnO	Kα	LiF (200)	KrSC	Fine	62.94	0	40	0
MgO	Kα	TLAP	FPC	Coarse	44.87	±0.80	200	200
CaO	Kα	LiF (200)	FPC	Coarse	113.09	0	40	0
Na_2O	Kα	TLAP	FPC	Coarse	54.71	−1.20	200	200
K_2O	Kα	LiF (200)	FPC	Fine	136.54	0	40	0
P_2O_5	Kα	Ge (111)	FPC	Coarse	140.92	0	100	0
Rh	K-C	LiF (200)	Scint	Fine	18.60	0	100	0
Nb	Kα	LiF (200)	Scint	Fine	21.37	±0.35	200	200
Zr	Kα	LiF (200)	Scint	Fine	22.53	±0.35	100	100
Y	Kα	LiF (200)	Scint	Fine	23.78	±0.40	100	100
Sr	Kα	LiF (200)	Scint	Fine	25.14	±0.41	100	100
Rb	Kα	LiF (200)	Scint	Fine	26.59	±0.60	100	100
Zn	Kα	LiF (200)	Scint	Fine	41.78	±0.40	60	60
Cu	Kα	LiF (200)	Scint	Fine	45.02	±0.40	60	60
Ni	Kα	LiF (200)	Scint	Coarse	48.68	±0.60	60	60
Cr	Kα	LiF (200)	FPC	Fine	69.33	±0.50	60	60
Fe	Kα	LiF (220)	FPC	Fine	85.73	−0.40+0.70	40	40
V	Kα	LiF (220)	FPC	Fine	123.20	−0.50	60	60
TiO_2	Kα	LiF (200)	FPC	Fine	86.10	±0.50	40	40
Ce	Lα	LiF (220)	FPC	Coarse	128.33	±1.50	100	100
Ba	Lβ	LiF (220)	FPC	Coarse	128.92	±1.50	100	100

* = total Fe as Fe_2O_3.
FPC = flow proportional counter using P_{10} gas.
KrSC: = sealed krypton gas counter.
Scint = NaI scintillation counter.
All elements analyzed under vacuum on goniometer 2, at generator settings of 60 kV and 50 mA.

PHYSICAL PROPERTIES

Shipboard measurements of physical properties provide information that aids characterization of lithologic units, allows correlation of lithology with downhole geophysical logging results, and provides constraints on interpretation of seismic reflection and other geophysical data. Furthermore, these data help to determine the mechanical state of sediments and rocks, identify geotechnical boundaries, and contribute to paleoceanographic interpretation of sedimentary units. The goal of the physical properties program of Leg 132, in addition to providing a link between lithologic and geophysical data, was to evaluate narrow-diameter cores recovered using the ODP DCS in different drilling environments.

Several types of measurements were performed on the whole-round core sections. Measurements of bulk density, compressional-wave velocity, and magnetic susceptibility were provided by the MST. The MST incorporates the GRAPE, a Compressional-Wave Core Logger (PWL), and a Magnetic Susceptibility Monitor. Physical property measurements made on samples obtained from the split cores included: vane shear strength, compressional-wave velocity, and index properties. Samples were chosen to be representative of the core or section in undisturbed sediment. Measurements and samples were obtained generally at the frequency of two per section.

Multisensor Track (MST)

The MST incorporates the GRAPE, *P*-wave logger, and magnetic susceptibility devices in scans of the whole-round core sections. Individual unsplit core sections were placed horizontally on the MST, which moves the section through the three sets of sensors. The smaller diameter of DCS core liners required some modifications to the MST apparatus and default parameters when processing these cores.

The GRAPE makes measurements of bulk density at 1 cm intervals by comparing attenuation of gamma rays through the cores with attenuation through an aluminum standard (Boyce, 1976). The GRAPE data is most reliable in HPC cores.

Wet-bulk density was also determined in hard rock using the GRAPE special 2 min count technique as described by Boyce (1976). The GRAPE measurements were on discrete samples of rock cut from the core for index properties measurements. All counts for the samples and accompanying air (background) counts were made in duplicate and averaged. Grain density values from gravimetric measurements were used to correct the wet-bulk density determined by the GRAPE for deviation of the grain density of the sample from that of quartz. The precision estimated for this technique is ±1.5% (Boyce, 1976).

The PWL transmits a 500-kHz compressional-wave pulse through the core at a repetition rate of 1 kHz. The transmitting and receiving transducers are aligned perpendicular to the core axis. A pair of displacement transducers monitor the separation between the compressional wave transducers; variations in the outside diameter of the liner therefore do not degrade the accuracy of the velocities. Measurements are taken at 2 cm intervals. Generally, only the HPC cores were measured, as the XCB and RCB cores have voids between the core and the liner which cause transmission losses. Weak returns with signal strengths below a threshold value of 100 were removed.

Magnetic susceptibility was measured on all sections at 3 cm intervals (or less) using the 0.1 range on the Bartington meter with a 8 cm diameter loop. The close sampling was carried out to provide another measure for between-hole correlations and to investigate the eolian component of the sediments recovered.

Index Properties

Index properties (bulk density, grain density, water content, porosity, and dry density) were calculated from measurements of wet and dry weights and dry volume. Samples of approximately 10 cm^3 were taken for determination of index properties. Soft sediment samples were placed in precalibrated aluminum containers prior to weight and volume measurements. Index properties measurements for lithified sediment and basement rock samples were made on crushed portions of the sample cubes cut for velocity determinations or from mini-cores drilled into the sample half of the split core.

Sample weights were determined aboard ship to a precision of ±0.01 g using a Scitech electronic balance. Volumes were determined using a Quantachrome Penta-Pycnometer, a helium-displacement pycnometer. The Quantachrome pycnometer measures volumes to an approximate precision of 10^{-4} cm^3. Dry weight and volume measurements were obtained after the samples were oven dried at 110°C for 24 hr and allowed to cool in a desiccator. A salt correction assuming 35 ppt interstitial fluid salinity was applied to density and porosity computations as per Hamilton (1971).

Water Content

The determination of water content followed the methods of the American Society for Testing and Materials (ASTM) designation (D) 2216 (ASTM, 1989). As outlined in ASTM D2216, corrections are required for salt when measuring marine samples. In addition to the recommended water content calculation presented in ASTM D2216, which is the ratio of the pore fluid mass to the dry sediment mass (% dry wt), a calculation of the ratio of pore fluid mass to total sample mass was also reported (% wet wt). The equations for each water content calculation are as follows:

$$W_c\ (\%\ \text{dry wt}) = (M_t - M_d)/(M_d - S\ M_t) \tag{1}$$

$$W_c\ (\%\ \text{wet wt}) = (M_t - M_d) \times (1 + S)/M_t \tag{2}$$

where:

M_t = total mass (saturated)
M_d = dry mass
S = salinity.

Bulk Density

Bulk density (ρ) is the density of the total sample, including the pore fluid or $\rho = M_t/V_t$ where V_t is the total sample volume. The mass (M_t) was measured using the electronic balance and the total volume was measured with the helium pycnometer. In high porosity sediment, the bulk density was calculated directly using Çr = M_t/V_t. A calculation check was performed for bulk density using specific gravity (G_s). The specific gravity was calculated using the measured bulk density and water content as follows:

$$G_s = \rho/(\rho_w - W_c\,(\rho - \rho_w)) \tag{3}$$

where:

ρ_w = density of pore fluid
W_c is the water content reported as a decimal ratio of % dry wt.

When the specific gravity varied from known values for the measured lithologies or from the measured grain density, the bulk density reported was calculated from water content and grain density. These values are used in the data tables and plots as r_{calc} and were determined as follows:

$$\rho_{calc} = ((1 + W_c)/(1 + (W_c \times (\rho_{grain}/\rho_w)))) \times \rho_{grain} \tag{4}$$

where:

W_c is the water content reported as a decimal ratio of % dry wt.

Porosity

The porosity was calculated using:

$$\phi = (W_c \times \rho)/((1 + W_c) \times \rho_w) \tag{5}$$

where:

ρ used in the equation is either the directly measured bulk density or ρ_{calc}.
W_c is the water content reported as a decimal ratio of % dry wt.

Grain density

The grain density was calculated from the dry mass (Scitech balance) and dry volume (penta-pycnometer) measurements. Both mass and volume were corrected for salt as follows:

$$\rho_{grain} = (M_d - s)/(V_d - (s/\rho_{salt})) \tag{6}$$

where:

V_d = dry mass
s = salt correction
ρ_{salt} = density of salt (2.257 g/cm^3).

Dry density

The dry density is the ratio of the dry mass (M_d) to the total volume. The dry density was calculated using the corrected water content and porosity for each measurement:

$$\rho_d = (\phi/W_c) \times \rho_w. \tag{7}$$

Vane Shear Strength

The undrained shear strength of the sediment was determined using the motorized Wykeham-Farrance vane shear device following the procedures of Boyce (1976). Calibrated springs were used to ensure shearing at 20°–90° of rotation. The vane used for all measurements has a 1:1 blade ratio with a dimension of 1.27 cm.

In the analyses of vane tests, the assumption is made that a cylinder of sediment is uniformly sheared about the axis of the vane in an undrained condition, with cohesion as the principal contributor to shear strength. Departures from this assumption include progressive cracking within and outside of the failing specimen, uplift of the failing core cylinder, drainage of local pore pressures (i.e., the test can no longer be considered to be undrained), and stick-slip behavior.

Compressional Wave Velocity

Compressional-wave (*p*-wave) velocity measurements were obtained using the Hamilton Frame Velocimeter to measure compressional-wave velocities at 500 kHz in discrete sediment samples. In lithified sediments and basement rocks when insertion became impossible samples were carefully cut using a double-bladed diamond saw. Sample thickness was measured directly from the velocimeter-frame lead screw through a linear resistor output to a digital multimeter or by using a micrometer. Zero travel times for the velocity transducers were estimated by linear regression of travel time vs. distance for a series of aluminum and lucite standards. Filtered seawater was used to improve the acoustic contact between the sample and the transducers.

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