2. EXPLANATORY NOTES[1]

Shipboard Scientific Party[2]

ORGANIZATION AND AUTHORSHIP

Volume 76, covering Leg 76 of the cruises of the *Glomar Challenger*, is divided into two main sections. The first part comprises the Introduction, Explanatory Notes, Sites 533 and 534 reports (on objectives, operations, and principal results), and a report of the underway data. The second section is composed of more detailed discussions on specific subjects studied after the cruise by the scientists who were on board ship and by other interested investigators. It contains five subsections: (1) Gas Hydrates—Blake Outer Ridge; (2) Organic and Inorganic Geochemistry and Sedimentology; (3) Biostratigraphy; (4) Geophysics and Igneous Petrology—Blake-Bahama Basin; (5) Regional Studies and Geological Models; and (6) Synthesis of Leg 76 Results.

The authorship of the site reports is shared collectively by the shipboard scientific party, although the ultimate responsibility for their content lies with the two Co-Chief Scientists. Each site chapter follows the same general outline, and individual participants assume the major responsibility for contributing specific sections. The site chapters are largely compiled on the basis of work initiated aboard ship during Leg 76. Additional information from onshore studies has been incorporated to provide a more complete and accurate report. Some discussions, taken from more detailed chapters by shipboard scientists, are presented in their entirety in the second section of this volume.

Individual sections of the Leg 76 site reports were compiled according to the format listed here. This division sometimes led to differences in interpretation of the data collected at each site; an attempt has been made to reconcile widely different interpretations. Authors responsible for each section are indicated in parentheses:

Background and Objectives (Sheridan, Gradstein, and, for Site 533, Kvenvolden)

Operations (Sheridan and Gradstein)

Sedimentology and Graphic Core Descriptions (Kagami and Kostecki [533]; Bliefnick, Kagami, Kostecki, Robertson, and Ogg [534]); Leg 76 Extension (Ogg, Kostecki, Cotillon, Halley, and Tyson)

Biostratigraphy (Moullade and Gradstein [foraminifers]; Roth [nannofossils]; and Habib [palynology for Site 534]); Leg 76 Extension (Premoli-Silva and Gradstein [foraminifers]; Bowdler and Watkins [nannofossils])

Sedimentation Rates (Roth and Moullade)

Organic Geochemistry (Kvenvolden, Barnard [533]; Keenan [534]); Leg 76 Extension (Patton)

Inorganic Geochemistry (Jenden)

Physical Properties (Shipley); Leg 76 Extension (Kinoshita)

Paleomagnetism (Ogg); Leg 76 Extension (Ogg and Testarmata)

Mechanical Logging (Sheridan); Leg 76 Extension (Sheridan and Axline)

Correlation of Drilling Results with Seismic Profiles (Sheridan, Shipley, and Gradstein)

Summary and Conclusions (Sheridan and Gradstein)

SEISMIC SURVEY AND UNDERWAY DATA

The seismic survey data that formed the basis for Leg 76 site selections were provided by Lamont-Doherty Geological Observatory, based on site surveys made aboard *Robert Conrad* on Cruise 21-02 (Bryan et al., 1980). Surveys were also made aboard *Glomar Challenger* during approach to and departure from the sites.

Instruments aboard *Glomar Challenger* continuously recorded water depth, intensity of magnetic field, and seismic profiles while the ship was underway. Water depths were recorded under way on an EDO precision depth recorder and corrected according to Matthews' tables. Depths are given in meters. (The site reports also contain water depth determined by length of drill pipe to bottom less 10 m—the distance between the sea surface and rig floor.)

The magnetic intensity data were collected with a Varian proton magnetometer, and readings were taken at 5-min. intervals from an analog recorder. The sensor was towed 300 m behind the ship.

The seismic profiling system consisted of two Bolt air guns, a Scripps-designed hydrophone array, Bolt amplifiers, two bandpass filters, and two EDO recorders. Variations in second sweeps, filter and gain settings, and air gun size are recorded on individual profiler records. Seismic profiler records, made while steaming between sites, are reproduced as back pocket figures (see

[1] Sheridan, R. E., Gradstein, F. M., et al., *Init. Repts. DSDP*, 76: Washington (U.S. Govt. Printing Office).

[2] Robert Sheridan (Co-Chief Scientist), Department of Geology, University of Delaware, Newark, Delaware; Felix Gradstein (Co-Chief Scientist), Bedford Institute of Oceanography, Geological Survey of Canada, Dartmouth, Nova Scotia, Canada; Leo A. Barnard, Department of Oceanography, Texas A&M University, College Station, Texas; Deborah M. Bliefnick, Earth Sciences Department, University of California, Santa Cruz, California; Daniel Habib, Department of Earth and Environmental Sciences, Queens College, Flushing, New York; Peter D. Jenden, Institute of Geophysics and Planetary Physics, University of California, Los Angeles, California; Hideo Kagami, Ocean Research Institute, University of Tokyo, Nakano, Tokyo, Japan; Everly M. Keenan, Department of Geology, University of Delaware, Newark, Delaware; John Kostecki, Lamont-Doherty Geological Observatory, Columbia University, Palisades, New York; Keith Kvenvolden, U.S. Geological Survey, Menlo Park, California; Michel Moullade, Centre de Recherches Micropaleontologiques, Université de Nice, Nice, France; James Ogg, Geological Research Division, Scripps Institution of Oceanography, La Jolla, California; Peter H. Roth, Department of Geology and Geophysics, University of Utah, Salt Lake City, Utah; Thomas Shipley, Deep Sea Drilling Project, Scripps Institution of Oceanography, La Jolla, California (present address: University of Texas, Institute of Geophysics, Austin, Texas).

Sheridan, this volume). Greenwich Mean Time (indicated by Z) is used on the seismic profiles and other underway data, but in order to be consistent with drilling logs and other ship's operations, the authors used "local time" in the text of the site reports.

BIOSTRATIGRAPHIC FRAMEWORK

Foraminifer Zonation

The Late Cenozoic planktonic foraminifer zonation follows Blow (1969) and Stainforth et al. (1975). The Early Cretaceous foraminiferal biostratigraphy is based on studies by Bartenstein et al., (1957, 1966, 1973), Moullade (1966, 1974, in press), compilations by Sigal (1977) and van Hinte (1976), and regional studies in the western Atlantic by Luterbacher (1972, Leg 11) and Gradstein (1978, Leg 44).

Middle and Late Jurassic biostratigraphy is derived from information by Lutze (1960); Simon and Bartenstein (1962), Espitalié and Sigal (1963), Pazdro (1969), Wernli and Septfontaine (1971), Ohm (1967), Ruget (1973), Bielecka and Geroch (1974), Gradstein (1976), and Jansa et al. (1980).

Foraminifer Abundance and Preservation

The term abundance was used in two different ways—first, for the abundance of foraminifers in the sediment, and second, for the abundance of a particular species in the assemblages in a residue.

For the first case (which was employed in the abundance boxes at the top of the paleo-biostratigraphic forms), terms were

A = abundant (about 2 cm^3 of dry, foraminifer residue from 10 cm^3 of a sediment or rock sample)

C = common (about 1 cm^3, as just described)

F = few (about 0.5 cm^3)

R = rare (0.2 cm^3 or less)

For the second case, the terminology employed was:

A = over 30% of the foraminifer population of a residue

C = 15 to 30%

F = 3 to 15%

R = less than 3%

Percentages were estimated by visual examination.

Preservation included in this case the effect of dissolution on abundance and diversity of residues as well as on the condition of individual tests.

G = good (dissolution effects rare and obscure)

M = moderate (specimen dissolution common but minor; abundance is typically few or, at best, common; and diversity is noticeably reduced, such as 10 species or less)

P = poor (these specimens are small, compact, thick-walled, mineral-filled, and encrusted or variously perforated; one to six species).

Nannofossil Biostratigraphy

Calcareous nannoplankton zonations for the Cenozoic have been largely standardized. The zonation used in this report is based mostly on Bukry (1973, 1975), with minor modifications at the subzonal level (Table 1).

Table 1. Cenozoic nannofossil zonation.

Age	Zone	Subzone
Pleistocene	*Emiliania huxleyi*	
	Gephyrocapsa oceanica	*Ceratolithus cristatus* *Emiliania ovata*
	Crenalithus doronicoides	*Gephyrocapsa caribbeanica* *Pseudoemiliania lacunosa*
upper Pliocene	*Discoaster brouweri*	*Cyclococcolithus macintyrei* *Discoaster pentaradiatus* *Discoaster surculus* *Discoaster tamalis*
lower Pliocene	*Reticulofenesira pseudoumbilica*	*Discoaster asymmetricus* *Sphenolithus neoabies*
	Ceratolithus tricomiculatus	*Ceratolithus rugosus* *Ceratolithus acutus* *Triquetrorhabdulus rugosus*
upper Miocene	*Discoaster quinqueramus*	*Ceratolithus primus* *Discoaster berggrenii*
	Discoaster neohamatus	*Discoaster neorectus* *Discoaster bellus*
	Discoaster hamatus	*Catinaster calyculus* *Helicosphaera carteri*
middle Miocene	*Catinaster coalitus*	
	Discoaster exilis	*Discoaster kugleri* *Coccolithus miopelagicus*
	Spenolithus heteromorphus	
lower Miocene	*Helicosphaera ampliaperta*	
	Sphenolithus belemnos	
	Triquetrorhabdulus carinatus	*Discoaster druggii* *Discoaster deflandrei* *Cyclicargolithus abisectus*
upper Olicene	*Sphenolithus ciperoensis*	*Dictyococcites bisectus* *Cyclicargolithus floridanus*
middle Oligocene	*Sphenolithus distentus*	
	Sphenolithus predistentus	
lower Oligocene	*Helicosphaera reticulata*	*Reticulofenestra hillae* *Cyclococcolithus formosus* *Coccolithus subdistichus*
upper Eocene	*Discoaster barbadiensis*	*Isthmolithus recurvus* *Chiasmolithus oamoruensis*
middle Eocene	*Reticulofenestra umbilica*	*Discoaster saipanensis* *Discoaster bifax*
	Nannotetrina fulgens	*Coccolithus staurion* *Chiasmolithus gigas* *Discoaster strictus*
lower Eocene	*Discoaster sublodoensis*	*Rhabdosphaera inflata* *Discoasteroides kuepperi*
	Discoaster lodoensis	
	Tribrachiatus orthostylus	
	Discoaster diastypus	*Discoaster binodosus* *Tribrachiatus contortus*
upper Paleocene	*Discoaster multiradiatus*	*Campylosphaera eodela* *Chiasmolithus bidens*
	Discoaster nobilis	
middle Paleocene	*Discoaster mohleri*	
	Heliolithus kleinpellii	
	Fasciculithus tympaniformis	
lower Paleocene	*Ellipsolithus maccellus*	
	Chiasmolithus danicus	
	Cruciplacolithus temus	

The Cretaceous is subdivided using the zonation summarized in Roth (1978) (Table 2). Documentation of ranges of Jurassic nannofossils is still too inadequate to establish a reliable zonation. Information on Jurassic biostratigraphy comes from Barnard and Hay (1974), Hamilton (1978), Medd (1971, 1979), Wind (1978), Čepek (1978), and Thierstein (1975, 1976).

Abundance Estimates

Relative abundances in smear slides are expressed as follows:

A: abundant (10–100 specimens per field of view)
C: common (1–10 specimens per field of view)
F: few (single specimen in 1–10 fields of view)
R: rare (single specimen in 10–100 fields of view)

Preservation

The etching and overgrowth scale of Roth and Thierstein (1972) is used to express the degree of etching and overgrowth of nannofossils. The following criteria were used to assign preservation values to the samples.

Etching

E-1: slightly jagged outlines of more delicate forms; delicate central structures damaged in some but not in all specimens.

E-2: more jagged outlines; delicate central structures frequently affected, more delicate forms slightly fragmented.

E-3: only the more robust forms are preserved. Dominant genera, because of their resistance to dissolution, are the following: *Watznaueria, Cyclagelosphaera, Retecapsa, Cretarhabdus, Cruciellipsis, Manivitella, Lithastrinus*, and *Eiffellithus*.

E-4: only fragments of coccoliths are preserved; impossible to identify fragments as to genus level.

Overgrowth

O-1: slight overgrowth on central area structures and shield elements.

O-2: increased overgrowth; some of the more delicate forms become sufficiently masked by secondary calcite to make identification difficult.

O-3: only the most robust forms are preserved; reduced diversity due to removal of delicate forms.

O-4: complete recrystallization; coccoliths are no longer identifiable to genus.

PALEOMAGNETIC SAMPLING AND ANALYSIS

The magnetostratigraphy of the Lower Cretaceous and Upper Jurassic sediments and the magnetic directions and properties of the basal basalts were studied partially on board ship and partially postcruise. Oriented minicores (2.5 cm diameter, 2.5 cm length) were drill-pressed from the sediment cores at intervals ranging from 0.25 to 1.0 m and from the basalt cores in an extensive suite of all lithologies. Of the approximately 500 sediment and 100 basalt cores, half were partially analyzed aboard ship by using a Digico Balanced Fluxgate Rock Magnetometer connected to a Digico Micro 16V minicomputer. Progressive alternating field (AF) demagnetization was done on a Schonstedt Model GSD-1 AC Geophysical Specimen Demagnetizer.

The 0.2×10^{-6} emu/cm^3 noise level of the magnetometer yielded high error factors on the weak limestones. Viscous behavior of some of the limestones and basalts was exhibited at higher AF demagnetization steps. For these reasons and to run progressive thermal demagnetization on red limestones, all the samples were taken to the paleomagnetics facility of the California Institute of Technology and Sierra Geophysics to be analyzed on a ScT cryogenic magnetometer in a special field-free room.

Because the declination values of the cores are unknown, only inclination data can be used to determine polarity. The paleolatitude of Site 534 in the Late Jurassic was about 15°N, implying expected magnetic inclinations of about 25°. Therefore, given the normal spread of magnetic directions in any rock unit and variable degree of postdepositional overprinting, special care must be taken to distinguish low-angle negative (reversed) inclinations from low-angle positive (normal) inclinations. For this reason, every sample was progressively demagnetized in a minimum of four steps to identify the trend of the changing direction as the overprint was gradually removed. This procedure could not be carried out on board.

NUMBERING OF SITES, HOLES, CORES, AND SAMPLES

DSDP drill sites are numbered consecutively from the first site drilled by *Glomar Challenger* in 1968; the site number is unique. A site refers to the hole or holes drilled while the ship is positioned over one acoustic beacon. Several holes may be drilled at a single locality (site) by pulling the drill string above the seafloor ("mudline") and moving the ship some distance (usually 100 m or more) from the previous hole.

The first (or only) hole drilled at a site takes the site number (e.g., Hole 533.) A letter suffix distinguishes each additional hole at the same site (e.g., Hole 533A). Note that recovered sediments or rocks from different holes at the same site usually do not come from equivalent positions in the stratigraphic column; thus this distinction is important.

Serial "cored intervals" are not necessarily adjacent, but may be separated by "drilled intervals" without recovery. In soft sediment, this is accomplished by "washing down," drilling with core barrel in place but circulating water with sufficient 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, or if pump pressure is insufficient, it is possible to get "spotty" sampling within the washed interval and thus to core an interval of greater than 9.5 m (each coring interval is generally 9.5 m long). Likewise, if recovery is expected to be low, it is possible to "overcore" an interval of more than 9.5 m and recover less than 9.5 m of material.

Cores are numbered sequentially from the top down. Full core recovery comprises 9.28 m of sediment or rock in a plastic liner (6.6 cm diameter) and a short sample

Table 2. Cretaceous nannofossil zonation (Roth, 1978).

European stages	Age (m.y.)	Calcareous nannoplankton zones		Important nannoplankton biostratigraphic horizons
Danian	65	*Markalius astroporus*	NP1	*Cretaceous nannoflora*
Maestrichtian		*Micula mura/Nephrolithus frequens*	NC23	*Micula mura* *Nephrolithus frequens*
		Lithraphidites quadratus	NC22	*Lithraphidites quadratus s. str.*
	70	*Lithraphidites praequadratus* (a)	NC21	*Lithraphidites praequadratus* *Tetralithus trifidus*
		Tetralithus trifidus	NC20	*Tetralithus trifidus*
Campanian	75	*Tetralithus aculeus*	NC19	*Tetralithus aculeus*
		Broinsonia parca	NC18	*Broinsonia parca*
	80	*Tetralithus obscurus-Micula concava* (a)	NC17	*Tetralithus obscurus* *Micula concava* *Lithraphidites helicoidens*
Santonian		*Broinsonia lacunosa*	NC16	*Broinsonia lacunosa*
Coniacian	85	*Marthasterites furcatus*	NC15	*Marthasterites furcatus* *Eiffellithus eximius*
Turonian		*Kamptnerius magnificus*	NC14	*Kamptnerius magnificus*
	90	*Micula staurophora*	NC13	*Micula staurophora* *Tetralithus pyramidus*
		Gartrierago obliquum	NC12	*Gartnerago obliquum* *Lithraphidites acutum*
Cenom.		*Lithraphidites acutum*	NC11	*Lithraphidites acutum*
Albian	95 100	*Eiffellitus turriseiffeli*	NC10	*Eiffellithus turriseiffeli*
		Axipodorhabdus albianus	NC9	*Axipodorhabdus albianus*
	105	*Prediscosphaera cretacea*	NC8	*Prediscosphaera cretacea*
Aptian		*Parhabdolithus angustus* *(Vagalapilla matalos)*	NC7	*Parhabdolithus angustus*
	110	*Chiastozygus litterarius*	NC6	*Chiastozygus litterarius* *Vagalapilia matalosa* *Nannoconus colonii*
Barremian		*Watznaueria oblonga* (NC5): *Micrantholithus obtusus*	NC5b	*Lithradphidites bollii*
	115	*Nannoconus bucheri* (a)	NC5a	*Cruciellipsis cuvillieri*
Hauterivian		*Cruciellpsis cuvillieri* (NC4): *Lithraphidtes bollii* (b)	NC4b	*Lithraphidites bollii*
	120	*Calcicalathina oblongata*	NC4a	*Tubodiscus verenge* *Diadorhombus rectus*
Valanginian	125	*Tubodiscus verenae-Diadorhombus rectus*	NC3	*Tubodiscus verenae* *Diadorphombus ectus* *Calcicalathina elongata*
	130	*Retecapsa neocomiana* (a)	NC2	*Retecapsa angustiforata* *Cruciellipis cuvillieri* s. str. *Retecapsa neocomiana*
Berriasian	135	*Nannoconus colomii-Lithraphidites carniolensis*	NC1	*Nannoconus colomii* *Lithraphidites carniolensis*
		Conusphaera mexicana	Jurassic	*Conusphaera mexicana*

Note: a = new zone defined in this paper; b = zonal boundary definitions modified in this paper; and c = lowest sample studied.

(~22 cm) in the core catcher (a multifingered device at the bottom of the core barrel that prevents cored materials from sliding out). Cores are cut into 1.5 m sections and numbered sequentially from top to bottom. Because the core barrel is 9.28 m long rather than 9 m, another segment may be recovered in addition to six 1.5-m sections. This segment is designated the "7-section"; it comprises whatever is "left-over" at the bottom of the core after six 1.5-m sections have been cut. Both the "7-section" and core-catcher samples are split and described along with the remainder of the core. (Before Leg 43, these pieces frequently were not split or described).

Recovery is often less than 100%. In cases of partial recovery, if the sediment core is continuous, the recovered material is assigned to the top of the cored interval, and 1.5-meter sections—as many as needed to accommodate the length of core recovered—are numbered sequentially (starting with Section 1 at the top). Sections are cut starting at the top of the recovered material; hence, the "void" (which occurs when the recovered sediment is not evenly divisible by 1.5) comes at the bottom section. When recovery is partial, the original position of recovered material in the cored interval is unknown, so we employ this convention for consistency and for convenience in data handling. If recovery is partial and core fragments are separated, and if shipboard scientists believe the fragments of sediments were not continuous, the intervening spaces are noted as "void." Whether it is continuous or not, the core-catcher sample is described in the visual core descriptions beneath the lowest section, and depth below seafloor is assigned on this basis. Core labeling is graphically depicted in Figure 1. The position of Section 1 is justified upward to the top of the cored interval.

Samples are designated by the interval (cm) from the top of the core section from which the sample was extracted. A full sample designation would consist of the following information: Leg-site-hole-core number-section number-interval (cm from top of section). Sample

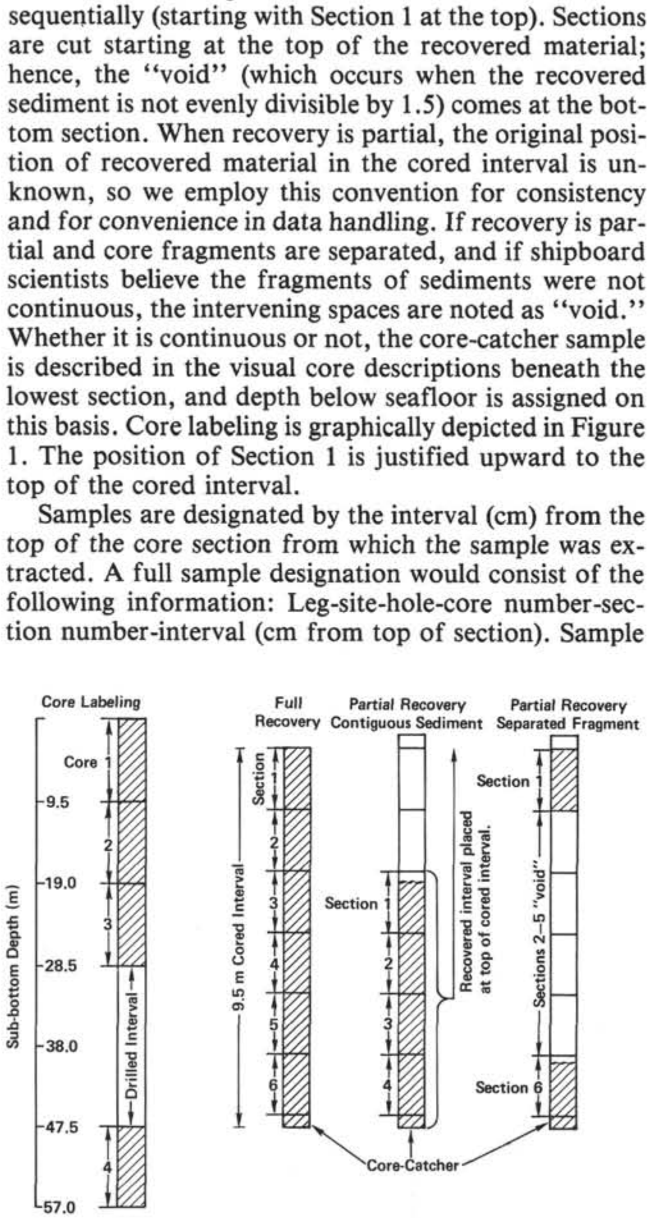

Figure 1. Conventions for core and section labeling.

76-533A-4-3, 122–124 cm designates a sample taken at 122 to 124 cm from the top of Section 3 of Core 4, from the second hole drilled at Site 533 during Leg 76. The depth below the seafloor for this sample would then be the depth to the top of the cored interval plus 3 m for Sections 1 and 2, plus 122 cm (depth below the top of Section 3). For example, if the top of the cored interval were 100 m, this would equal 104.2 m. (Note that sample requests refer to a specific interval within a core section rather than level below seafloor.) A sample from the core catcher of this core is designated 533A-4,CC.

Hydraulic Piston Corer and Pressure Core Barrel

As in the case of the drilled cores, Hydraulic Piston Corer (HPC) recovery is also measured from the top of the cored section to the bottom of the cored section; however, because the maximum length of the HPC section is 4.4 m, there is a maximum length of three sections per core instead of seven. The Pressure Core Barrel (PCB), employed to collect cores in the gas hydrate layers, will recover a maximum of 6 m in the pressurized section and less than 1.5 m in the lower, unpressurized section. Core sections in the PCB will therefore be designated 1 to 5 (maximum), the lower unpressurized section given the suffix (u) to delineate it as such.

CORE HANDLING

The paleontologist makes initial assessment of core material from samples taken from the core catcher as soon as the core is brought aboard.

The core is cut into 1.5-m sections, sealed, labeled, and moved into the core laboratory for processing. On Leg 76, conductivity measurements and standard gamma-ray attenuation porosity evaluation (GRAPE) analyses for bulk density and porosity were made on the unsplit core sections.

The cores are then split longitudinally into the "work" and "archive" halves. The archive half is described; color, texture, structure, and composition of the various lithologic units are noted on the standard visual core description forms. The archive half is then photographed and stored. Samples and measurements are taken from the working half. Samples include those for grain size, carbon-carbonate, water content, and paleontological determinations. Measurements on Leg 76 were primarily those of sonic velocity, accomplished with a Hamilton Frame velocimeter on the split core.

After sediment cores are sampled and described, they are maintained in cold storage aboard *Glomar Challenger* until they can be transferred to the DSDP East Coast Repository (Lamont-Doherty Geological Observatory, Palisades, New York).

GRAPHIC CORE DESCRIPTION
(barrel sheets)

The core descriptions, smear-slide descriptions, and bomb (% $CaCO_3$) data (all obtained on board ship) and grain-size and carbon-carbonate determinations (obtained following the cruise from shore-based labs) serve as the bases for the graphic core descriptions presented at the end of each site report (see Figs. 2–6).

Sediment Classification

The sediment classification scheme used on Leg 76 with minor modification is that devised by the JOIDES Panel on Sedimentary Petrology and Physical Properties adopted for use by the JOIDES Planning Committee in March 1974. The scheme, which closely follows earlier usage, is as follows:

A. Sediment applies only to the names of those components present in quantities greater than 10%.
B. In sediment in which more than one component is present, the most abundant component is listed *farthest to the right*—other components are listed progressively to the left in order of decreasing abundance.
C. Induration is indicated by the sediment name. Although the determination of induration is subjective, the following criteria are useful:
   1. *Terrigenous sediments:*
      If the material is soft enough that the core can be split with a wire cutter, only the sediment name is used (e.g., silty clay, sand). If the core must be cut on the band saw or diamond saw, the suffix "stone" is added (e.g., silty claystone, sandstone).
   2. *Biogenic sediments:*
      Ooze—*soft*, with very little strength and readily deformed with a spatula blade.
      Chalk—*firm*, partly indurated calcareous ooze or friable limestone readily scratched with a fingernail or the edge of a spatula blade.
      Limestone—*hard*, cemented or recrystallized calcareous rocks.
      Porcellanite—*firm*, partly indurated siliceous ooze.
      Radiolarite, diatomite, or spiculite—*hard*, cemented biogenic siliceous ooze.
      Chert—*hard*, cemented and recrystallized siliceous rocks.
D. The class limits of the sediment classification system are defined by percentages of components, as follows:
   1. *Terrigenous sediments:*
      >30% terrigenous components
      <30% calcareous microfossils
      <10% siliceous microfossils
      <10% authigenic components
      Sediments in this category are subdivided into textural groups 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 of Shepard (1954) (Fig. 2).
      If $CaCO_3$ is 10 to 30%, "calcareous," "nannofossil," "foraminifer," or "foraminifer-nannofossil ooze" is used as a qualifier.
      Other qualifiers (e.g., feldspathic, glauconitic, etc.) show that components are present in quantities greater than 10%.

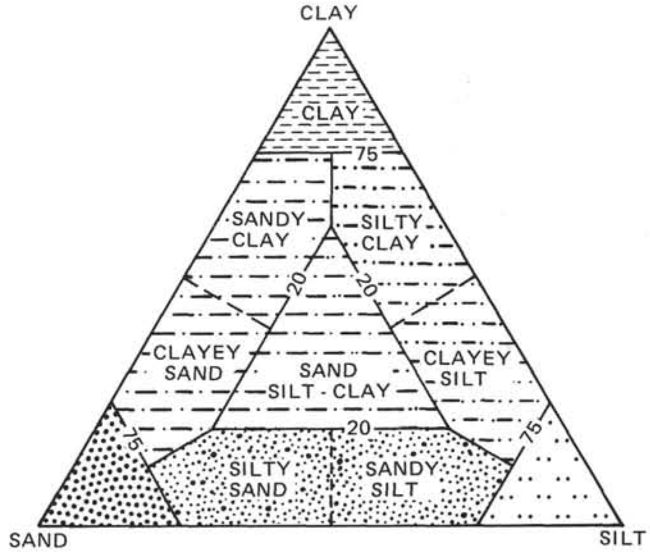

Figure 2. Textural classification of clastic sediments (after Shepard, 1954).

   2. *Volcanogenic sediments:*
      Pyroclastic rocks are described according to the textural and compositional scheme of Wentworth and Williams (1932). The textural groups are:
      >32 mm—volcanic breccia
      <32 mm—volcanic lapilli
      <4 mm—volcanic ash (tuff, if indurated)
      Compositionally, these pyroclastic rocks are described as vitric (glass), crystalline, or lithic.
   3. *Pelagic clay:*
      >10% authigenic components
      <30% siliceous microfossils
      <30% calcareous microfossils
      <30% terrigenous components
   4. *Biogenic calcareous sediments:*
      >30% calcareous microfossils
      <30% terrigenous components
      <30% siliceous microfossils
      The principal components of biogenic calcareous sediments are nannofossils and foraminifers. Qualifiers are as follows:

Foraminifer (%)	Name
<10	*nannofossil ooze* (chalk, limestone)
10-25	*foraminifer-nannofossil ooze* (chalk, limestone)
25-50	*nannofossil-foraminifer ooze* (chalk, limestone)
>50	*foraminifer ooze* (chalk, limestone)

The sediment is *calcareous ooze* if it contains more than 50% $CaCO_3$ of unknown origin. Calcareous sediments containing 10 to 30% siliceous fossils are qualified by "radiolarian," "diatomaceous," or "siliceous," depending upon the type of siliceous component. (See also Item 8 [Special rock types] for more detailed limestone classification.)

5. *Biogenic siliceous sediments:*
   $>30\%$ siliceous microfossils
   $<30\%$ calcareous microfossils
   $<30\%$ terrigenous components
   When the siliceous component is mixed or unidentifiable, it is a *siliceous ooze*.
   Siliceous sediments containing 10 to 30% $CaCO_3$ are qualified by "nannofossil," "foraminifer," "calcareous," nannofossil-foraminifer, or foraminifer-nannofossil, depending on the kind and quantity of the $CaCO_3$ component.
6. *Transitional terrigenous/biogenic calcareous sediments:*
   $>30\%$ $CaCO_3$
   $<30\%$ terrigenous components
   $<30\%$ siliceous microfossils
   "Marly" qualifies transitional sediments in the biogenic calcareous series (e.g., "marly nannofossil ooze").
   If 10 to 30% siliceous microfossils are present, the appropriate qualifier is used (e.g., "diatomaceous marly chalk").
7. *Transitional terrigenous/biogenic siliceous sediments:*
   $>10\%$ siliceous microfossils
   $<30\%$ terrigenous components
   $<30\%$ $CaCO_3$
   10 to 30% siliceous microfossils—(*name of siliceous fossil*) *mud* or *mudstone* (e.g., 10 to 30% radiolarians = *radiolarian mudstone*).
   30 to 70% siliceous microfossils—*muddy* (*name of siliceous fossil*) *ooze* or (*name of siliceous fossil*) (e.g., 50% diatoms = *muddy diatom ooze* or *diatomite*).
8. *Special rock types:*
   During Leg 76, the sedimentologists applied Dunham's (1962) classification of limestones (on the bases of depositional texture) to the displaced shallow-water limestones recovered at Site 534. Frequently used terms are defined as follows:
   a. Original components *not* bound together during deposition and containing clay and/or fine silt-size particles:
      Mud supported:
      $<10\%$ grains = *mudstone*
      $>10\%$ grains = *wackestone*
      Grain-supported (contains mud) = *packstone*
      Grain-supported (lacks mud) = *grainstone*
   b. Original components bound together during deposition and retained in the position of growth (as shown by intergrown skeletal material, laminations contrary to gravity) = *boundstone*.

Figure 3 contains a key to the lithologic symbols used to denote the standard sediment and rock types on the graphic core descriptions.

Color

Color determinations were made on the basis of the standard Munsell or GSA color charts. The Leg 76 sedimentologists recorded sediment on the graphic core descriptions shortly after the core sections were split.

Smear Slides

Smear-slide inspection was the basis of most mineral identification aboard the ship. The sedimentologists determined mineral abundances by percentage of smear-slide area covered by each constituent. Past experience has shown that abundances so determined may be accurate to within a few percentage points for very distinctive minor constituents; but accuracy of ± 10 to 20% is considered very good for major constituents. Consequently, the smear-slide data are presented on the graphic core descriptions as relative abundances. Despite these difficulties, abundances are quoted here in percentages. The sample interval is designated by two numbers: a section number followed by cm below the top of the section, for example; 2-148 = Section 2, 148 cm below the top of the section. A prime ′ placed next to the smear-slide symbol (*) in the "lithology sample" column (*′) or following the sample interval (148′) indicates that the smear slide was taken from a minor lithology. (See also Fig. 4.)

Carbon-Carbonate

Following the cruise, sediment samples were analyzed at the DSDP sediment lab on a Leco 70-Second Analyzer. Procedures are outlined in Boyce and Bode (1972). Accuracy and precision of the results are as follows:

Total carbon = $\pm 0.3\%$ (absolute)
Organic carbon = $\pm 0.06\%$ (absolute)
$CaCO_3$ = 3% (absolute)

The carbon and calcium carbonate data are presented in Appendix I (at the end of this volume), and selected data are shown on the graphic core descriptions. The sample interval (1 cm) is designated by two numbers: section number followed by top of sampled interval within a section (e.g., 1-15 = Section 1, 15–16 cm below top of section.

Bomb

The percent of $CaCO_3$ was determined aboard ship by the "carbonate bomb" technique of 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 the $CaCO_3$ percent. An accuracy of ± 2 to 5% can be obtained. Generally the "bomb" values calculated aboard ship were higher than those obtained on shore from the Leco 70-Second Analyzer.

The sample interval is designated by two numbers: the section number followed by the top of the sampled 1-cm interval within the section (e.g., $CaCO_3$ at 5-11 = 10% means that the $CaCO_3$ content in Section 5 at 11–12 cm below the top of the section equals 10%).

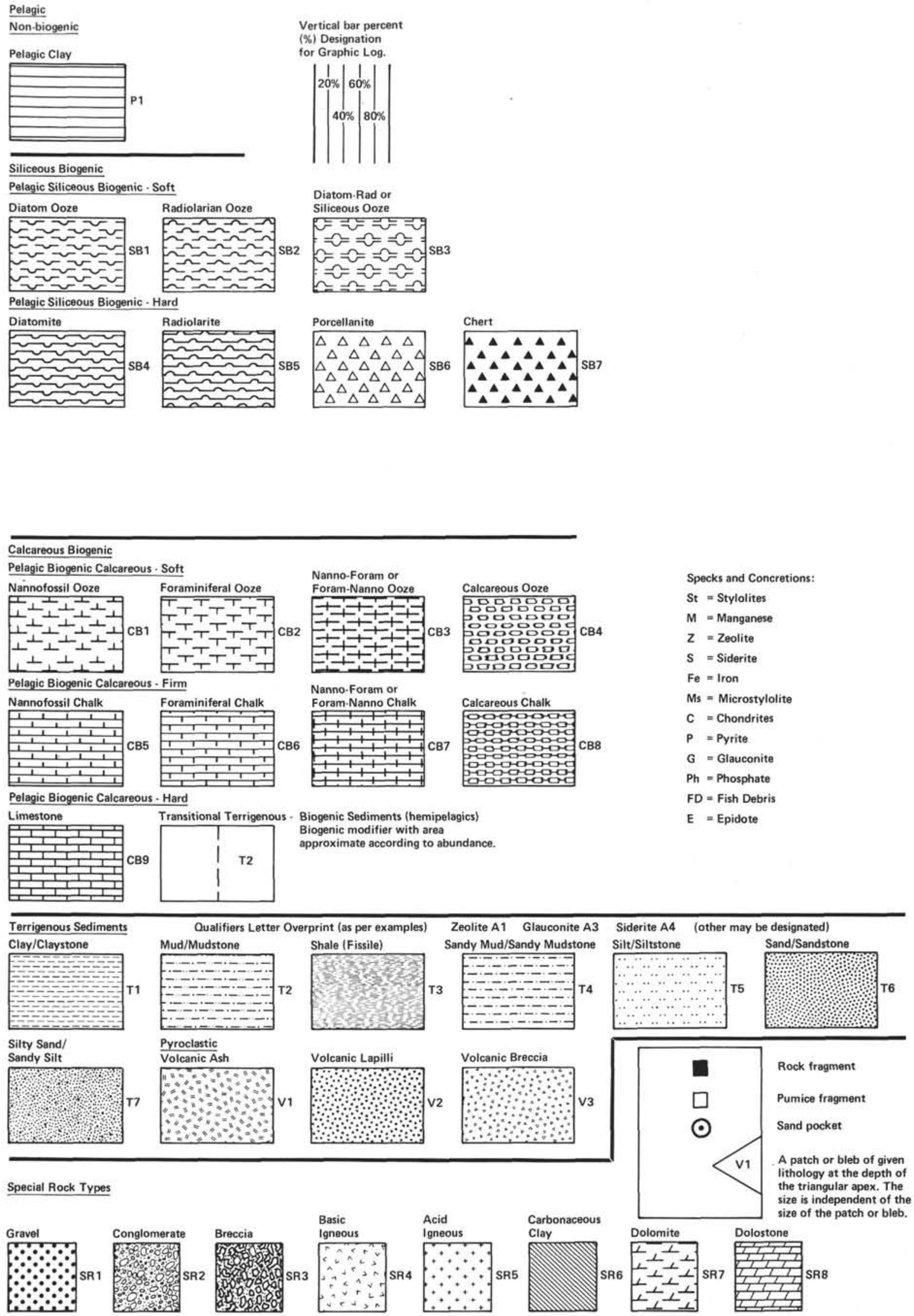

Figure 3. Symbols used in the Graphic Lithology column of the core description form (sediments).

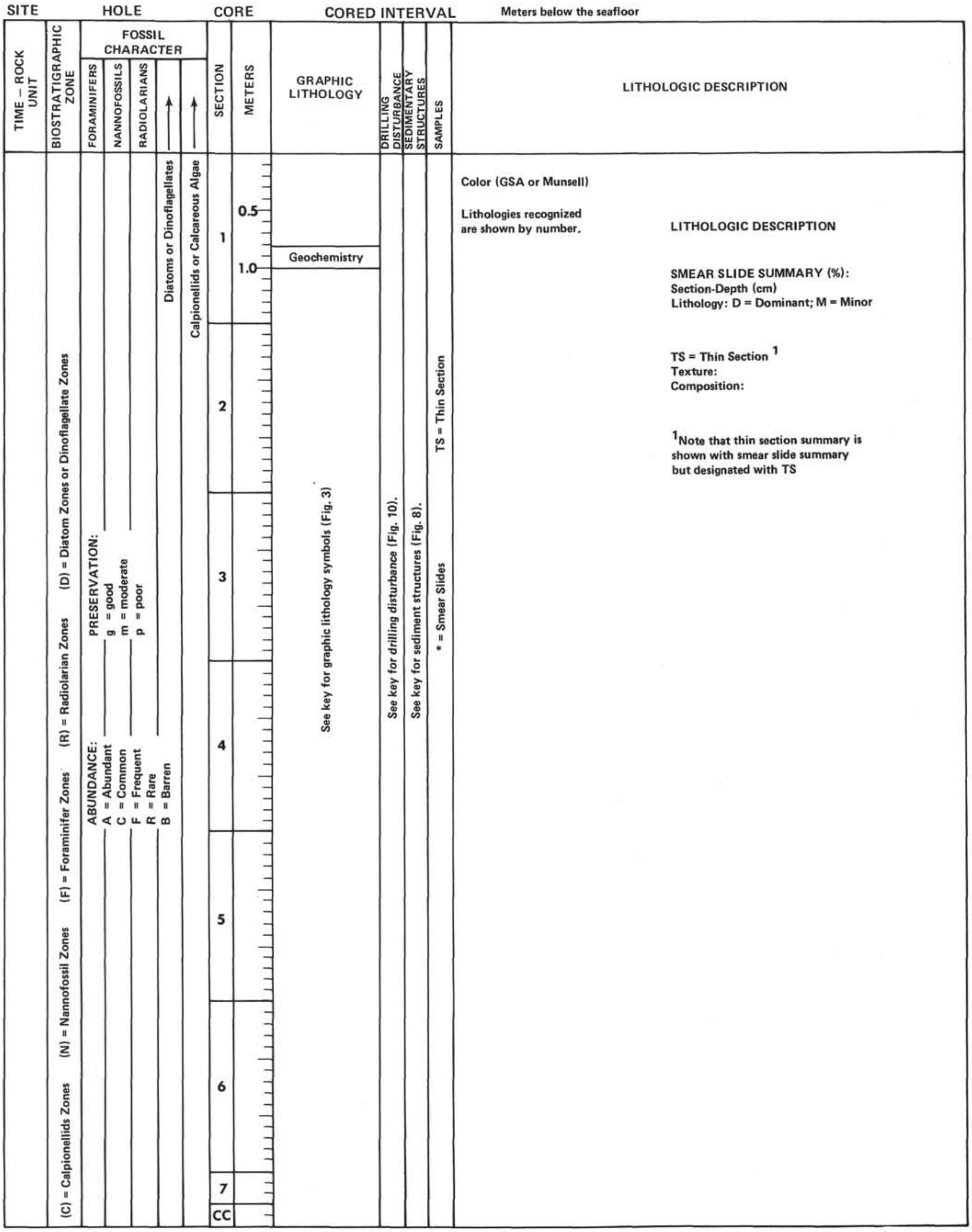

Figure 4. Core description form.

Grain Size

Distribution of sand, silt, and clay-size particles was determined at the DSDP and Lamont-Doherty sediment laboratories by standard sieve and pipette methods (see Appendix III of Volume 4, *Initial Reports of the Deep Sea Drilling Project*, p. 745, Bader et al., 1970), with modified settling times as in Boyce (1972). The sediment name was determined from sediment classification, and the sand, silt, and clay boundaries are those defined by Wentworth (1922). The particle size of the sand, silt, and clay fractions ranges from 2000 to 62.5 μm, 62.5 to 3.91 μm, and less than 3.91 μm, respectively.

Paleontology

Relative abundance and preservation of foraminifers, nannofossils, and radiolarians are noted on the core description form under "Fossil Character." Figure 4 contains a key to the symbols used. The bases for zonal and age determinations are discussed in an earlier part of this chapter (Biostratigraphic Framework).

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 was optional. Locations and types of structures appear as graphic symbols in the column headed "Sedimentary Structures" on the core description form (Fig. 4). Figure 5 gives the keys to these symbols.

Bioturbation is difficult to recognize in the monotonous muds but is noted, where distinguishable, on the graphic column.

Core Disturbance and Downhole Contamination

Unconsolidated sediments are often disturbed by the rotary drilling and coring technique. Bedding contacts in cores may be slightly bent (slightly disturbed) or so extensively bent that the bedding planes are nearly vertical (highly disturbed). By contrast, sediments obtained by hydraulic piston coring are normally much less disturbed, with the exception of flow structures at the ends of cores. In extreme cases, bedding may be completely disrupted to produce a "drilling slurry."

Consolidated sediments and rocks seldom show much internal deformation, but are usually cracked and sometimes extensively fragmented. Adjacent pieces in the core liner may not be contiguous, and intervening sediment may have been lost. In extreme cases (drilling breccia), pieces have completely lost their original orientation and stratigraphic position. Symbols used on the core descriptions to depict various types of drilling disturbance are shown in Figure 6.

Downhole contamination results when sediment, rock fragments, manganese nodules, chert, and pebbles are washed or dragged downhole. Fragments may become incorporated into sediments at levels far below their proper stratigraphic position. Displaced sediment and rock fragments are frequently difficult to recognize, but known downhole contaminants are recorded on the core descriptions.

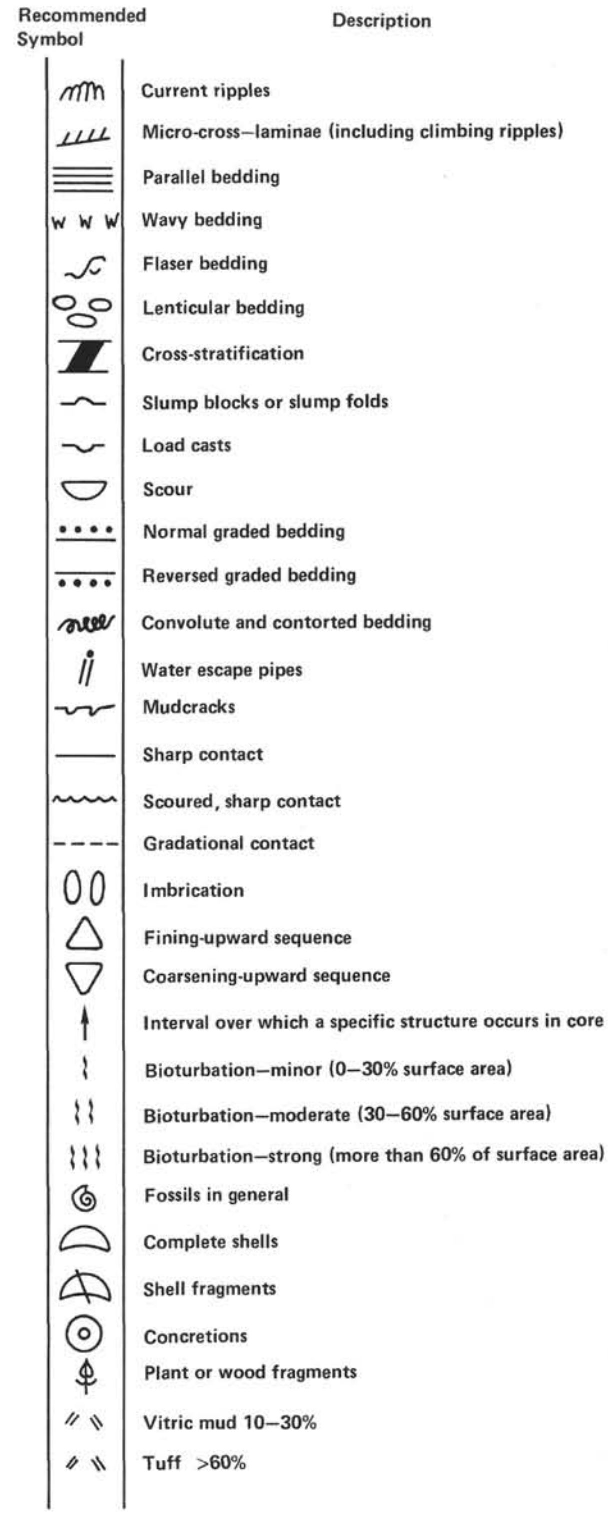

Figure 5. Symbols of sedimentary structures used on core description forms (sediment).

When hydrates occur, core deformation is caused by degassing after recovery. All efforts were made to pho-

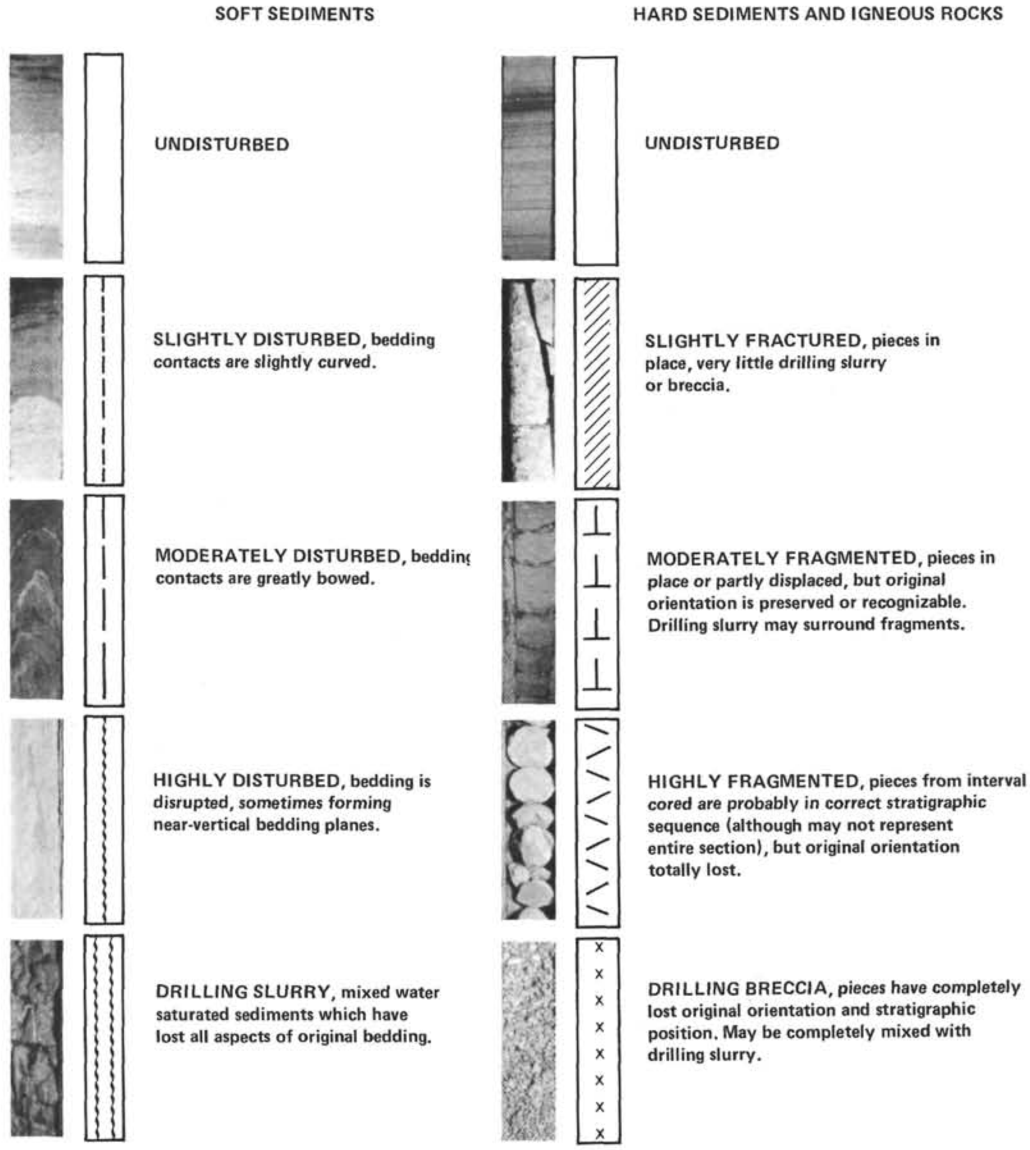

Figure 6. Key to drilling disturbance symbols used on the graphic core descriptions.

tograph hydrates before deformation to show primary structures.

IGNEOUS ROCKS

Visual Core Description Forms

All igneous rocks were split using a rock saw into working and archive halves described and sampled on board the ship. Figure 7 shows a composite visual core description form used for the description of igneous rocks recovered on Leg 76. On this form, each section of a core is described under a set of five column headings: (1) "Piece Number," (2) "Graphic Representation," (3) "Orientation," (4) "Shipboard Studies," and (5) "Alteration."

In the graphic representation column, each piece is accurately drawn, and different features, such as texture, glassy margins, or vesicles, are coded according to the symbols presented in Figure 8. Two closely spaced horizontal lines in this column indicate the location of styrofoam spacers taped between pieces inside the liner. Each piece is numbered sequentially from the top of the section, beginning with the number 1 (piece number column). Pieces are labeled on the rounded surface rather than the flat slabbed face. Pieces that fit together before splitting were given the same number, but are consecutively lettered as 1A, 1B, 1C, etc. Spacers were placed only between pieces that did not fit together; those pieces were given different numbers. In general, spacers may or may not indicate missing material (not recovered) between pieces. All cylindrical pieces longer than the diameter of the liner have arrows in the "orientation" column indicating that top and bottom have not been reversed as a result of drilling and recovery. Arrows also appear on the labels of these pieces on both archive and working halves.

The "Shipboard studies" column designates the location and the type of measurements made on a sample on

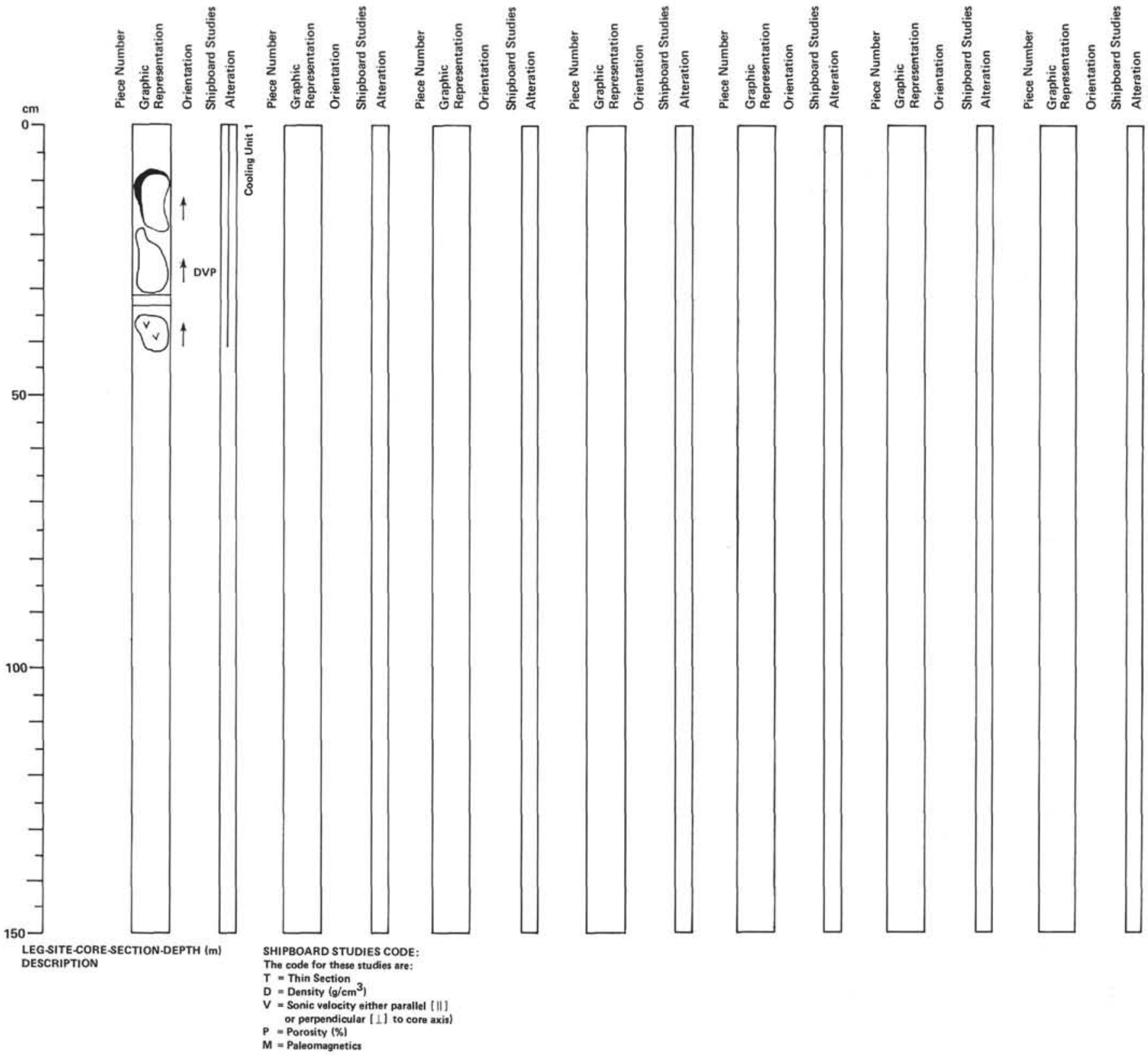

Figure 7. Visual core description form (igneous rocks).

board. The "Alteration" column gives the degree of alteration using the code presented in Figure 8. Below each set of five descriptive columns is the designation for core and section for which these data apply.

For each core, the core number, sections, and centimeter interval recovered are listed followed by the major and minor rock types and a short description. Thin-section data are tallied below this, then shipboard data.

Classification of Igneous Rocks

We informally classified igneous rocks recovered on Leg 76 according to mineralogy and texture determined from visual inspection of hand specimens and thin sections. Standard rock names, such as basalt and diabase, come from mineralogic compositions. Textural terms follow Williams et al. (1954).

PHYSICAL PROPERTIES

Compressional sound velocity, GRAPE (gamma-ray attenuation porosity evaluation) wet-bulk density, gravimetric determinations of wet-bulk density, water content, porosity, shear strength, and thermal conductivities were measured routinely on board the *Glomar Challenger* on Leg 76. A complete discussion of the procedures and assumptions used in data reduction are given by Boyce (1976, 1977). Only a brief outline is given here.

The compressional sound velocity was measured on undisturbed sediment or rock chunks with a standard Hamilton Frame velocimeter. Sample thickness varied between 1 and 2 cm measured with a dial micrometer. Time delay was measured with an oscilloscope cali-

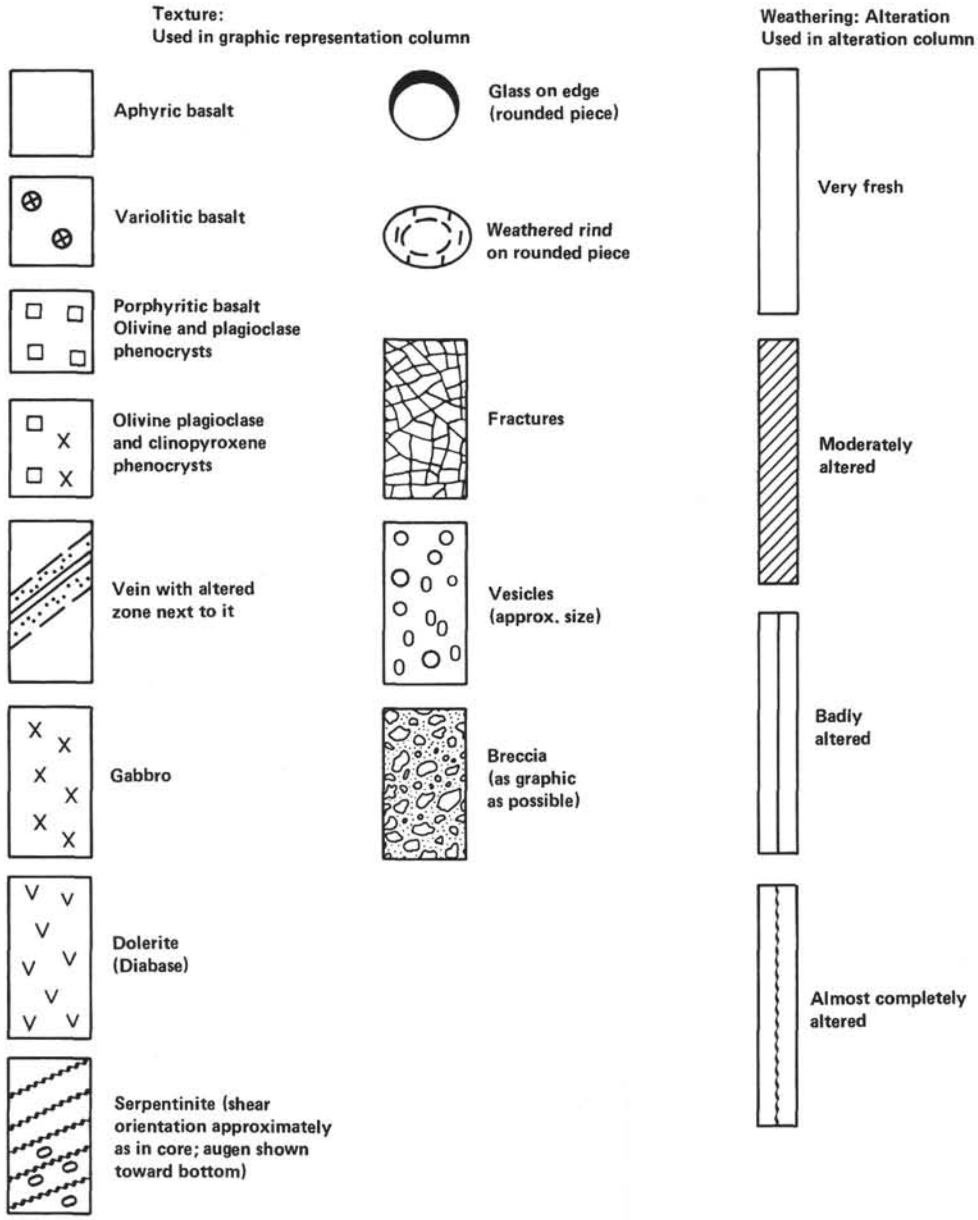

Figure 8. List of symbols for igneous rocks.

brated with both absolute and semi-standards at the beginning of the leg (Table 3). At the 1-μs setting, a correction factor of 1.0192 was applied to the reported velocities; in slower-velocity materials where a 2-μs setting was used, a correction factor of 0.9935 was applied.

Continuous GRAPE measurements of all cores were routinely made. This method provides a semiqualitative measurement of wet-bulk density (Boyce 1976). In addition, small 2.54-cm minicores or rock chunks were measured during special 2-minute GRAPE counts. Calibration for the 2-minute GRAPE measurements was made with 2.54-cm and 6.61-cm aluminum standards; and the apparent quartz attenuation coefficients were 0.0996 and 0.0313, respectively. All 2-minute GRAPE calculations reported here were made with the 0.0996 attenuation coefficient. Traditional gravimetric determinations of wetbulk density, water content, and porosity

Table 3. Hamilton Frame velocity corrections.

Material	Scale setting	Correction factor	N
H_2O (0.6 cm)	1 μs	1.0126	10
(2.1 cm)	2 μs	0.9924	10
Brass (2.5 cm)	1 μs	1.0258	10
(2.5 cm)	2 μs	1.0018	10
Aluminum (2.5 cm)	1 μs	1.0116	10
Lucite (2.5 cm)	2 μs	0.9946	10

Note: N = number of samples.

were completed on these same samples on board or at DSDP. These gravimetric analyses allow better correlation and correction of the continuous GRAPE data.

Shear strength was measured parallel to bedding in undisturbed, soft, clayey sediment samples while they were still water saturated. The vane was 1.28 cm in diameter placed 1.0 cm into the sediment. Some remolding tests were run following initial failure.

Thermal conductivity of soft sediment was determined using the common needle probe technique, whereas in slabs of harder sediment a needle probe modified to a half space was used. The probes were recalibrated just prior to the cruise (K. Becker, personal communication, 1980). The method of measurement varies slightly from earlier DSDP legs. With calibration data supplied, we could substitute the calibration curve for the particular probe and thus directly measure the temperature on the recorder. See Becker (in press) for a more complete description.

In-hole temperature measurements were made from the *Glomar Challenger* by lowering a Uyeda Temperature Probe into the hole in place of the inner core barrel. The top of the probe is inserted into the sediments in the bottom of the hole and allowed about 20 min. to approach an equilibrium temperature. The water temperature is also measured at the seafloor during each run. Thermistor accuracy is better than 0.1°C, but nonequilibrium conditions make actual measurements accurate to about 1°C. A more complete description of this tool is found in Becker (in press).

GEOCHEMISTRY

Shipboard geochemistry programs included measurements of both inorganic and organic parameters. Primary site objectives were: Site 533—test for and determine the composition of gas hydrates; Site 534—determine source rock characteristics of the black shales of the Cretaceous Hatteras Formation. Secondary objectives were to investigate pore-water chemistry and hydrocarbon gas compositions at selected intervals throughout the sedimentary section cored at both sites. In addition, samples were collected for shore-based geochemical studies.

Inorganic Geochemistry

Pore-water samples, recovered from sediments using squeezing techniques described by Manheim and Sayles (1974), were analyzed on board ship for: pH, alkalinity, salinity, Cl^-, Ca^{++}, and Mg^{++}, following procedures of Gieskes (1974). Pore-water samples were packaged in heat-sealed polyethylene tubes, plastic syringes, and glass ampules for shore-based studies that included measurements of NH_4^+, SO_4^{--}, K^+, Sr^{++}, Mn^{++}, H_4SiO_4, $^{87}Sr/^{86}Sr$, $S^{18}O$, and δD of pore water (Jenden and Gieskes, this volume), and $S^{13}C$ of CO_2^{--} and δD of SO_4^{--} (Claypool, this volume). Micronodules were also collected for microprobe and SEM investigators (Barnard, this volume).

Organic Geochemistry

A detailed study of sediment gases provided information on the composition of gas hydrates. Hydrocarbon gases, methane through pentanes, were removed from sediments by a headspace analysis procedure (Kvenvolden and Redder, 1980) and by directly sampling gas pockets in sediment within the core-liner utilizing punch-in vacutainers. Gas chromatography was used to identify and quantify the gases. These shipboard measurements were augmented by shore-based studies. Measurements were made of molecular and isotopic compositions of gases extracted from sediments by procedures outlined by Bernard, Brooks, and Sackett (1978) and of gases collected in vacutainers (Galimov, this volume). A pressurized core barrel (PCB), designed by the DSDP engineering staff, sampled gas hydrates. Gas samples were collected directly from the PCB sampling manifold and stored in high-pressure cylinders for preliminary analysis aboard ship (Kvenvolden, Barnard, and Cameron, this volume) and later, shore-based studies (Barnard et al., this volume). Free hydrocarbons (bitumens) and the hydrocarbon-generating potential of the Cretaceous black shales of the Hatteras Formation were determined by the shipboard Girdle Rock Eval, utilizing techniques of Espitalié et al. (1977). Additional shore-based organic geochemical studies on samples from Site 534 are described in other chapters of this volume.

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