1. INTRODUCTION AND EXPLANATORY NOTES[1]

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INTRODUCTION

The drilling of Leg 77 is part of an overall program by the JOIDES Passive Margin Panel to study the evolution of the western North Atlantic passive margin. A series of 14 sites or areas were documented and considered by the panel and designated ENA-1 to ENA-14. Leg 77 was designed to drill three of these sites located in the southeastern Gulf of Mexico, western Straits of Florida (ENA-12, ENA-13, and ENA-14).

The history of the central North Atlantic is probably the best known of all ocean basins, but the origin and history of the neighboring Gulf of Mexico are still very much uncertain. Some geologists consider it the oldest ocean basin still in existence (Paleozoic), but others doubt the existence of "true" oceanic crust under the central Gulf. After a decade of extensive geophysical studies, however, including new multichannel seismic, refraction, and paleomagnetic data, there appears to be a consensus emerging for a general model of the early evolution of the basin (e.g., Humphris, 1978; Pilger, 1978; Buffler et al., 1980, 1981; Dickinson and Coney, 1980; Salvador and Green, 1981; Pindell and Dewey, 1982; Hall et al., 1983; Klitgord et al., in press). This model suggests an early history relating to the opening of the North Atlantic. It calls for: (1) a late Triassic through Middle Jurassic period of rifting and attenuation of continental crust, accompanied by mafic volcanism and culminating in widespread deposition of thick evaporites in basins throughout the central Gulf; (2) a Late Jurassic to Early Cretaceous episode of seafloor spreading and formation of oceanic crust in the deep central Gulf; and (3) a long post-Jurassic history of subsidence caused by thermal cooling and sediment loading as the basin evolved from a shallow-water to a deep-water setting. This later history was accompanied by the buildup of thick Lower Cretaceous carbonate banks around the periphery of the entire basin and was punctuated by a major mid-Cretaceous episode of erosion and lithologic change.

This evolutionary history is, in part, reflected in the structure and stratigraphy inferred from regional seismic reflection and refraction data in the deep southeastern Gulf of Mexico, western Straits of Florida. This area apparently represents a subsided, thinned or attenuated, rifted continental crust (transitional crust) that formed, in part, during the early rift phase of the early evolution of the Gulf (Buffler et al., 1981). Later, during the seafloor spreading phase, the area probably was part of a broad transform boundary that connected the central Gulf with the opening North Atlantic (Klitgord et al., in press). The crust here has lower seismic refraction velocities and is thicker than the oceanic crust to the north (Buffler et al., 1981). The top of the crust is characterized on seismic data by tilted fault blocks filled in and covered by thick synrift and postrift sedimentary sequences of Jurassic–Lower Cretaceous age (Buffler et al., 1981). These rocks occur at or near the seafloor because of faulting and deep-sea erosion and are within easy reach of the *Glomar Challenger*.

The nature and origin of the transitional crust and the overlying Mesozoic sedimentary sequences in the southeastern Gulf, therefore, was the main objective of Leg 77. By drilling these rocks, it is possible to test, at least in part, the above model for the early evolution of the Gulf basin. It also should provide information about the geologic history of adjoining provinces such as the Florida Bank, the Straits of Florida–Bahamas area, Cuba, the Yucatan Basin, and the Campeche Bank. More specifically, some of the general problems that these holes address include:

1) the tectonic evolution of the southeastern Gulf of Mexico and how it relates to the formation of the deep Gulf basin;

2) the nature, age, and origin of (a) the rifted basement (transitional crust) beneath the southeastern Gulf, (b) the synrift sediments associated with tilted basement blocks; and (c) the postrift pre–mid-Cretaceous sedimentary sequence of the southeastern Gulf, which probably contains the transition from shallow-marine to deep-marine environments as the basin subsided;

3) a comparison between deep Gulf of Mexico sedimentation and deep North Atlantic Basin sedimentation, such as drilled in Hole 534 (Leg 76), and the determination of the time at which the Straits of Florida opened up as a seaway between the Gulf and the Atlantic;

4) a key link for the Mesozoic paleogeography, paleoenvironments, and paleoceanography of the region;

5) the structural history of the southeastern Gulf and how it affected sedimentation;

6) the subsidence and thermal history of the southeastern Gulf;

[1] Buffler, R. T., Schlager, W., et al., *Init. Repts. DSDP*, 77: Washington (U.S. Govt. Printing Office).
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7) the nature, age, and origin of the prominent mid-Cretaceous unconformity in the area;

8) The post–mid-Cretaceous sedimentary and paleoceanographic history of the western Straits of Florida, in particular, the history of the Gulf Stream current and the origin of prominent middle Tertiary scalloped erosional surfaces.

Taken a step further, the above objectives are part of the larger question of the early Mesozoic continent assembly and the low-latitude connection of Tethys and the Pacific.

The general geologic setting of the study area was first established by analysis of regional multichannel seismic data collected by the University of Texas Institute for Geophysics (UTIG) and previous drilling results from Leg 10 (Worzel, Bryant, et al., 1973). These data were supplemented by an extensive new grid of multichannel data shot by UTIG as part of a site survey specifically for Leg 77. All of these data were used to develop a preliminary seismic stratigraphic framework for the area and to identify specific drilling objectives and sites.

The preliminary seismic stratigraphic framework of the area subdivides the sedimentary section into two major seismic sequences separated by a prominent unconformity. This unconformity is a key Gulf-wide horizon recognized by truncation (or onlap), or simply as a major reflector. It represents a major event and separates the Gulf history into two phases. It had been tentatively dated as mid-Cretaceous in age and was designated as the mid-Cretaceous unconformity (MCU).

The specific objective of Leg 77 was to sample basement and the overlying pre-MCU sedimentary section. This could be accomplished by drilling in two main geologic areas as defined by the seismic data. The eastern part of the study area is underlain by a thick pre-MCU section that either outcrops or subcrops beneath a thin Cenozoic cover along a broad north-south erosional channel (ENA-12 sites). The sequence is up to 3 km thick and overlies an irregular block-faulted basement. It was thought to represent a Jurassic through Lower Cretaceous upward transition from nonmarine to shallow-marine to deep-marine rocks that occurred as the basin subsided. This sequence had never been drilled before, although it originally was the primary objective of Hole 97 (Worzel, Bryant, et al., 1973). Drilling the mid-Cretaceous unconformity (MCU) and this sequence, therefore, would provide a valuable look at the early history of this part of the Gulf basin.

The western part of the study area consists of a series of high-standing blocks of acoustic basement inferred to be tilted basement fault blocks of rifted crust. The high parts of the blocks appear to be capped by a relatively thin pelagic sediment cover, making the basement blocks accessible to the drill. The other main objective of the leg, therefore, was to drill through this thin cover and sample the crust and overlying early sediments. These were sites designated ENA-14.

A secondary drilling objective of this leg was to study the post-MCU sedimentary and paleoceanographic history of the western Straits of Florida region. This could be accomplished by drilling the post-MCU section in the eastern part of the study area, where it is relatively thick (ENA-13). These objectives could be partially met by drilling a more abbreviated post-MCU section while drilling the pre-MCU section at the ENA-12 sites. This, in fact, was what actually happened during the leg.

Glomar Challenger sailed from Ft. Lauderdale, Florida on 27 December 1980 and returned to San Juan, Puerto Rico on 30 January 1981, a relatively short five-week cruise for the *Challenger*. Eight holes were drilled at six sites in a small area of the southeastern Gulf of Mexico, western Straits of Florida (Figs. 1–2). This cruise represented a return of the *Challenger* into the Gulf after more than a decade of absence.

The strategy of Leg 77 was not to attempt deep penetration at one reentry site, but to drill two sets of single-bit holes. The first set, 535 and 540, here called the "basin" sites, were drilled on the flank of an erosional valley (Figs. 1–2) and recovered a deep-water limestone sequence of Berriasian (Lower Cretaceous) through late Miocene age. Site 539 represents an unsuccessful attempt to spud. The "basement" sites (536, 537, and 538), located on high-standing fault blocks, penetrated pre-Mesozoic basement at two sites and documented, in abbreviated sedimentary sections, the transition from terrestrial to shallow-marine to deep-sea conditions (Figs. 1–2). Overall, Leg 77 achieved most of the principal objectives outlined above and was very successful. Perhaps the only major disappointments of the leg were the failure to reach Jurassic rocks and failure to log the basin sites.

The details and results of the leg are outlined in the following site chapters and specialty papers.

EXPLANATORY NOTES

Numbering of Sites, Holes, Cores, and Samples

DSDP drill sites are numbered consecutively from the first site drilled by *Glomar Challenger* in 1968. Site numbers are slightly different from hole numbers. A site number refers to one or more holes drilled while the ship was positioned over one acoustic beacon. These holes can be located within a radius as great as 900 m from the beacon. Several holes may be drilled at a single site by pulling the drill pipe above the seafloor (out of the hole), moving the ship 100 m or more from the previous hole, and then drilling another hole.

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

Cores are numbered consecutively from the top of each hole downward regardless of whether they are separated by intervals drilled but purposely not recovered. The depth interval specified for each core corresponds to the respective depths in meters below the seafloor at which

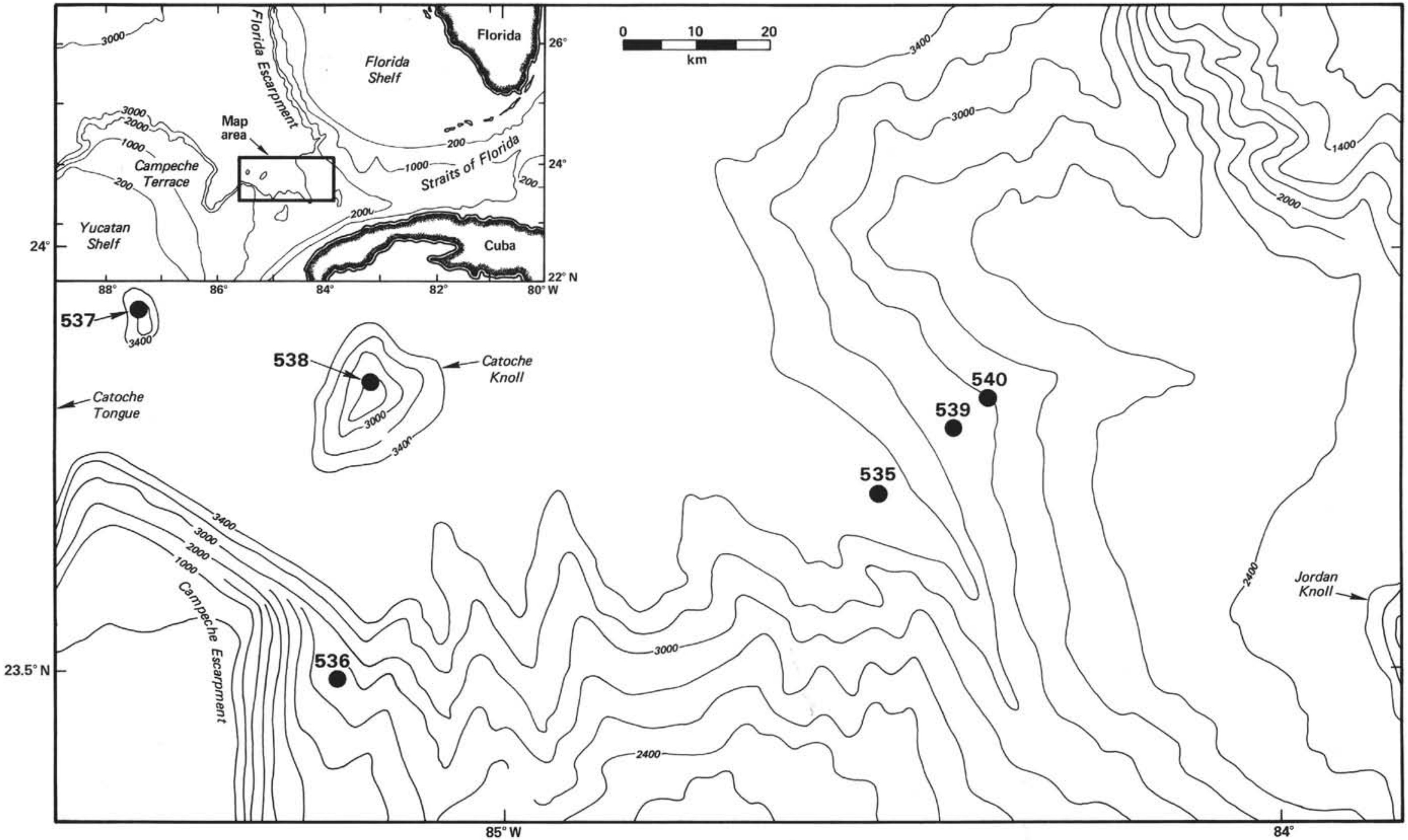


Figure 1. Location map of Leg 77. Bathymetric contours in meters.

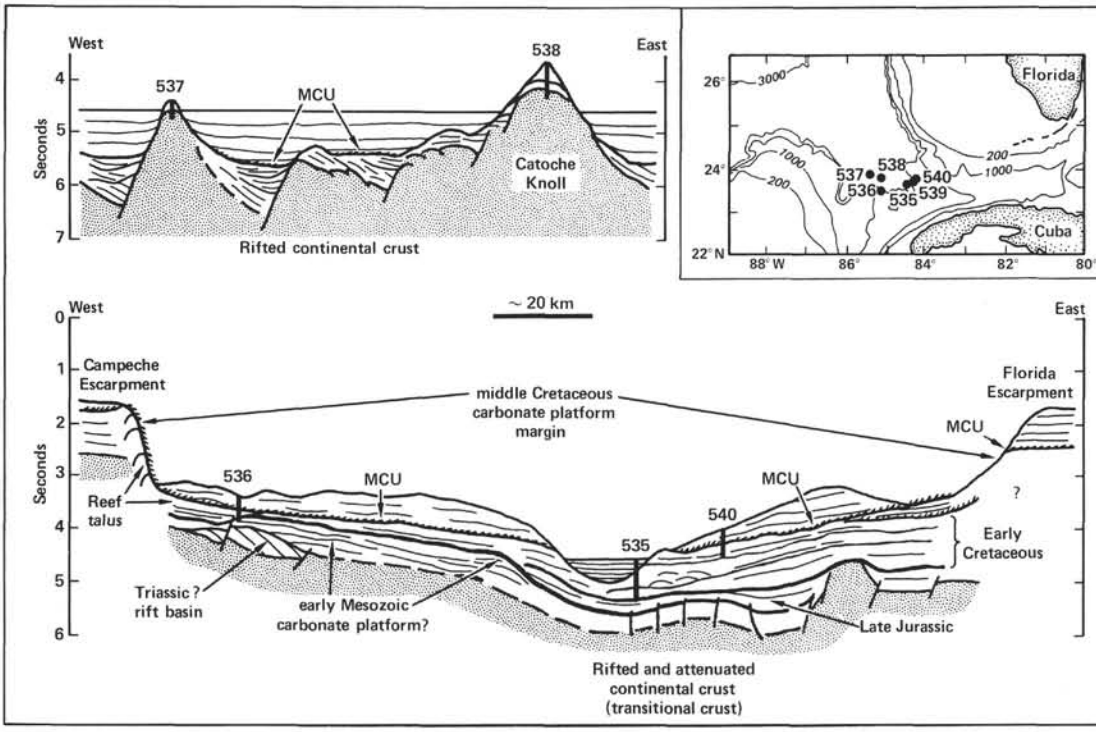


Figure 2. Generalized geologic and structural cross sections across the southeastern Gulf of Mexico/western Straits of Florida showing the variety of Mesozoic sequences encountered during Leg 77 drilling. Locations of cross sections are delineated by site positions shown on the map inset. MCU refers to the mid-Cretaceous unconformity discussed in the text.

the coring operation began and ended. Each interval is nominally the length of the core barrel—in conventional rotary drilling, 9.5 m for cores drilled with standard pipe and 9.0 m for cores drilled with knobby pipe because of slow penetration. No hydraulic piston coring was done during Leg 77.

Full recovery for a single conventional core is 9.28 m of sediment or rock in a plastic liner (6.6 cm inner diameter) plus about 0.2 m of material in the core catcher, which is not in the liner. The core catcher is a device at the bottom of the core barrel that prevents the cored sample from sliding out when the barrel is being retrieved from the hole. The core is then cut into 1.5 m-long sections and numbered serially from the top of the core (Fig. 3). When we obtain full recovery for conventional cores, the sections are numbered from 1 through 7, with the last section shorter than 1.5 m. The core catcher sample is placed below the last section when the core is described, and labeled core catcher (CC); it is treated as a separate section.

For partial recovery, the original stratigraphic position of the material in the cored interval is unknown. If the recovered material is contiguous, we assign the top of this material to the top of the cored interval and number the sections serially from the top beginning with Section 1 (Fig. 3)[4]. There are as many sections as needed to accommodate the length of the recovered material. For example, 4 m of material are divided into three sections, two upper sections each 1.5 m long and a final lower section only 1.0 m in length. If the material recovered is not contiguous, as determined by the shipboard scientists, then sections are divided and numbered serially as with contiguous material and gaps labeled as voids for sediments (Fig. 3) or marked by spacers for igneous and metamorphic rocks (see Igneous and Metamorphic Rocks section).

Samples are designated by centimeter distances from the top of each section to the top and bottom of the sample in that section. A full identification number for a sample consists of the following information: leg, site, hole, core number, and interval in centimeters from the top of section. For example, a sample identification number of 77-538A-4-2, 12–14 cm is interpreted as follows: 12–14 cm designates a sample taken at 12–14 cm from the top of Section 2 of Core 4, from the second hole drilled at Site 538 during Leg 77. The depth of the sample below the seafloor is the summation of the following: (1) the depth to the top of the cored interval for Core 4, which in this case is 21.5 m; (2) plus 1.5 m for Section 1, and (3) plus the 12 cm depth below the top of Section 2. All of these variables add up to 23.12 m.[5] A sample from the core catcher of this core is designated as 77-538A-4,CC. Note that because of the slight uncertainties of actual water depth when holes are spudded at each site, the first core may be variable in length (i.e., 9.5 m maximum but typically less). Each depth computation, as described above, takes the variable length of this initial core into account.

[4] This technique differs from the labeling systems used on Legs 1 through 45, which had a designation called "zero section," but did not have a "Section 7."

[5] Sample requests should refer to a specific interval within a section of a core, rather than a total depth below sea level.

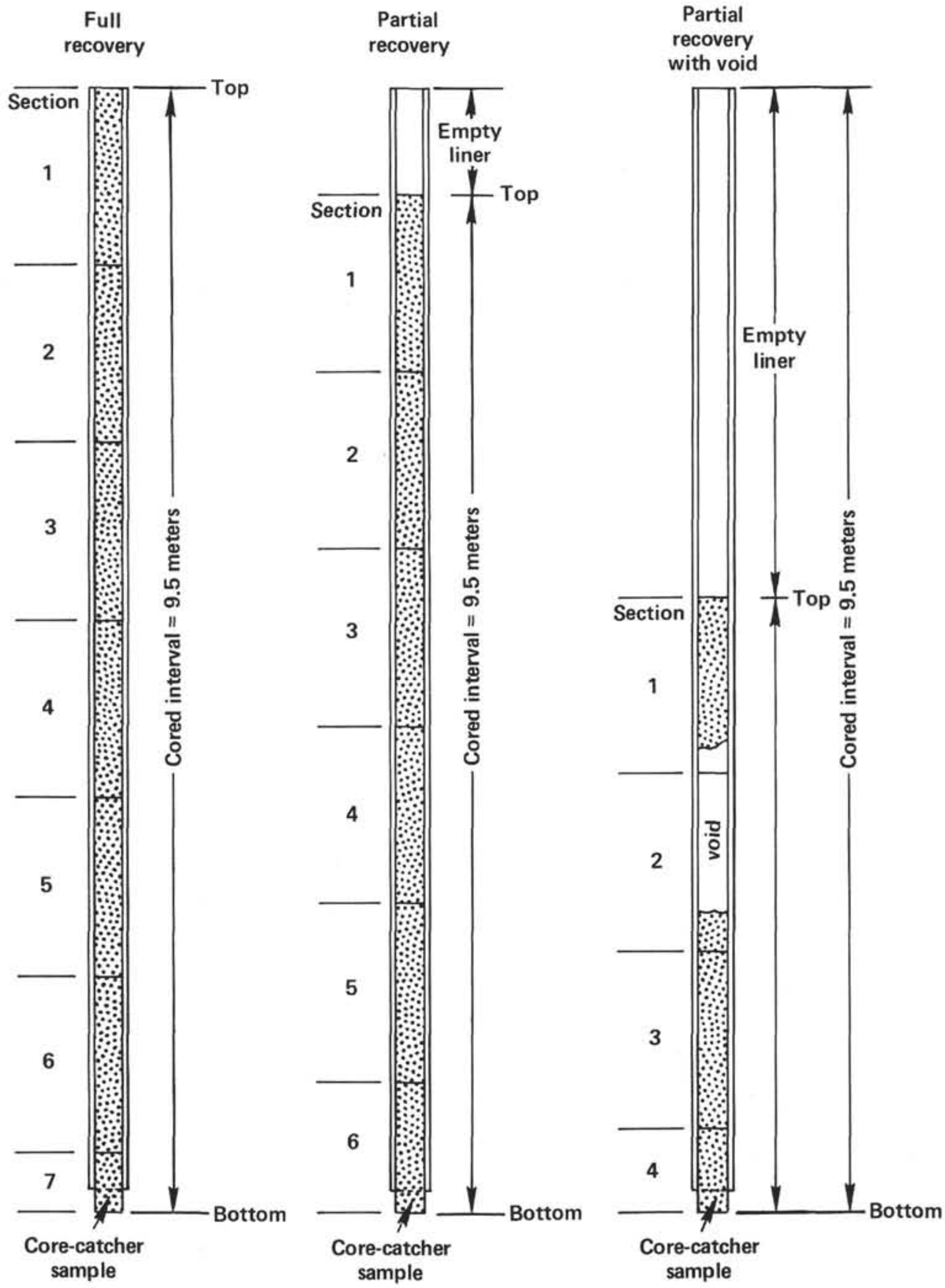


Figure 3. Diagram showing procedure in cutting and labeling of core sections (example shown for conventional 9.5 m cores).

Handling of Cores

A core is normally cut into 1.5-m sections, sealed, and labeled, then brought into the core laboratory for processing. Continuous wet-bulk density determinations using the Gamma Ray Attenuation Porosity Evaluator (GRAPE) are measured first on unsplit sections. The cores are then split longitudinally into "working" and "archive" halves. Samples are taken from the "working" half, including those for determination of paleomagnetic directions and intensities, grain-size distribution, sonic velocity by the Hamilton Frame method, wet-bulk density by a static GRAPE technique, water content by gravimetric analysis, carbon-carbonate analysis, calcium-carbonate percentage (carbonate bomb), geochemical analysis, paleontologic studies, and others. Smear slides (thin sections for lithified sedimentary and igneous and metamorphic rocks) from each major lithology, and most minor lithologies, are prepared and examined microscopically. The archive half is then described and photographed. Physical disturbance by the drill bit, color, texture, structures, and composition of the various lithologies are noted on standard core description forms.

After the cores are sampled and described, they are maintained in cold storage aboard *Glomar Challenger* until they can be transferred to the DSDP repository. All

Leg 77 cores are presently stored at the DSDP East Coast Repository (Lamont-Doherty Geological Observatory).

Core Description Forms

Data for each core of sediment and sedimentary rock are compiled on standard core description forms (Fig. 4). For Leg 77 we have added an additional column to some of these forms to include magnetic polarity data (Fig. 4).

The Graphic Lithology column of the core description form illustrates lithologic types and variations by a single symbol or combinations of two or more symbols. Each symbol corresponds to a sediment type keyed in Figure 5; the relative abundance of each component equals the percentage of the width of the graphic column its symbol occupies. Locations of small patches of unique lithologies that do not extend across the entire core are indicated by triangular insets of the appropriate symbol.

The descriptive portion of the core form includes the identification of sediment types (see following lithologic classification) and a brief description of their characteristics—color, drilling disturbance, sedimentary structures, and composition. Colors, determined immediately after the cores were split and still wet, follow the Geological Society of America Rock-Color Chart. We recognized six categories of drilling disturbance for soft and firm sediment and hard sedimentary rocks: (1) undisturbed—sedimentary structures intact with no visible deformation; (2) slightly deformed—bedding contacts slightly bent; (3) moderately deformed—bedding contacts considerably bent or bowed but still recognizable (soft sediment); firm sediment is fractured; (4) very deformed—bedding completely disturbed or homogenized by drilling, sometimes showing diapirlike structures (soft sediment); firm sediment is broken into cylinders or "drilling biscuits" set in a homogeneous drilling matrix; (5) soupy—water-saturated intervals with no recognizable structures; and (6) drilling breccia—indurated sediment broken into angular fragments and mixed by the drilling process. These categories are also coded on the core forms under the Drilling Disturbance column (Fig. 4). Sedimentary structures noted in the lithologic description are displayed in the appropriate column by use of the symbols explained in Figure 6. Compositional data come from smear slides and thin sections and from carbonate analyses (percent $CaCO_3$) done on board. These data are listed below the lithologic descriptions. Individual samples are designated by two numbers separated by a hyphen (section-interval, in centimeters), and their locations are shown by keyed symbols in the Samples column (Fig. 4). Locations and intervals of interstitial water samples (IW) and organic geochemistry samples (OG) are also shown in this column. When available, locations and polarities of paleomagnetic samples are plotted in the Magnetic Polarity column. Biostratigraphic zones, age assignments, and relative estimates of microfossil abundance and preservation appear in the left-hand columns of the core description form.

A rock saw was used to split igneous and metamorphic rocks into working and archive halves. Figure 7 shows a composite visual core description form used for the description of these rocks recovered on Leg 77. On this form, each section of a core is described under a set of five categories: (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 coded according to the symbols given 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 falt slabbed face. Pieces that fit together before splitting are given the same number, but are consecutively lettered as 1A, 1B, 1C, and so on. Spacers are placed only between pieces that did not fit together; those pieces are given different numbers. In general, spacers may or may not indicate missing material (i.e., 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 board. The Alteration column gives the degree of alteration using the code given in Figure 8.

Figure 7 gives the outline for core descriptions of igneous and metamorphic rocks in the right-hand margin of the visual core description form. If more than one core appears on the core form, these data are listed below the description of the first core using the same format. As many cores as space allows are included on one visual core description form. When space for descriptions is inadequate on this form, these data appear on the following or facing page. However, in no case does information from one core appear on successive core forms. For each core, the core number, sections, and depth interval recovered are listed followed by the major and minor rock types and a short description. Thin-section data are tallied below this, followed by shipboard data such as physical properties and paleomagnetic measurements.

Lithologic Classification of Sediments

The basic classification system used in this volume was devised by the JOIDES Panel on Sedimentary Petrology and Physical Properties (SPPP) and adopted for use by the JOIDES Planning Committee in March 1974. This classification is principally descriptive; divisions between the different types of sediments are somewhat arbitrary. We have modified this classification only slightly in two aspects: (1) we have dropped the term "pelagic" from all but one category to keep this classification mostly descriptive, and (2) we used values of 33⅓ and 66⅔% as cutoff percentages for compositional class

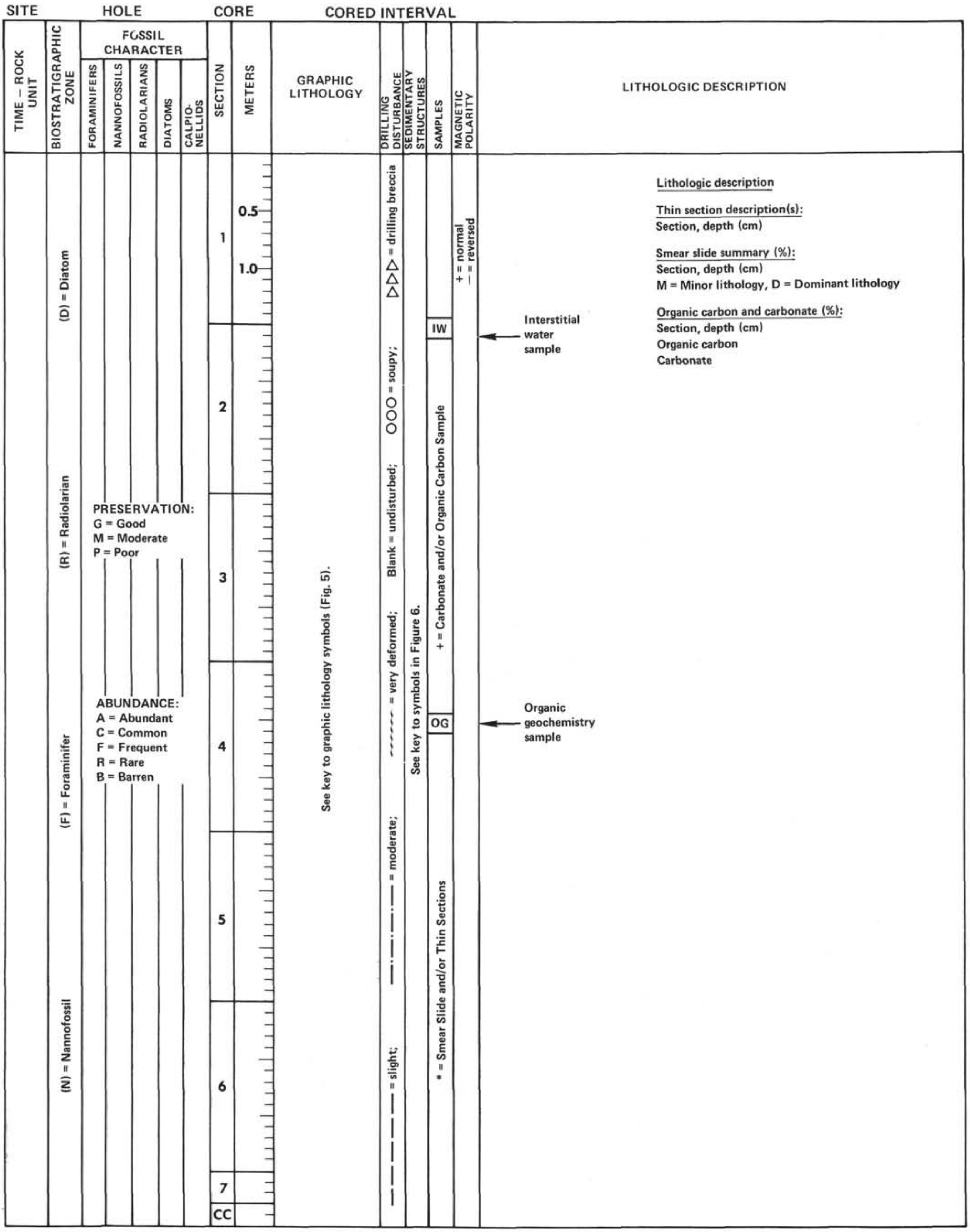


Figure 4. Sample core form (sediment).

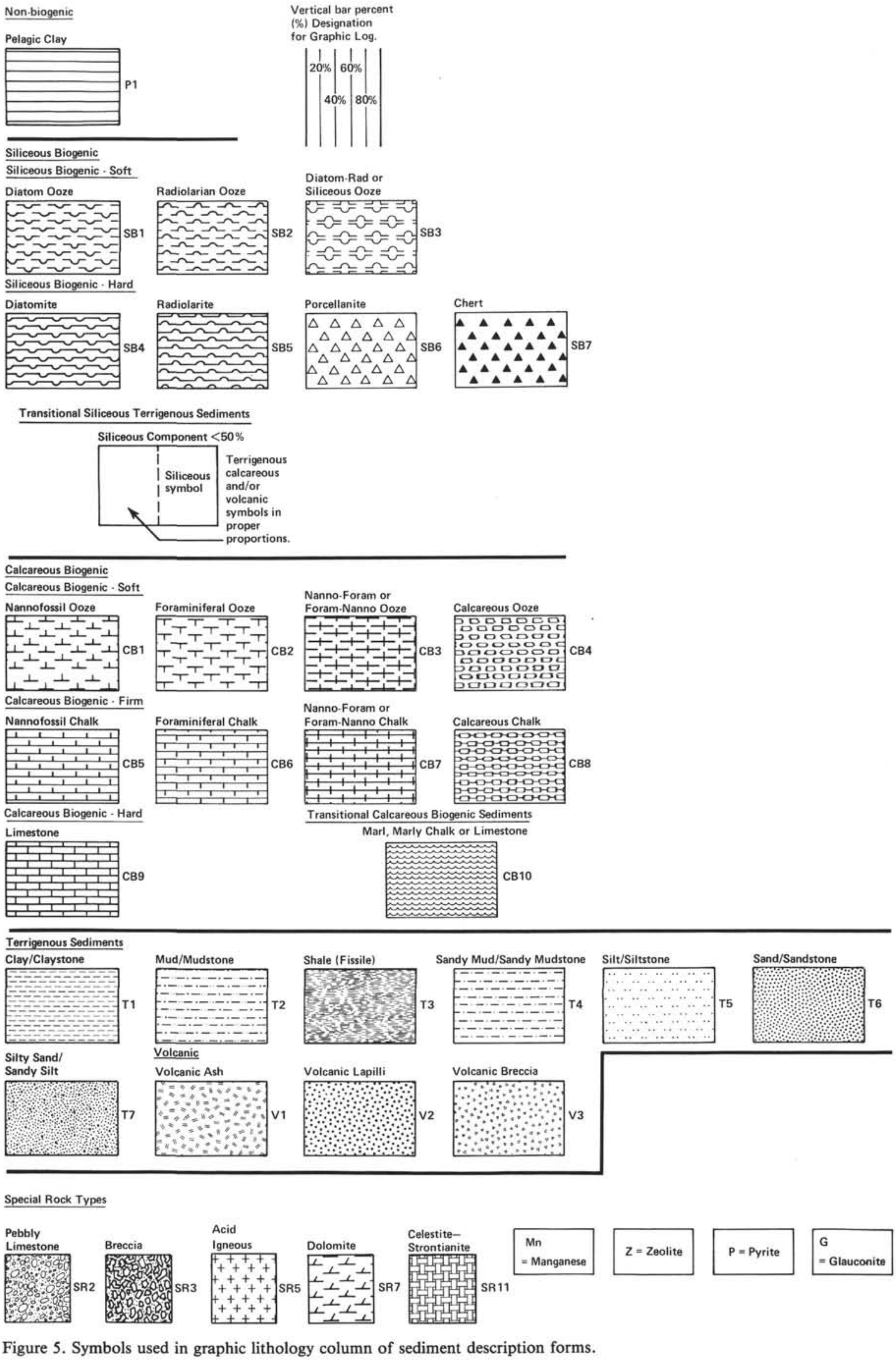


Figure 5. Symbols used in graphic lithology column of sediment description forms.

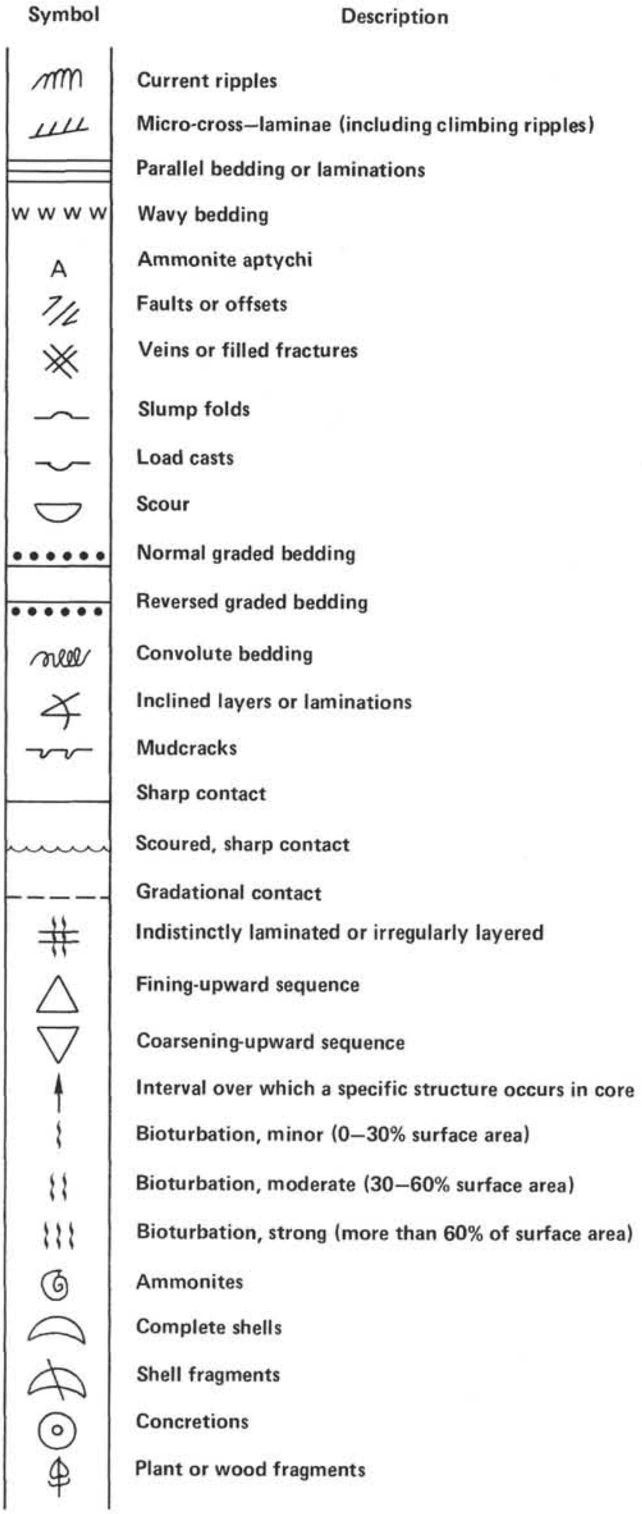


Figure 6. Symbols of sedimentary structures used on core description forms (sediment).

boundaries rather than the 30 and 60% limits suggested by the SPPP (Fig. 9). Lithologic types not covered in this classification we treat separately under the heading "Special Rock Types." A brief outline of the conventions and descriptive data used to construct this classification follows.

Conventions and Descriptive Data

Composition and Texture

In this classification, composition and texture are the only criteria used to define the type of sediment or sedimentary rock. These data are derived from smear slides taken from soft and firm sediments and from thin sections of hard sedimentary rocks. They represent semiquantitative visual estimates of areal abundances and size fractions of lithologic components on the slide. From past experience, these estimates are accurate to within several percent for distinctive minor components in the sample, but less accurate (±10%) for major constituents. All smear-slide and thin-section estimates were done on board.

Qualifiers

If necessary, we use one or several modifiers in naming the types of sediments encountered. In all cases, the dominant component appears last in the name; minor components precede with the least common constituent listed first. If minor constituents occur in amounts less than 10%, they are not included in the name. In addition, we use Dunham's (1962) textural classification of limestones (Fig. 10) to supplement the limestone term used in the SPPP classification. These textural terms are modified by compositional terms, such as skeletal, oncolitic, and oolitic, when applicable.

Induration and Lithification

We recognize three classes of induration or lithification for carbonate sediments and sedimentary rocks and two classes for all other lithologic categories as follows:

Carbonate sediments and sedimentary rocks (after Gealy et al., 1971)

1) Soft calcareous sediment (ooze) has little strength and is easily deformed under fingernail or broad blade of spatula.

2) Firm calcareous sediment (chalk) is partially lithified and readily scratched with a fingernail or the edge of spatula.

3) hard calcareous sedimentary rocks (limestone, marl, or dolomite) are well-lithified and/or cemented; they are resistant or difficult to scratch with a fingernail or the edge of a spatula.

Other sediment types

1) Soft sediment core can be split with a wire cutter; if siliceous, soft sediment is called ooze; if mostly terrigenous, then the proper terrigenous term is used (e.g., sand, mud, etc.; see next section).

2) Hard rock can only be cut with a saw; if siliceous, the rock is called chert, porcellanite, radiolarite, or diatomite; if mostly terrigenous, the suffix -stone is added to the relevant terrigenous term (e.g., sandstone, mudstone, etc.).

Types of Sediments and Composition Boundaries

Pelagic Clay

Pelagic clay is principally an inorganic authigenic and pelagic deposit that accumulates in the deep sea at slow

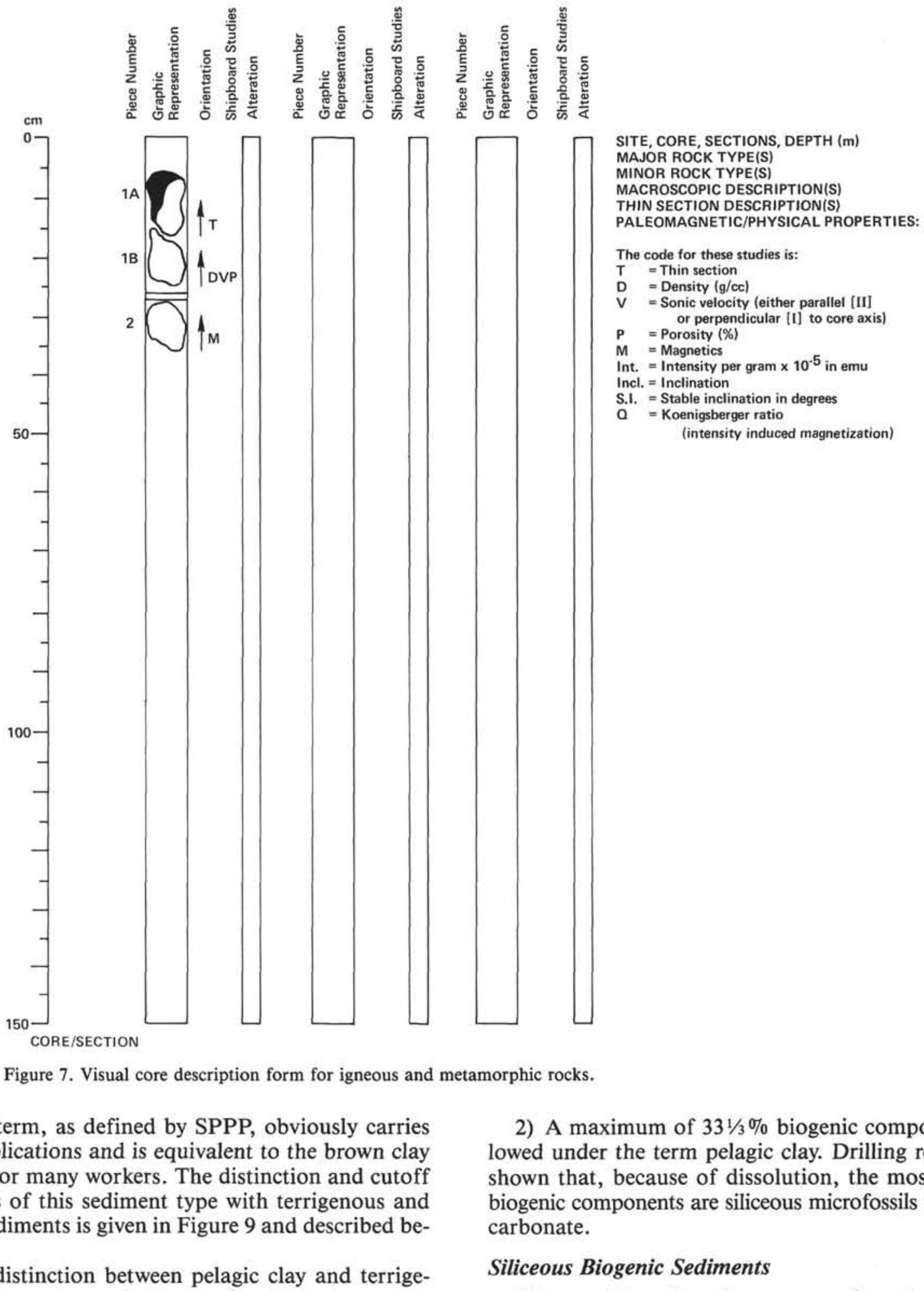


Figure 7. Visual core description form for igneous and metamorphic rocks.

rates. The term, as defined by SPPP, obviously carries genetic implications and is equivalent to the brown clay or red clay or many workers. The distinction and cutoff percentages of this sediment type with terrigenous and biogenic sediments is given in Figure 9 and described below.

1) The distinction between pelagic clay and terrigenous clay is made on the basis of authigenic components. When these components (e.g., Fe/Mn micronodules, zeolites, etc) exceed 10% of the total sediment as seen in smear slides, the term pelagic clay is used. Because the depositional environments and rates of accumulation of terrigenous and pelagic clay differ markedly, transitional deposits (i.e., mixtures of pelagic and terrigenous clay) are rare.

2) A maximum of 33⅓% biogenic component is allowed under the term pelagic clay. Drilling results have shown that, because of dissolution, the most common biogenic components are siliceous microfossils rather than carbonate.

Siliceous Biogenic Sediments

Siliceous biogenic sediments contain at least 66⅔% biogenic silica (Fig. 9). Diatoms, radiolarians, and silicoflagellates are the most common siliceous microfossils. Sponge spicules are less common. The remaining 33⅓% of this sediment type consists of calcareous, terrigenous, and/or volcanic material in varying amounts. These are listed as prefixes in increasing order of abundance. For example, a soft sediment with 70% diatoms,

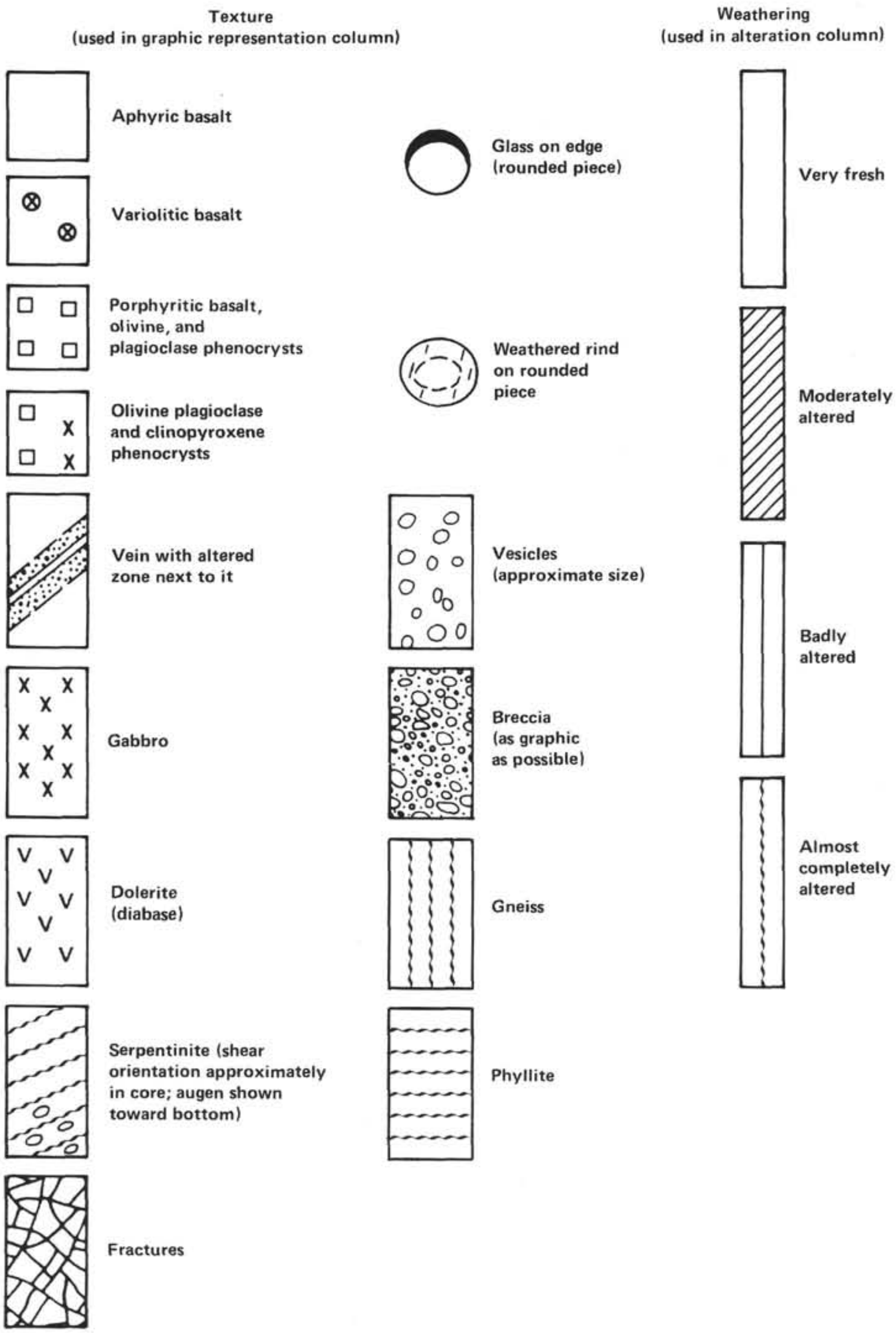


Figure 8. Key to codes used on igneous and metamorphic core forms.

20% nannofossils, and 10% clay is called a clayey nannofossil-diatom ooze. The symbols and terminology for hard and soft siliceous biogenic sediments and sedimentary rocks are given in Figure 5.

Calcareous Biogenic Sediments

Calcareous biogenic sediments contain at least 66⅔% biogenic carbonate (Fig. 9). Nannofossils and foraminifers are the principal calcareous microfossils. The remaining 33⅓% of this sediment type consists of siliceous plus terrigenous (and/or volcanic) material in varying amounts. These are listed as prefixes in increasing order of abundance. For example, a firm sediment containing 70% nannofossils, 20% diatoms, and 10% clay is termed a clayey diatom-nannofossil chalk.

Terrigenous Sediments

Terrigenous sediments contain an inorganic terrigenous component in excess of 66⅔%, siliceous and authigenic components less than 10% each, and a biogenic calcareous component less than 33⅓% (Fig. 9). Sediments and sedimentary rocks in this category are subdivided into textural groups by smear-slide estimates and sometimes by shore-based grain-size analyses. The size

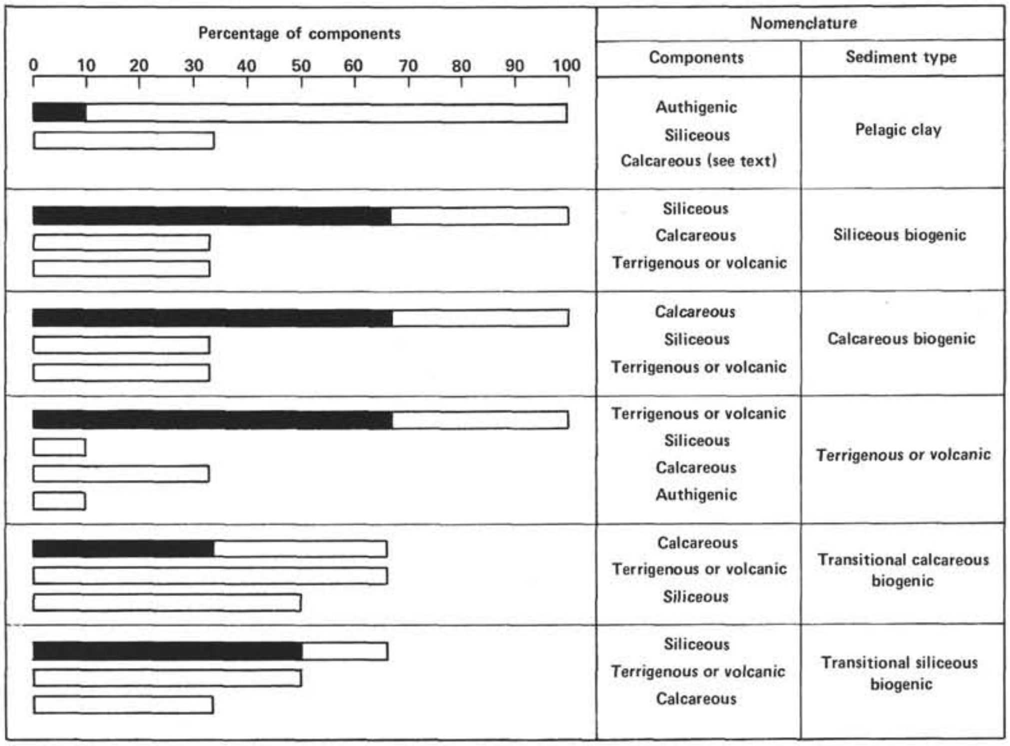


Figure 9. Summary of sediment classification. Solid parts of bars show minimum amount of significant component needed for specific categories. Hollow bars show maximum allowable amounts of significant components and supplementary components. See text for explanation.

Depositional texture recognizable					Depositional texture not recognizable
Original components not bound together during deposition				Original components were bound together during deposition . . . as shown by intergrown skeletal matter, lamination contrary to gravity, or sediment-floored cavities that are roofed over by organic or questionably organic matter and are too large to be interstices.	Subdivide according to classifications designed to bear on physical texture or diagenesis.
Contains mud (Particles of clay and fine silt size)			Lacks mud		
Mud supported		Grain supported			
Less than 10% grains	More than 10% grains				
Mudstone	*Wackestone*	*Packstone*	*Grainstone*	*Boundstone*	*Crystalline carbonate*

Figure 10. Textural classification of limestones (after Dunham, 1962).

limit and textural groups are illustrated in Figure 11. Biogenic component qualifiers are added as prefixes to the terrigenous term in increasing order of abundance.

Volcanic Sediments and Pyroclastic Rocks

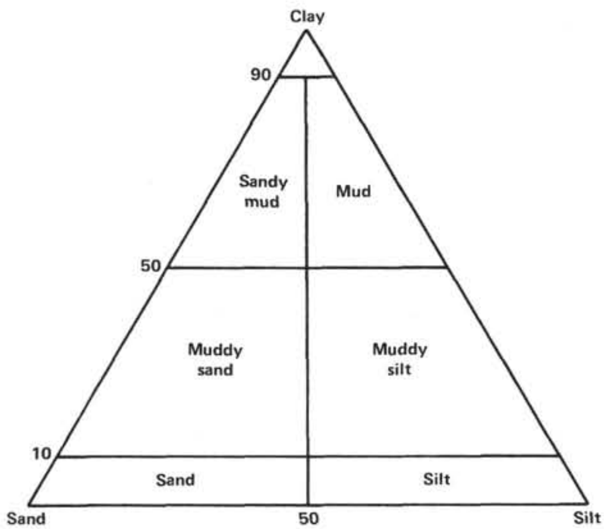
The terminology for volcanic sediments and pyroclastic rocks follows the textural classification of Wentworth and Williams (1932):

≥ 32 mm = volcanic breccia
4–32 mm = volcanic lapilli
≤ 4 mm = volcanic ash (tuff if indurated)

The limiting percentages are the same as the boundaries used for terrigenous sediments (see Fig. 9). Qualifiers are added in the same manner; the additional terms—vitric, crystal, or lithic—describe the principal volcanic component.

Transitional Biogenic Sediments

Two types of transitional sediment categories are recognized. Transitional calcareous biogenic sediments contain at least $33\frac{1}{3}\%$ and no more than $66\frac{2}{3}\%$ carbonate with siliceous, terrigenous volcanic components comprising the remaining sediment (Fig. 9). These sediments



	Millimeters		Phi (ϕ) units	Wentworth size class
	2.00	2	−1.0	Granule
Sand	1.68		−0.75	Very coarse sand
	1.41		−0.5	
	1.19		−0.25	
	1.00	1	0.0	
	0.84		0.25	Coarse sand
	0.71		0.5	
	0.59		0.75	
	0.50	1/2	1.0	
	0.42		1.25	Medium sand
	0.35		1.5	
	0.30		1.75	
	0.25	1/4	2.0	
	0.210		2.25	Fine sand
	0.177		2.5	
	0.149		2.75	
	0.125	1/8	3.0	
	0.105		3.25	Very fine sand
	0.088		3.5	
	0.074		3.75	
	0.0625	1/6	4.0	
Silt	0.053		4.25	Coarse silt
	0.044		4.5	
	0.037		4.75	
	0.031	1/32	5.0	Medium silt
	0.0156	1/64	6.0	Fine silt
	0.0078	1/128	7.0	Very fine silt
	0.0039	1/256	8.0	
Mud	0.0020		9.0	Clay
	0.00098		10.0	
	0.00049		11.0	
	0.00024		12.0	
	0.00012		13.0	
	0.00006		14.0	

Figure 11. Textural classification of terrigenous sediments used on Leg 77 (size limits after Wentworth, 1922).

and rocks are termed marl, marly chalk, or marly limestone. Transitional siliceous biogenic sediments contain at least 50% but less than 66⅔% siliceous components (Fig. 9). The remaining sediment consists of carbonate and terrigenous (and/or volcanic) material in varying amounts. The name consists of diatom or radiolarian ooze with the work "terrigenous," "calcareous," or "volcanic" added as a qualifier (e.g., "calcareous radiolarian ooze").

Special Rock Types

Special rock categories used on Leg 77 include: (1) pebbly chalk and limestone: poorly sorted, brecciated limestone fragments set in a carbonate matrix (analogous to pebbly mudstone); and (2) celestite-strontianite-barium and strontium sulfate occurring as burrow fillings and thin zones at Site 535.

Classification of Igneous and Metamorphic Rocks

We informally classified igneous and metamorphic rocks recovered on Leg 77 according to mineralogy and texture determined from visual inspection of hand specimens and thin sections. Standard rock names come from mineralogic compositions. Textural terms follow Williams and others (1954).

Biostratigraphic Framework

Calcareous nannofossils, planktonic foraminifers, and calpionellids are used to delineate the stratigraphic successions at Leg 77 sites. Cenozoic planktonic foraminiferal age determinations are based on a combination of the biostratigraphic schemes of Blow (1969), Bolli (1966), Cita (1973), and Hardenbol and Berggren (1978). The Cretaceous sediments are biostratigraphically subdivided following a composite zonation after Sigal (1977) and Premoli Silva and Sliter (1981). The biostratigraphic zonation of Remane (1978) is followed for calpionellids.

Cenozoic nannofossil age determinations are based on the biostratigraphic scheme of Bukry (1973, 1975) as enumerated in Okada and Bukry (1980). The Cretaceous sediments are biostratigraphically subdivided by the use of biodatum levels from Thierstein (1976) and Perch-Nielsen (1979). Zonal names for the Early Cretaceous follow those in Thierstein (1973).

The foraminiferal and nannofossil biozonations are tentatively correlated to the geochronologic time scales of Berggren and Van Couvering (1974), Hardenbol and Berggren (1978), and van Hinte (1976).

CN and CP correspond to Neogene and Paleogene nannofossil zones. MPL and N correspond to Pliocene and Neogene foraminiferal zones.

Shipboard Studies

Organic Geochemistry

Gas Analyses

When gas is evident in a core, the core liner is punctured, and a small valve assembly fitted with a syringe needle is used to fill a vacutainer (as used in medical clinics for blood samples). After a gas sample is extracted into a vacutainer, it is immediately taken to the geochemistry lab for analysis. First, a 100-μl sample is taken from the vacutainer and the gas is analyzed by the Carle Gas Chromatograph, which gives the percentage of methane, ethane, and carbon dioxide in approximately 1–1½ minutes. This provides a rapid reading on the amount of methane in the gas, which can be related to previous samples for indications of any rapid and large increases in gas concentrations. If methane or ethane is detected by the Carle Gas Chromatograph, then a second sample of 1.0 ml, is extracted for analyses by the Hewlett-Packard 5710A Gas Chromatograph. The Hewlett-Packard gives readings in parts per million for ethane, propane, butane, and pentane (C_2–C_5). This analysis, which involves alternating cold and hot baths, takes approximately 15 minutes. On Leg 77, no methane or ethane was ever detected in any gas samples from any cores recovered; consequently, no samples were run on the Hewlett-Packard 5710A Gas Chromatograph.

CHN Analyzer

Organic carbon contents of sediments are determined using a Hewlett-Packard Model 185B CHN Analyzer. Samples are first treated with HCl to remove carbonate; then 20–30 mg of the residue are introduced into the analyzer. Operating parameters for the CHN Analyzer are oxidation furnace T = 1050°C; reduction furnace T = 510°C; column oven T = 100°C; oven shell T = 80°C; bridge current = 150 mA, and carrier gas-flow rate = 50 psig = 100 ml/minute. Catalyst and boat blanks are made and used in the calculations. Standard runs are made by using the amino acids cystine (NBS #143b) and acetanilide (NBS #141b). In all cases, the determinations are performed in duplicate. The percent carbon obtained from the CHN Analyzer is multiplied by the fraction of the sample that is noncarbonate to obtain the percent organic carbon in the original sediment sample.

There was not enough time to analyze all of the samples for organic carbon using the CHN analyzer on board ship. Consequently, the Rock-Eval instrument was used to screen samples, and selected samples were analyzed for organic carbon content so that hydrogen and oxygen indices could be obtained for kerogen typing. Additional organic carbon analyses were made after the cruise using a LECO carbon analyzer. These data appear in Appendix I at the end of this volume.

Rock-Eval

Pyrolysis of samples to give information on the amount, type, and thermal maturity of the organic matter is performed with the Girdal Rock-Eval apparatus (Espitalié, Madec, et al., 1977; Clementz et al., 1979). Samples selected for the Rock-Eval are broken into small chips and air-dried for 12 hr., then dried in a desiccator for 12 hr. After drying, 50–100 mg of sample are weighed to the nearest 0.1 mg with a gimble-mounted Cahn electrobalance, then transferred to a stainless steel crucible, whose bottom and removable top are sintered. (The crucibles are stored beforehand in an oven at 125°C to prevent their absorbing small amounts of organic material from the air.) Samples are introduced into a heated chamber of the Rock-Eval, and the volatile products are swept out in a stream of helium. This stream is split, half going to a flame ionization detector to measure the hydrocarbons and other organic compounds either volatized or pyrolyzed as the sample is heated from 250 to 550°C at 25°C/minute. The other half goes to a trip removing high molecular weight material and then to a molecular sieve trap where carbon dioxide produced from 250 to 390°C is absorbed. Carbon dioxide formed from temperatures higher than 390°C may come from mineral decomposition and so it is discarded. The carbon dioxide trapped is recovered and measured by heating the molecular sieve trap for 3 minutes to release it to the gas chromatography column and a thermal conductivity detector in the Rock-Eval. The analysis time for a single sample is 25 minutes.

Four significant parameters are recorded in the form of temperature versus analysis time plots (Espitalié, Laporte, et al., 1977; Espitalié, Madec, et al., 1977):

1) S_1 peak corresponds to the quantity of hydrocarbons in the rock (i.e., volatile organic matter). This parameter is measured by the flame ionization detector.

2) S_2 peak corresponds to hydrocarbon compounds produced by thermal cracking of kerogen in the rock up to 550°C. This is also measured by the flame ionization detector.

3) S_3 peak corresponds to the CO_2 produced by the pyrolyzed organic matter in the rock. This parameter is measured by a thermal conductivity detector.

4) T_{max} corresponds to the maximum of hydrocarbon generated during pyrolysis of the kerogen in the rock. Practically, this is the maximum temperature recorded by the S_2 peak.

These parameters allow interpretation of:

1) hydrocarbon source potential (S_1);

2) identification of the type of organic matter (S_2/S_3);

3) maturation of the organic matter (T_{max});

4) detection of oil shows ($S_1/[S_1 + S_2]$).

More fully, S_1 corresponds to hydrocarbons that have been produced by nature through the effects of temperature and geologic time, and S_2 represents hydrocarbons that could have been generated if the samples had experienced higher temperature and/or a longer burial time to produce a state of overmaturity.

The ratio of S_2/S_3 can be used to compare samples for their oil-producing versus gas-producing potential. Higher values (greater than 5) favor oil, lower values (less than 2.5) favor gas, and intermediate values indicate mixed potential (Clementz et al., 1979).

The S_2 peak temperature, T_{max}, is a measure of the maturity of the kerogen in the rock sample. Peak temperatures below 435°C are generally believed to represent immature samples, those that have not begun to generate significant quantities of hydrocarbons. The ratio $S_1/(S_1 + S_2)$ is referred to as the production index and is that fraction of hydrocarbons that has been generated of the total potential production. The production index normally increases with maturity, if the sample has not been perturbed by migrating (mobilized or accumulated) hydrocarbons.

van Krevelen Diagram

Rock-Eval data and organic carbon results were combined to characterize the type of kerogen in Leg 77 samples. Hydrogen (S_2/organic carbon) and oxygen (S_3/organic carbon) indices were related to the atomic ratios H/C and O/C, respectively, and plotted on a traditional van Krevelen diagram (Fig. 12). R_o-values of vitrinite reflectance have also been added to illustrate the effects of maturation. These relationships were used to characterize the type of kerogen encountered in Leg 77 samples.

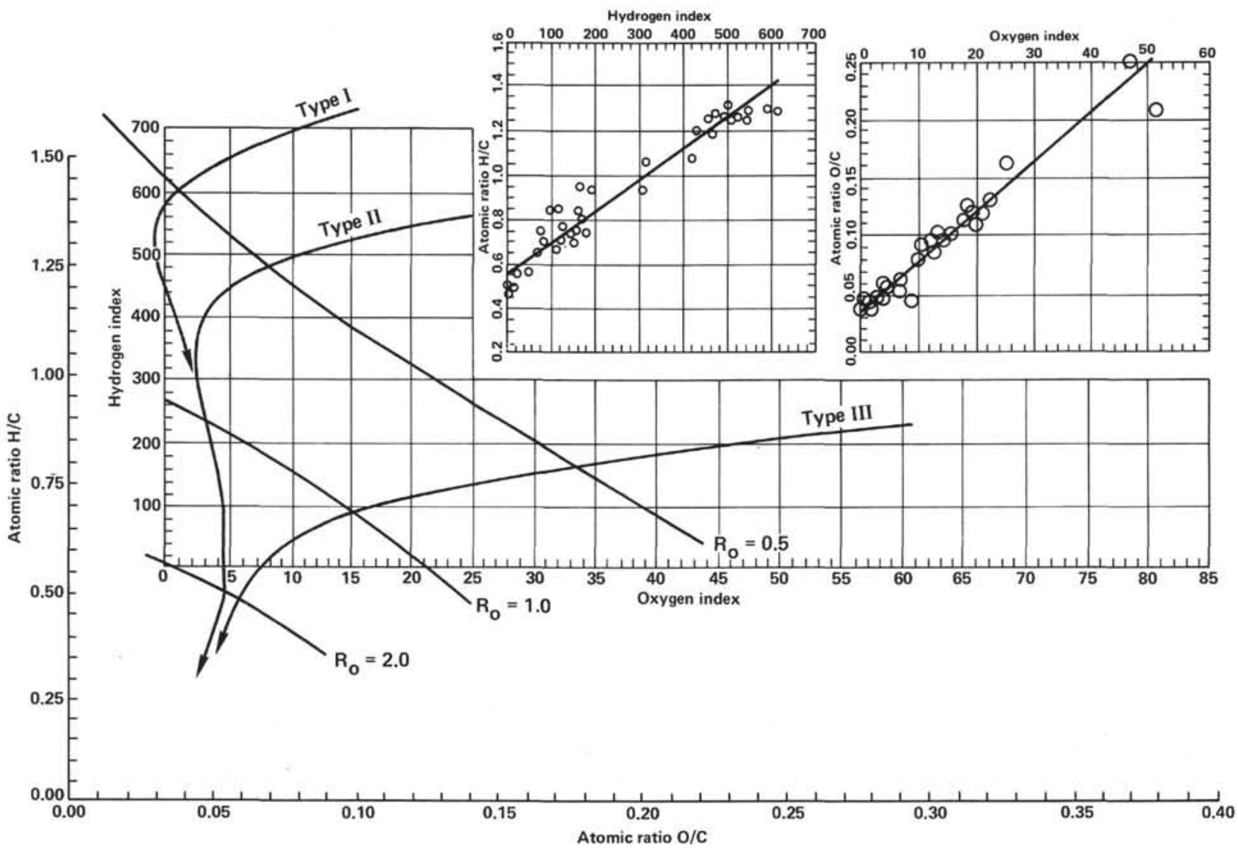


Figure 12. Example of a van Krevelen diagram. The upper right insets show the correlation of hydrogen and oxygen indices as measured by the Rock-Eval and organic carbon analyses to H/C and O/C ratios as measured by elemental analyses of kerogen samples. The straight lines added to the insets represent least squares fits to the data (Espitalié, Madec, et al., 1977) to obtain the indices for the grid shown on the rest of the figure in relation to H/C and O/C ratios by elemental analyses. The approximate iso-values for vitrinite reflectance (R_0) are adapted from figure 11.5.1 of Tissot and Welte, 1978.

Inorganic Geochemistry

Carbonate Determinations

Bulk carbonate analyses were made routinely on board using the carbonate bomb method described by Müller and Gastner (1971). Additional carbonate determinations were done following the cruise. These data appear in the Appendix at the end of this volume.

Interstitial Water

Interstitial waters were analyzed on board according to the techniques described by Gieskes (1974). All water samples were squeezed from sediments recovered by coring. Analyses included pH, salinity, alkalinity, chlorinity, and calcium and magnesium concentrations.

Physical Properties

Boyce (1976) describes in considerable detail the equipment, methods, and corrections routinely used by shipboard scientists to measure physical properties of sediments and rocks recovered at DSDP sites. On Leg 77 we determined saturated bulk density using the Gamma Ray Attenuation Porosity Evaluator (GRAPE) and the gravimetric technique, porosity calculated from 2-minute GRAPE and gravimetric measurements, water content from gravimetric measurements, sonic velocity using the Hamilton Frame velocimeter, and shear strength of undisturbed sediments (see Boyce, 1977). For density and porosity calculations, we assumed grain densities of 2.70 g/cm^3 for sediments and 2.90 g/cm^3 for igneous rocks and pore-fluid densities of 1.025 g/cm^3 (true) and 1.128 g/cm^3 (corrected).

In addition we measured thermal conductivities of selected samples and collected downhole temperature data using a heat flow probe described in Volume 60 of the DSDP *Initial Reports* (Hussong, Uyeda, et al., 1982). The temperature and conductivity results were combined to give thermal gradient and heat flow estimates for several sites. The data and calculations are given in specific site chapters. Comprehensive listings of the physical properties data for this cruise are available on request from the Deep Sea Drilling Project. No downhole logs were run during this cruise.

X-Ray Diffraction

X-ray diffraction was used selectively on Leg 77 to identify fine-grained components not detectable in smear slides or thin sections. It proved most useful in distinguishing carbonate types and phyllite compositions. Specific results are detailed in the site chapters.

Grain-Size Analyses

Routine samples were collected for grain-size analyses during Leg 77. The results of the shore-based work are given in the Appendix at the back of this volume.

Paleomagnetism

Several procedures were followed for paleomagnetic samples on Leg 77. For soft material, oriented samples were taken by pressing plastic boxes into the sediments. In consolidated lithologies, 1-inch diameter minicores were taken. All samples were oriented with respect to vertical (i.e., core axis).

Initial susceptibility was measured on board with a Bison Magnetic Susceptibility System (Model 3101). Remanent magnetization measurements were attempted with the on board Digico Fluxgate Magnetometer, which had a noise level of approximately 2×10^{-7} emu. On Leg 77, only basement samples could be measured with this instrument; the intensities of all sedimentary samples were close to or below its noise level. The magnetic field in the ship laboratory was usually 0.8–1.0 Oe and was directed horizontally. Any viscous component of magnetization could be influenced by this field during the transport of the sample between the demagnetizer and the magnetometer. For this reason, no demagnetization was conducted on board.

Further work was conducted at the University of Texas, Galveston Marine Geophysics Laboratory following the cruise. Samples were stored in a magnetically shielded room (about 100 gamma residual field) and remained in this room throughout the experimental procedures. Samples were measured with a cryogenic magnetometer that had a noise level of 3×10^{-8} emu. Each component of magnetization was measured twice and averaged to obtain the final reading for each sample at a particular demagnetization step. Alternating-field demagnetization was conducted with a Schonstedt single-axis demagnetizer in which samples were demagnetized in three mutually perpendicular directions. The residual magnetic field in the demagnetization coil was less than 3 gammas. For the thermal demagnetization procedure, the samples were heated in air for 10 minutes at the chosen temperature, then cooled in a residual field of less than 3 gammas.

The stability of samples during demagnetization was analyzed using orthogonal vector diagrams (Zijderveld, 1967). By this technique, components of magnetization are recognized by linear trends, and the most stable component is distinguished by a linear trend toward the origin.

Photography

Both color and black-and-white photos of whole cores were taken on Leg 77. In addition, close-up black-and-white photos of significant structures and relationships were taken for documentation (Table 1). Both data sets are available for consultation at DSDP.

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Table 1. Leg 77 detail core photographs (black-and-white).

Negative number	Hole-Core-Section (interval in cm)	Negative number	Hole-Core-Section (interval in cm)
1	535-21-1, 75–95	60	9-5, 120–150
2	21-2, 45–65	61	9-6, 0–30
3	22-3, 37–50	62	9,CC
4	22-5, 48–70	63	10-1, 0–30
5	22-5, 80–100	64	10-1, 30–60
6	22-6, 40–70	65	11-1, 0–20
7	22-6, 100–120	66	14-1, 0–30
8	23-1, 20–40	67	18-1, 25–35
9	23-1, 80–100	68	21-1, 75–85
10	23-6, 70–90	69	21-2, 25–45
11	27-3, 70–90	70	22-2, 95–120
12	27-3, 100–110	71	23-3, 15–40
13	30-4, 40–90	72	537-3-1, 0–19
14	30-4, 65–90	73	3-2, 0–40
15	32-3, 97–112	74	11-1, 0–50
16	33-4, 15–25	75	11-1, 100–120
17	34-2, 115–150	76	13-1, 0–25
18	35-3, 25–55	77	13-1, 120–130
19	35-3, 55–85	78	13-2, 0–15
20	35-3, 85–105	79	14
21	39-1, 95–110	80	15
22	39-5, 30–40	81	20-2, 60–95
23	39-5, 80–110	82	538A-21-1, 0–40
24	42-4, 10–40	83	21-1, 40–85
25	42-4, 40–70	84	21-4, 50–85
26	42-4, 70–100	85	21-4, 85–120
27	44-2, 67–71	86	21-4, 120–150
28	44-2, 67–71	87	30-1, 5–10
29	46-2, 0–50	88	30-1, 125–135
30	46-2, 50–100	89	31-1, 15–30
31	52-4, 73–81	90	31-1, 85–105
32	55-4, 65–85	91	31-2, 52–77
33	55-6, 30–55	92	31-2, 115–122
34	58-4, 10–35	93	31-2, 135–145
35	58-4, 30–55	94	32-4, 1–20
36	58-4, 55–90		34-1, 65–90
37	58-4, 50–70	95	33-1, 56–72
38	58-5, 50–70	96	33-3, 15–30
39	59-4, 88–110	97	34-2, 21–29
40	63-2, 0–25	98	34-2, 40–52
41	63-4, 18–23	99	34-2, 95–130
42	64-3, 125–150	100	34-2, 131–140
43	64-1, 70–95	101	35-1, 5–30
44	64-4, 95–120	102	16-6, 0–50
45	64-5, 125–150	103	26-3, 40–50
46	66-1, 30–40	104	29-1, 100–120
47	67-4, 90–100	105	30-2, 40–70
48	67-5, 5–15	106	31-1, 18–45
49	68-3, 70–90	107	31-1, 73–97
50	68-4, 123–131	108	31-2, 85–110
51	71-2, 85–100	109	32-1, 80–100
52	79-1, 50–75	110	68-1, 80–105
53	79-1, 80–105	111	68-1, 105–135
54	79-1, 100–125	112	68-2, 70–100
55	79-2, 0–25	113	68-2, 100–125
56	536-9-5, 0–30	114	68-2, 125–150
57	9-5, 30–60	115	69-1, 1–38
58	9-5, 60–90	116	70-6, 120–145
59	9-5, 90–120	117	71-1, 35–55