1. INTRODUCTION AND EXPLANATORY NOTES[1]

Roger L. Larson,[2] Lamont-Doherty Geological Observatory, Palisades, New York,
S. O. Schlanger, Hawaii Institute of Geophysics, Honolulu, Hawaii
and
R. E. Boyce, Deep Sea Drilling Project, La Jolla, California

PROGRAM AND OBJECTIVES

Leg 61 from Guam to Majuro, Marshall Islands, was planned to concentrate on the Mesozoic (Jurassic and Cretaceous) history of the oldest portion of the Pacific Ocean deep-sea floor. Our goals were to study the paleontologic, sedimentary, petrologic, tectonic, and magnetic histories of that area from Recent to Late Jurassic time, by drilling a deep re-entry site into the Nauru Basin west of the Ralik Chain of the Marshall Islands. This area formed at a fast-spreading Pacific Plate boundary 145 to 155 m.y. ago, in the Late Jurassic (Larson, 1976). Cores from this locale should allow us to better understand biostratigraphic evolution and sedimentary processes in a Mesozoic open-ocean environment, the petrologic nature of fast-spread oceanic crust, the tectonic history of the Late Jurassic Pacific Plate, and the nature of the Jurassic magnetic quiet zone.

The basement, or plate, age at Holes 462 and 462A in the Nauru Basin should be approximately 145 to 155 m.y., giving us an opportunity to core sediments possibly as old as Oxfordian. The section there should therefore encompass these stratigraphic intervals: late Barremian–Aptian–early Albian and Cenomanian–Turonian, occupied by organic-carbon-rich "black shales" or sapropels, cored at many DSDP sites.

It has been a top priority to obtain relatively deep crustal sections from oceanic crust formed at both slow- and fast-spreading ridges. Three DSDP Legs (51, 52, 53) involved drilling such sites on 110-m.y.-old, slow-spreading crust in the western Atlantic Ocean. The Nauru Basin site was meant to sample fast-spreading Mesozoic-aged crust. The Nauru Basin formed at 4.7 cm/yr (half-rate), and is an area of smooth oceanic crust characterized by a well-defined magnetic-lineation pattern.

The history of horizontal motion of the Pacific Plate back through the Early Cretaceous is relatively well known from magnetic-lineation patterns, magnetic studies of seamounts, and facies studies of sediments. The preceding Jurassic history is relatively unknown, and it was hoped that studies of Mesozoic sedimentary facies, and paleomagnetic studies of sediments, and sedimentary and volcanic rocks, would help outline the tectonic history of the Pacific Plate in the Jurassic.

Studies of remanent paleomagnetic inclination would contribute significant understanding to the Mesozoic tectonic evolution of the Pacific Plate, as described above. In addition, paleomagnetic and rock-magnetism studies of Jurassic sedimentary and volcanic rocks would be of great interest in understanding the history of the Earth's magnetic field at that time.

PRESENTATION OF DATA AND AUTHORSHIP

The scientific results of Leg 61 are presented in this volume in the same manner as in earlier volumes of this series. The first chapter contains the Site 462 Summary (Holes 462 and 462A) embracing the entire drilling program of this leg. The contributions to the Site Summary were written by members of the Shipboard Scientific Party, as follows: background and objectives by Roger L. Larson and Seymour O. Schlanger; operations by Roger L. Larson; sediment lithology by Hugh Jenkyns, Ralph Moberly, and Volker Riech: inorganic geochemistry by John Rutherford; biostratigraphy by Isabella Premoli Silva (pelagic foraminifers), William V. Sliter (benthic foraminifers) Hans Thierstein (calcareous nannofossils), and Patrick DeWever (radiolarians); sedimentation rates by Hans Thierstein and Seymour O. Schlanger; paleomagnetism by Maureen Steiner; physical properties and well logs by Robert E. Boyce, Seymour O. Schlanger, and Roger L. Larson; igneous petrology by Rodey Batiza, S. A. Shcheka, and Hidekazu Tokuyama; and summary and conclusions by Roger L. Larson and Seymour O. Schlanger.

Because of a two-week extension, after a port call in Majuro, Marshall Islands, on July 11 to 15, Batiza, Boyce, DeWever, Jenkyns, Moberly, Riech, Shcheka, Steiner, Thierstein, and Tokuyama disembarked the *Challenger*. Oncoming members of the scientific party that contributed to the Site Summary section for Hole 462A, Cores 75–92 (sub-bottom depths 953.0 to 1068.5 m, total depth), are as follows: Jørn Thiede, Vladimir I. Koporulin, David Rea (sediment lithology); Tracy Vallier, Ken Windom, and Karl Seifert (igneous petrology); Pavel Čepek (calcareous nannofossils); William Sayre (paleomagnetism); and Naoyuki Fujii (physical properties).

OPERATIONAL SUMMARY

D/V *Glomar Challenger* departed Guam at 1100 on May 22, 1978, to begin Leg 61. Because drilling and coring operations were interrupted by a lost bit cone in the re-entry hole, the leg was extended beyond the originally

[1] *Initial Reports of the Deep Sea Drilling Project*, Volume 61.
[2] Present address: Graduate School of Oceanography, University of Rhode Island, Kingston, Rhode Island.

planned termination date of July 9, 1978. Instead, an entire change of drilling and ship's crews and a partial change of scientific crew were accomplished by a port call at Majuro, Marshall Islands, from July 11 to July 15, 1978. The ship then returned to the prime drilling site to clean and deepen Hole 462A. The leg terminated at Majuro at 1400 on July 29, 1978.

Our intended strategy for Leg 61 was to drill a single re-entry hole in the northern Nauru Basin that would penetrate and sample the Cretaceous and Jurassic sediments and Jurassic-aged oceanic crust that should, judging from magnetic anomaly dating, be some of the oldest material in the Pacific basin. The pilot hole for this re-entry site (Hole 462) yielded sediments including turbidite oozes, volcanic ash, cherts, chalks, limestones, volcanogenic sandstones, and mudstones, down to 560 meters sub-bottom; these sediments were easy to drill and recover. At 560 meters, below Cenomanian sediments, a mid-Cretaceous volcanic complex was encountered and penetrated to 617 meters (total depth) in the pilot hole. Core recovery was 61%. Six Uyeda-temperature-probe runs were made in the lower part of the sediment section, at least three being successful. Six logging runs were made in the completed hole, three of which succeeded, as follows: (1) temperature and natural gamma, (2) induction and gamma, and (3) density, gamma, and temperature.

Because the upper part of the pilot hole could be penetrated and recovered easily, a re-entry cone was launched and emplaced 473 meters from Hole 462 on a bearing of 16.6°. This re-entry hole (462A) was the site of the main drilling and coring efforts, where 15 successful re-entries were ultimately made; it is located by the average of 12 very good satellite fixes at 07°14.5′N, 165°01.90′E. The upper 617 meters of Hole 462A virtually duplicated Hole 462. From 617 meters down to 1068.5 m (total depth), the drill penetrated a mid-Cretaceous igneous complex of sills, lava flows, and volcanogenic sediments. At 953.0 meters, the fifth drill bit was recovered, missing one bit cone that was left at the bottom of the hole. Five subsequent re-entries with various junk mills, magnets, and drill bits failed to recover or destroy the bit cone. Since the results to that point had been unexpected and significant, the mutual decision was made aboard the vessel and in the scientific community planning the drilling program to extend the leg after a crew change at Majuro. Joining the ship at Majuro was Arkie Slayton of the Midway Fishing Tool Co., Long Beach, who was employed to remove the bit-cone obstacle. This he did, with 1½ hours of rotation of a modified junk grinder on the first re-entry (re-entry 11 for the leg). Two more re-entries were subsequently made to deepen the hole to 1068.5 meters (total depth), although the mid-Cretaceous volcanic complex was not totally penetrated. After drilling to total depth, a successful sonic and gamma-ray log was run nearly to total depth. An attempt to log with the neutron guard log was aborted after a broken strand of logging cable was discovered snarled against the line wiper. The tool and cable were recovered, and the pipe was pulled out of the hole for the final time. When the hole was abandoned on July 27, 1978, it was clean, with no bit cones, logging tools, bits, or other junk at the bottom of the hole. Throughout the drilling program, the hole conditions and weather were excellent, with little caving between re-entries and little drill-string torquing during drilling operations.

NUMBERING OF SITES, HOLES, CORES, 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 could be located within a radius as great as 900 meters from the beacon. Several holes may be drilled at a single site by pulling the drill pipe above the sea floor (out of one hole) and moving the ship 100 meters or more from the previous hole, then drilling another hole.

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

The cored interval is measured in meters below the sea floor. The depth interval of an individual core is the depth below sea floor that the coring operation began to the depth that the coring operation ended. Each coring interval is generally 9.5 meters long, which is the nominal length of a core barrel; however, the coring interval may be shorter or longer (rare). "Cored intervals" are not necessarily adjacent to each other, but may be separated by "drilled intervals." In soft sediment, the drill string can be "washed ahead" with the core barrel in place, but not recovering sediment, by pumping water down the pipe at high pressure to wash the sediment out of the way of the bit and up the space between the drill pipe and wall of the hole; however, if thin, hard rock layers are present, then it is possible to get "spotty" sampling of these resistant layers within the washed interval, and thus have a cored interval greater than 9.5 meters. We cored particularly long intervals in Hole 462A for Cores 2, H-1, H-2, H-3, and H-4. In drilling hard rock, a center bit may replace the core barrel if it is necessary to drill without core recovery.

Cores taken from a hole are numbered serially from the top of the hole downward. Core numbers and their associated cored interval in meters below the sea floor are normally unique for a hole; however, problems may arise if an interval is cored twice. When this situation occurs, the core number is assigned a suffix, such as "S"[3]; for supplementary.

[3] Note that this designation has been used on previous legs as a prefix to the core number for sidewall core samples.

Full recovery for a single core is normally 9.28 meters of sediment or rock, which is in a plastic liner (6.6 cm I.D.), plus about a 0.2-meter-long sample (without a plastic liner) in the core catcher. The core catcher is a device at the bottom of the core barrel which prevents the cored sample from sliding out when the barrel is being retrieved from the hole. The sediment core, which is in the plastic liner, is then cut into 1.5-meter-long sections and numbered serially from the top of the sediment core (Fig. 1). When we obtain full recovery, the sections are numbered from 1 through 7, the last section possibly being shorter than 1.5 meters. 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.

When recovery is less than 100%, and if the sediment or rock is contiguous, the recovered sediment is placed in the top of the cored interval, then 1.5-meter-long sections are numbered serially, starting with Section 1 at the top. There will be as many sections as are needed to accommodate the length of the core recovered (Fig. 2); for example, 3 meters of core sample in plastic liners will be divided into two 1.5-meter-long sections. Sections are cut starting at the top of the recovered sediment, and the last section may be shorter than the normal 1.5-meter length.

This technique differs from the labeling systems used on Legs 1 through 45, which had a designation called "zero section." On Legs 1 through 45, there were seven sections, labeled 0, 1, 2, 3, 4, 5, and 6. The new system,

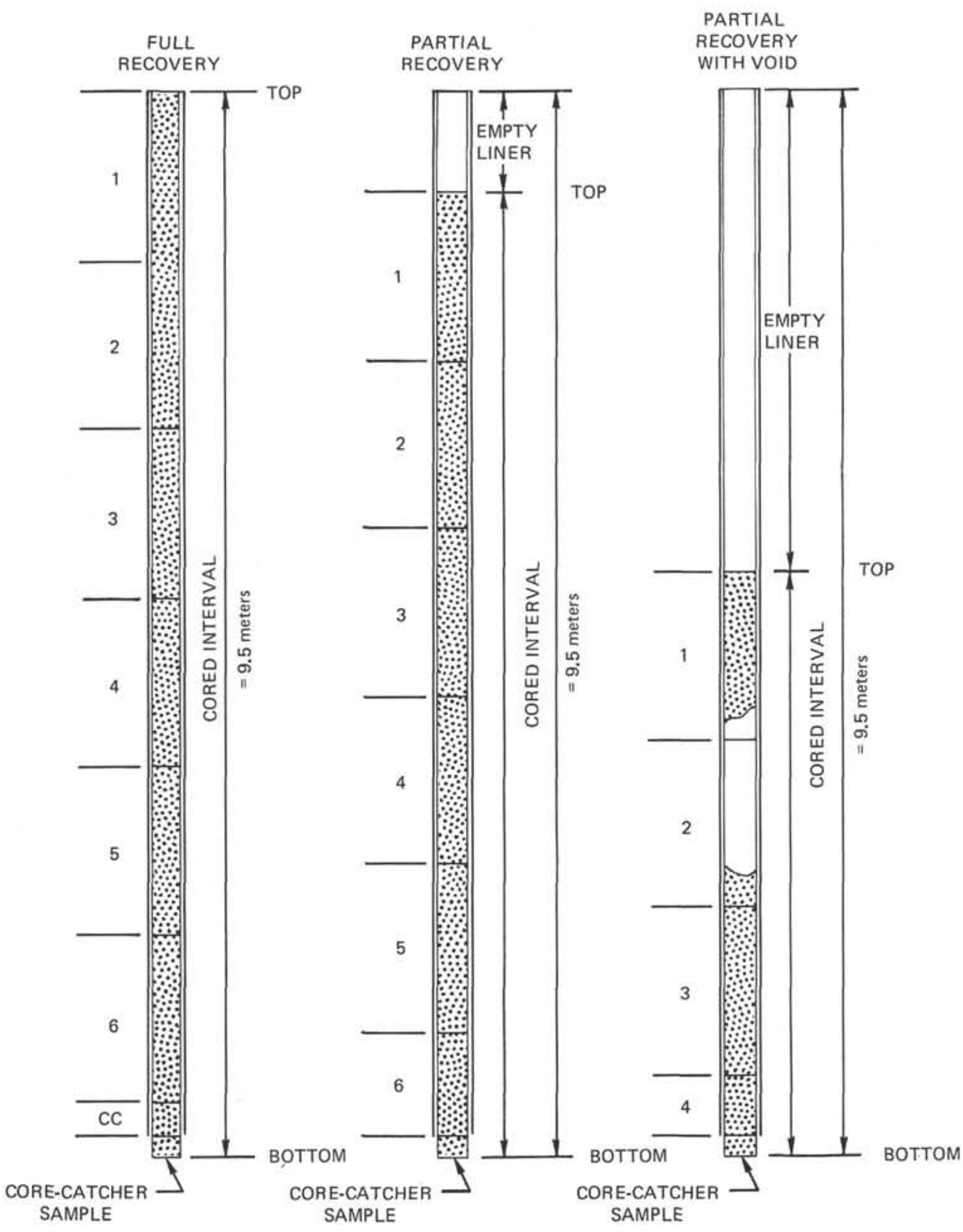

Figure 1. Diagram showing procedure in cutting and labeling of core sections.

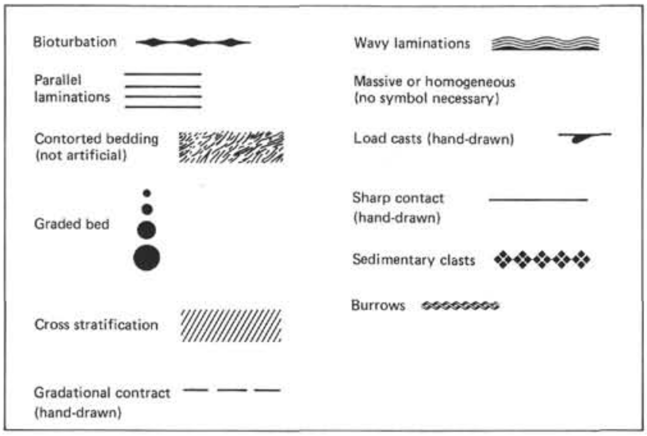

Figure 2. Sedimentary-structure symbols.

used from Leg 46 to the present, has seven sections, but they are labeled 1, 2, 3, 4, 5, 6, and 7. On Leg 61, we described piston cores which were taken prior to the leg, and these were inadvertently labeled with the old system, using a "zero section."

When recovery is less than 100%, the sediment's original stratigraphic position in the cored interval is unknown, so we conventionally assign the top of the recovered sediment to the top of the cored interval. This is done for convenience in data handling, and consistency. If recovery is less than 100%, and core fragments are separated, and if shipboard scientists believe that the sediment was not contiguous, then sections are numbered serially and the intervening sections are noted as void, whether contiguous or not. The core catcher sample is described in the core descriptions beneath the lowest 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
Interval in centimeters from the top of section

For example, a sample identification number of "61-462A-6-3, 12–14 cm" is interpreted as follows: a sample taken 12 to 14 cm from the top of Section 3 of Core 6, from the second hole drilled at Site 462 during Leg 61. A sample from the core catcher of this core is designated as "61-462A-6,CC, 12–14 cm."

The depth below sea floor for a sample numbered "61-462A-6-3, 12–14 cm" is the sum following: (1) the depth to the top of the cored interval for Core 6, which is 430 meters; (2) plus 3 meters for Sections 1 and 2 (each 1.5 meters long); (3) plus the 12 cm depth below the top of Section 3. These variables add up to 433.21 meters,[4] which theoretically is the sample depth below sea floor.

[4] Sample requests should refer to a specific interval within a core-section, rather than the level below sea floor.

HANDLING OF CORES

A core was normally cut into 1.5 meter sections, sealed, and labeled; the sections then were brought into the core laboratory for processing. Gas analysis and continuous wet-bulk-density determinations using the Gamma Ray Attenuation Porosity Evaluation (GRAPE) (Boyce, 1976) were normally made before the sections were split.

The cores were then split longitudinally into "working" and "archive" halves. Samples extracted from the working half include those for determination of grain-size distribution, mineralogy by X-ray diffraction, sonic velocity by the Hamilton Frame method (Boyce, 1976), wet-bulk density by a static GRAPE technique (Boyce, 1976), water content by gravimetric analysis, carbon–carbonate analysis, per cent calcium carbonate (Carbonate Bomb), geochemical analysis, paleontological studies, etc.

Smear slides or thin sections from each major lithology, and most minor lithologies, were prepared and examined microscopically. The archive half was then described and photographed. Physical disturbance by the drill bit, color, texture (for uncemented lithologies), and sedimentary and igneous structures and composition ($\pm 20\%$) of the various lithologies were noted on standard core-description sheets.

Sampled and described cores are maintained in cold storage aboard *Glomar Challenger* until they can be transferred to the DSDP repository. Core sections which were removed for organic geochemistry study were frozen immediately aboard ship and kept frozen. Leg 61 frozen cores are presently stored at the DSDP West Coast Repository (Scripps Institution of Oceanography).

These core descriptions, smear-slide descriptions (plus occasional peels and thin sections), x-ray-fluorescence analyses of basalts, carbonate bomb (%$CaCO_3$) determinations (all determined aboard ship), plus a few grain-size analyses and carbon-carbonate determinations (made at the DSDP shore-based laboratory), serve as the data for the visual core descriptions in this volume. These samples, and their location in the core, are coded with a symbol on the core-description sheets. The key to these codes is shown in Figure 3.

When igneous rocks are cored, each rock piece is numbered and separated from other pieces by a styrofoam spacer. Fragments of a single piece are labeled A, B, C, etc.: for example, Pieces 2A, 2B, 2C, etc.

VISUAL DESCRIPTIONS OF SEDIMENTARY ROCKS

Sediment Disturbance

The recovered rocks, particularly the soft sediments, may be extremely disturbed. This mechanical disturbance is the result of coring, which uses a large (25-cm-diameter) bit with a small, (6.0-cm-diameter) opening for the core sample. The following disturbance categories are used for soft and firm sediment. These categories will be indicated on the core description sheet (in

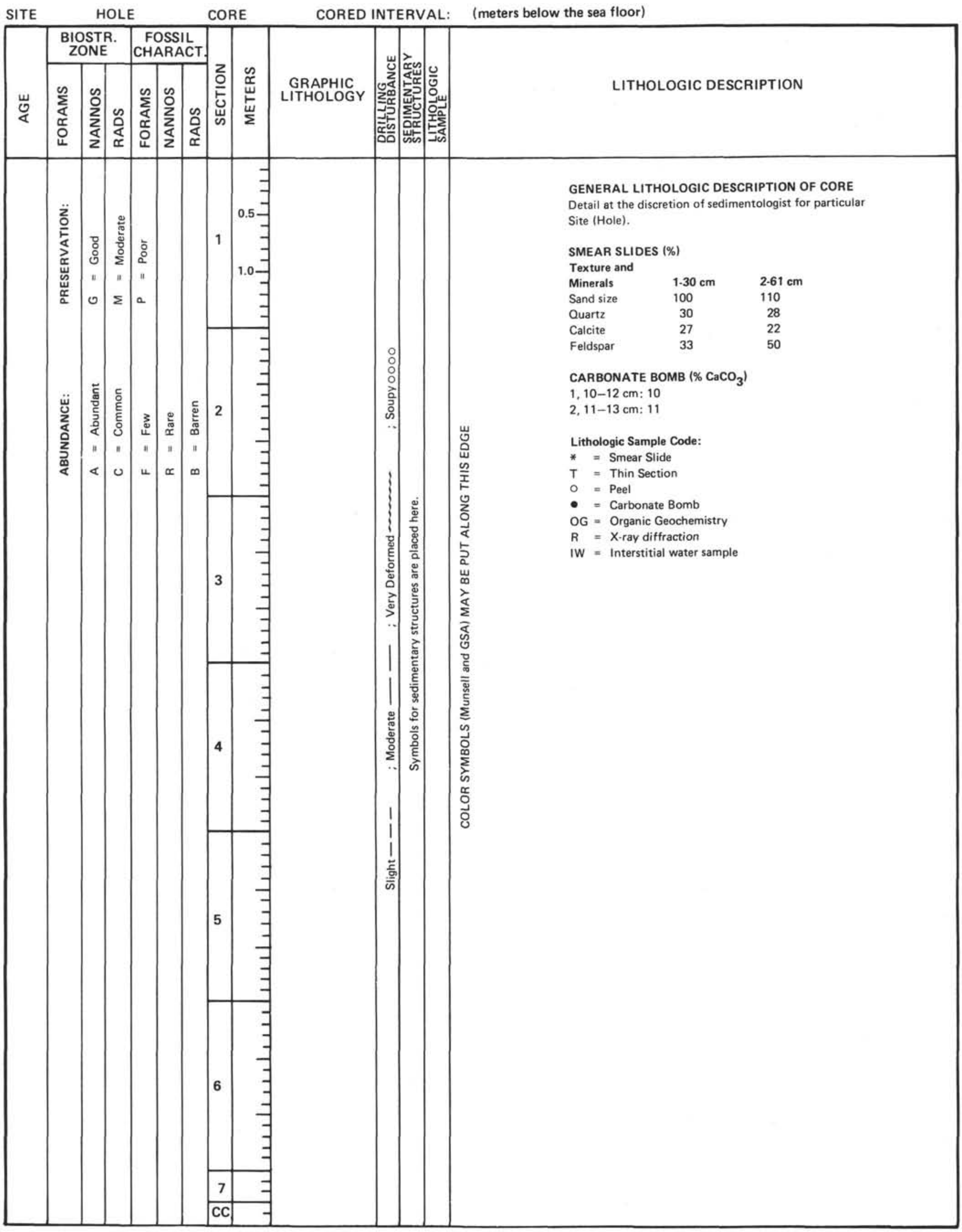

Figure 3. A typical sedimentary-core-description sheet, with sediment-deformation symbols, sample codes, and other general information.

a column) by coded patterns (Fig. 3). The categories are as follows:

1) Slightly deformed: bedding contacts are slightly bent.

2) Moderately deformed: bedding contacts have undergone extreme bowing.

3) Very deformed: bedding is completely disturbed, sometimes showing symmetrical, diapir-like structure.

4) Soupy: water-saturated intervals have lost all aspects of original bedding.

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 coring. Thus, the description of sedimentary structures was optional. A column on the core-description sheet (Fig. 3) may have patterns (coded symbols) to indicate typical structures. The structure-symbol codes are in Figure 2.

Color

Colors of the geologic materials are determined with a Munsell or Geological Society of American rock color chart. Colors were determined immediately after the cores were split, while they were wet.

Graphic-Lithology Column

This graphic column is based on this lithologic classification presented below. The lithologies and their corresponding symbols are shown in Figure 4. Often a single lithology will be represented by a single pattern. Some lithologies are represented by a grouping of two symbols. The symbols in this grouping may correspond to end-member sediment constituents, such as clay and nannofossil ooze. Normally, the symbol for the dominant constituent is placed on the right-hand side of the column, and the symbol for the subordinate constituent will be on the left-hand side of the column (see examples in Figure 4). The proportions of components may be represented in the graphic column by the proportionate employment of symbols. For example, the left 20% of the column may have a clay symbol, while the right 80% of the column may have a nannofossil-ooze symbol. This means that the sample was approximately 80% nannofossil ooze and 20% clay. The vertical lines which separate the symbols are shown in Figure 4 with their corresponding percentages and positions in the column.

Text of Core Description

Format, style, and terminology of the descriptive portion of the core-description sheets (Figure 3) are not controlled by the "Mandatory Graphic Lithologic Column Scheme," beyond the minimal name assignment, which is derived from the lithologic classification (described below). Colors and additional information, such as structure and texture, are normally included in the text portion of the core description.

LITHOLOGIC CLASSIFICATION

The basic classification system used here was devised by the JOIDES Panel on Sedimentary Petrology and Physical Properties (SPPP), and adopted for use by the JOIDES Planning Committee in March, 1974. For the sake of continuity, the Leg 61 shipboard scientists have used this classification, with some slight modification. We will point out our deviations from the classification when those topics are discussed.

General Principles

This classification is not comprehensive; therefore, a category of "Special Rock Types" will create additional definitions and terminology of rock types not covered. The classification is descriptive, and genetic implications are not intended. These divisions are naturally artificial, and the proposed classification is only a rough scheme of what we really find in nature. The classification, as used in this volume, will use data primarily estimated or measured aboard ship.

Descriptive Data

Sediment and rock names are defined solely on the basis of composition and texture. Composition is most important for description of those deposits more characteristic of open-water marine conditions, texture becoming more important for the classification of hemipelagic and near-shore facies. These data are primarily determined aboard ship by (1) visual estimates "in smear slides" with the aid of a microscope, (2) visual observation using a hand lense, and (3) simple unaided visual observations. Calcium carbonate content was estimated in smear slides using the Carbonate Bomb technique, or the Leco WR-12 (DSDP shore-based laboratory) technique. Textures were primarily estimated in smear slides, as only six grain-size samples were processed through the DSDP laboratory. Other geological features determined were color, sedimentary structures, and firmness.

Firmness

We use three classes of firmness for biogenic calcareous rocks which have a calcium carbonate content greater than 30%, and only two classes of firmness for all other lithologic types. Criteria for different classes of firmness are those of Gealy et al., (1971).

1. Biogenic-calcareous sediment with greater than 60% $CaCO_3$ has three classes of firmness, as follows:
   A. Soft: Sediment which has little strength and is readily deformed under the finger or broad blade of the spatula is soft and is termed ooze.
   B. Firm: Partly lithified ooze or friable limestone is called chalk. Chalk is readily deformed under the fingernail or the edge of a spatula blade. More-lithifed chalk is termed limestone (see below).
   C. Hard: Limestone is a term restricted to non-friable, cemented rock.
2. Only two classes of firmness are used for transitional carbonates with less than 30% $CaCO_3$, biogenic siliceous sediment, pelagic clay, and terrigenous sediments, as follows:

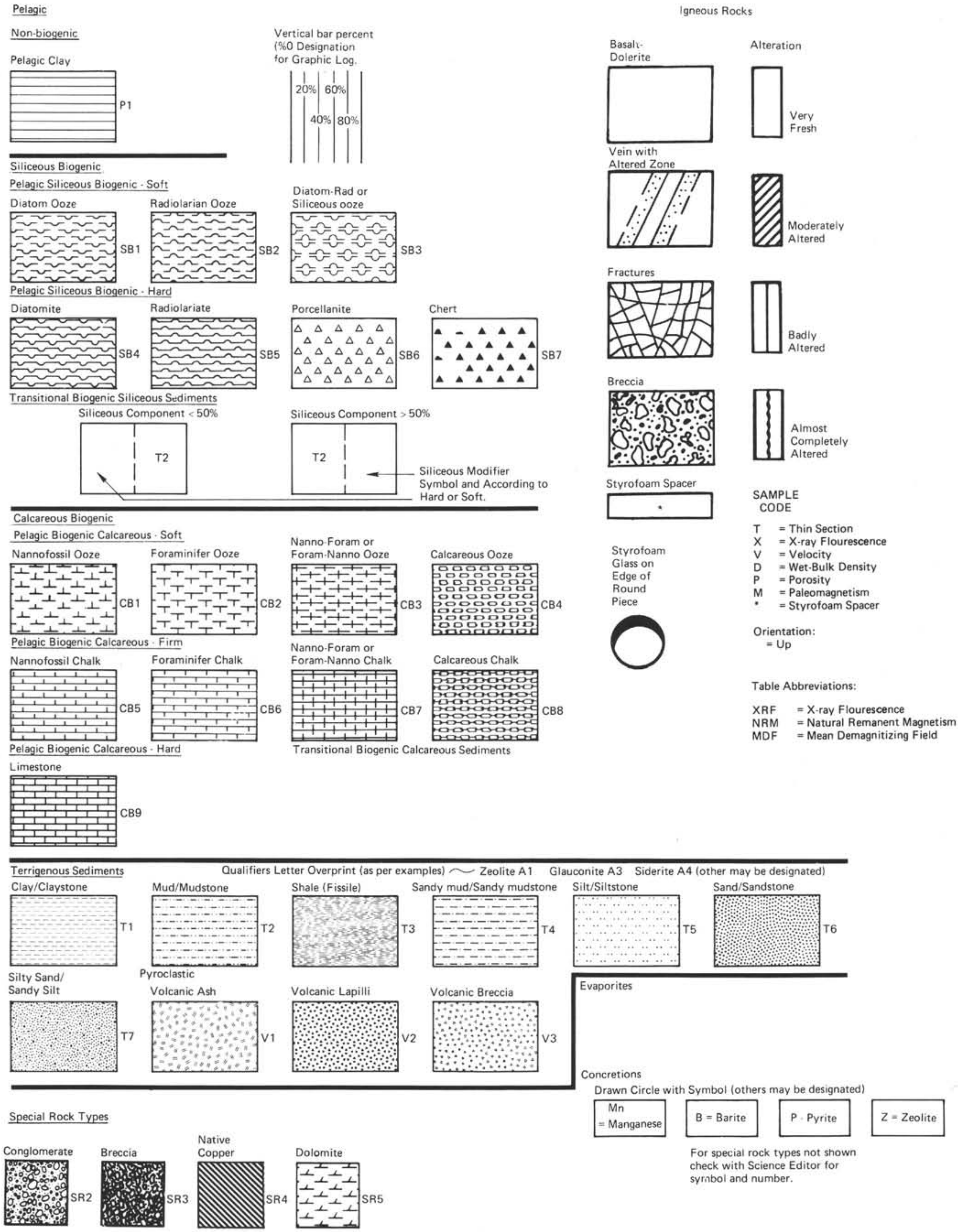

Figure 4. Graphic symbols used in the core-description sheets.

A. Soft: A sediment is soft if the sediment core can be split with a wire cutter. The following sediment terms are used for soft sediment:
   i. Soft biogenic-siliceous sediment (with greater than 50% siliceous fossils) is termed ooze (for example, radiolarian ooze, diatom ooze, or siliceous ooze).
   ii. Soft terrigenous sediment, pelagic clay, and transitional calcareous-biogenic sediment is termed sand, silt, clay, mud, or marl.

B. Hard: The core is hard if it must be cut with a band saw or diamond saw.
   i. Hard siliceous-biogenic sediment (greater than 50% silica) is termed radiolarite, diatomite, chert, or porcellanite.
   ii. Hard terrigenous sediment, transitional calcareous-biogenic sediment, and pelagic clay are termed as follows: a suffix, -stone, is added to the soft-sediment name, for example: sandstone, siltstone, claystone, mudstone (shale, if fissile), or marlstone.

Basic Sediment Types

Pelagic Clay

Pelagic clay is principally authigenic pelagic deposits that accumulate at very slow rates. The class is often termed brown clay, or red clay, but because these terms are confusing they are not used.

The boundary of pelagic clay with terrigenous sediments is where authigenic components (Fe-Mn micronodules, zeolites), fish debris, etc., become common (>10%) in smear slides, indicating pelagic clay. The accumulation rates of pelagic clay and terrigenous sediments are very different; therefore, transitional deposits are exceptional.

The boundary of pelagic clay with siliceous-biogenic sediments is where there is less than 30% siliceous remains.

The boundary of pelagic clay with calcareous-biogenic sediment is uncommon. Generally the facies passes from pelagic clay through siliceous ooze to calcareous ooze, with one important exception: at the base of many oceanic sections, black, brown, or red clays occur directly on basalt, overlain by or grading up into calcareous sediments. Most of the basal clayey sediments are rich in iron, manganese, and metallic trace elements. For proper identification, they require more-elaborate geochemical work than is available on board ship. These sediments would be placed in the special rock category.

Pelagic-Siliceous-Biogenic Sediment

Pelagic-siliceous-biogenic sediment is distinguished from pelagic clay because the siliceous-biogenic sediment has more than 30% siliceous microfossils. Siliceous-biogenic sediments are distinguished from the calcareous category by a calcium carbonate content of less than 30%.

For a pelagic-biogenic-siliceous sediment with ~50 to 100% siliceous fossils, the following terminology is used:

1. Soft: Siliceous ooze (radiolarian ooze, diatom ooze, etc., depending on the dominant fossil component).
2. Hard: Radiolarite, diatomite, chert, or porcellanite. The term "chert" in the past has been used in a very broad sense to designate almost any form of recrystallized silica. The term porcellanite (which had a very broad usage in the past) will be used here to refer to "low density, more or less porous and dull-lustered varieties of 'chert' made of opaline silica or cristobalite. . . ." (Lancelot, 1973). Chert as used here, will have a narrower scope than that of past usage, and will refer to "hard nodules and sometimes beds, that are largely quartz and/or chalcedony, and show a conchoidal fracture and a vitreous luster. . . ." (Lancelot, 1973).
3. Compositional Qualifiers: Diatoms and radiolarians may be the principle components; thus, one or two qualifiers may be used, for example:
   Indeterminate siliceous fossils: Siliceous ooze, chert, or porcellanite
   Radiolarians only: Radiolarian ooze, or radiolarite
   Diatoms only: Diatom ooze, or diatomite
   Diatom < radiolarians: Diatom radiolarian ooze, or diatom radiolarite
   Diatom > radiolarians: Radiolarian diatom ooze, or radiolarian diatomite
   The order of the two modifiers in the terms is dependent on the dominant fossil type. The most dominant component is listed last, and the minor component is listed first.

The terminology for the pelagic clay transition with diatom sediments is as follows:

% Biogenic Siliceous Fossil Particles	% Clay	Lithologic Type	
0 to 30	>70	Clay:	Soft
		Claystone:	Hard
50 to 30	50 to 70	Diatom mud:	Soft
		Diatom mudstone:	Hard
60 to 50	40 to 50	Muddy diatom ooze:	Soft
		Muddy diatomite:	Hard
100 to 60	0 40	Diatom ooze:	Soft
		Diatomite:	Hard

Other terms may be substituted for the terms diatom and diatomite, respectively, as follows: (1) radiolarian and radiolarite, if radiolarians are predominate, or (2) siliceous or chert if the fossil type is indeterminate.

Pelagic-Biogenic-Calcareous Sediments

Pelagic-calcareous sediments are distinguished by a biogenic $CaCO_3$ content in excess of 30%. There are two classes: (1) pelagic-biogenic-calcareous sediments which contain 60 to 100% biogenic $CaCO_3$, and (2) transitional biogenic sediments which contain 30 to 60% biogenic $CaCO_3$.

1. For the pelagic-biogenic-calcareous sediment with 60 to 100% $CaCO_3$, the following terminology is used:

A. Soft: Calcareous ooze
B. Firm: Chalk
C. Hard and cemented: Limestone
D. Compositional Qualifiers: If nannofossils and foraminifers are the principal components, then one or two qualifiers may be used, as in the following examples:

Indeterminate carbonate fossils: Calcareous ooze, calcareous chalk, or calcareous limestone

Foraminifers (0–10%)—nannofossils (90–100%): Nannofossil ooze, nannofossil chalk, or nannofossil limestone

Foraminifers (10–25%)—nannofossils (75–90%): Foraminifer-nannofossil ooze, foraminifer-nannofossil chalk, or foraminifer-nannofossil limestone

Foraminifers (25–50%)—nannofossils (50–75%): Nannofossil-foraminifer ooze, nannofossil-foraminifer chalk, or nannofossil-foraminifer limestone

2. The transitional biogenic-calcareous sediments with 30 to 60% $CaCO_3$ are termed marl or marlstone, as follows:
A. Soft: Calcareous marly ooze, foraminifer marly ooze, nannofossil marly ooze
B. Firm: Calcareous marly chalk, foraminifer marly chalk, or nannofossil marly chalk
C. Hard: Calcareous marly limestone, foraminifer marly limestone, or nannofossil marly limestone

The terminology for the pelagic clay transition with nannofossil sediments is as follows:

% Biogenic Calcareous Particles	% Clay	Lithologic Type	
0 to 10	90 to 100	Clay:	Soft
		Claystone:	Hard
30 to 10	70 to 90	Nannofossil mud:	Soft
		Nannofossil mudstone:	Hard
60 to 30	40 to 70	Nannofossil marly ooze:	Soft
		Nannofossil marly chalk:	Firm
		Nannofossil marly limestone:	Hard
100 to 60	0 to 10	Nannofossil ooze:	Soft
		Nannofossil chalk:	Firm
		Nannofossil limestone:	Hard

Other terms may be substituted for nannofossil, such as (1) foraminifer, nannofossil-foraminifer, foraminifer-nannofossil, if foraminifers are present in the percentages as discussed; or (2) calcareous, if the fossil type is indeterminate.

Terrigenous Sediment

Terrigenous sediments are subdivided into textural groups on the basis of the relative proportions of their grain-size constituents, i.e., clay-size, silt-size, and sand-size. Rocks coarser than sand-size are treated as "special rock types." The size limits of these constituents are defined by Wentworth (1922) (Fig. 5).

Five major textural groups are recognized on the accompanying triangular diagram (Fig. 6) (Shepard, 1954). These groups are defined according to the abundance of clay (greater than 90%, 90–10%, less than 10%), and the ratio of sand to silt. The terms clay, mud, sandy mud, silt, and sand are used for soft sediment. The hard or unconsolidated equivalents for the same textural groups are claystone, mudstone (or shale, if fissile), sandy mudstone, siltstone, and sandstone.

Sands and sandstones may be subdivided further into very fine- (0.0625–0.125 mm), fine- (0.125–0.25 mm), medium- (0.25–0.50 mm), coarse- (0.50–1.00 mm), or very coarse-grained (1.0–2.0 mm) sands and sandstones, according to their median grain size.

	Millimeters		Phi (ϕ) units	Wentworth size class
	2.00	2	1.0	Granule
	1.68		0.75	
	1.41		0.5	Very coarse sand
	1.19		0.25	
	1.00	1	0.0	
	0.84		0.25	
	0.71		0.5	Coarse sand
	0.59		0.75	
	0.50	1/2	1.0	
SAND	0.42		1.25	
	0.35		1.5	Medium sand
	0.30		1.75	
	0.25	1/4	2.0	
	0.210		2.25	
	0.177		2.5	Fine sand
	0.149		2.75	
	0.125	1/8	3.0	
	0.105		3.25	
	0.088		3.5	Very fine sand
	0.074		3.75	
	0.0625	1/16	4.0	
	0.053		4.25	
SILT	0.044		4.5	Coarse silt
	0.037		4.75	
	0.031	1/32	5.0	
	0.0155	1/64	6.0	Medium silt
	0.0078	1/128	7.0	Fine silt
	0.0039	1/256	8.0	Very fine silt
	0.0020		9.0	
	0.00098		10.0	Clay
MUD	0.00049		11.0	
	0.00024		12.0	
	0.00012		13.0	
	0.00006		14.0	

Figure 5. Terminology and class intervals for grade scales.

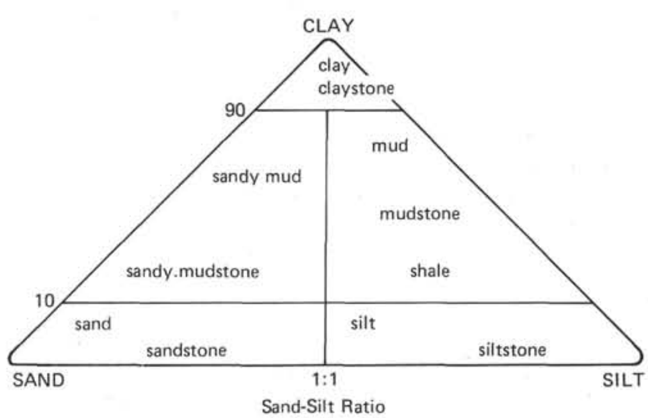

Figure 6. Textural groups of terrigenous sediments.

In this group, numerous qualifiers are possible, usually based on minor constituents (for example, glauconitic, pyritic, and feldspathic).

Qualifiers

In general, sediments containing various calcareous constituents in the 10 to 30% range may be identified with the adjective calcareous. Many qualifiers are possible, based on minor constituents (glauconitic, pyritic, feldspathic, etc.).

Special Rock Types

1. We desire to distinguish sandstones and siltstones made up predominantly of carbonate grains, instead of quartzose or lithic grains; therefore the term calcarenite is used for sandstone with predominantly carbonate grains.

2. Micritic limestones are those whose grains are microcrystalline calcite.

3. Coquina is a porous limestone or chalk composed of broken shells, corals, and other biogenic debris.

4. Dolomite is a rock composed primarily of dolomite, and some calcite.

5. Gravels, conglomerate, and breccia: Terms for clasts which are rounded are given below (after Pettijohn, 1957):

Size (mm)	Rounded Clasts	Unlithified Aggregate	Lithified Aggregate
64–256	Cobble	Cobble gravel	Cobble conglomerate
4–64	Pebble	Pebble gravel	Pebble conglomerate
2–4	Granule	Granule gravel	Granule conglomerate

If the clasts (2–256 mm) are angular, then the lithified or unlithified rock aggregate of these clasts will be referred to as breccia.

6. Concretion will refer to a nodular or irregular concentration of various authigenic minerals, such as barite, pyrite, phosphate, etc.

7. Coal will refer to a dark brown to black, combustible rock of variable physical and chemical composition, produced by the carbonization of vegetable matter.

IGNEOUS ROCK NOMENCLATURE

The terminology used for textures and rock types in the igneous rock section comprises standard terms. Usage is generally in accordance with the definitions given in the AGI glossary.

Grain-size variations noted in hand-specimen descriptions are relative only; no absolute grain-size criteria are employed.

For lithologic symbols, see Figures 4 and 7.

BIOSTRATIGRAPHY

Biostratigraphic studies of Leg 61 material and biostratigraphic boundaries are based on Premoli Silva, Sliter, Thierstein, and DeWever (this volume). The Cenozoic and Mesozoic faunal and floral zonations used on Leg 61 are shown in Figures 8, 9, and 10.

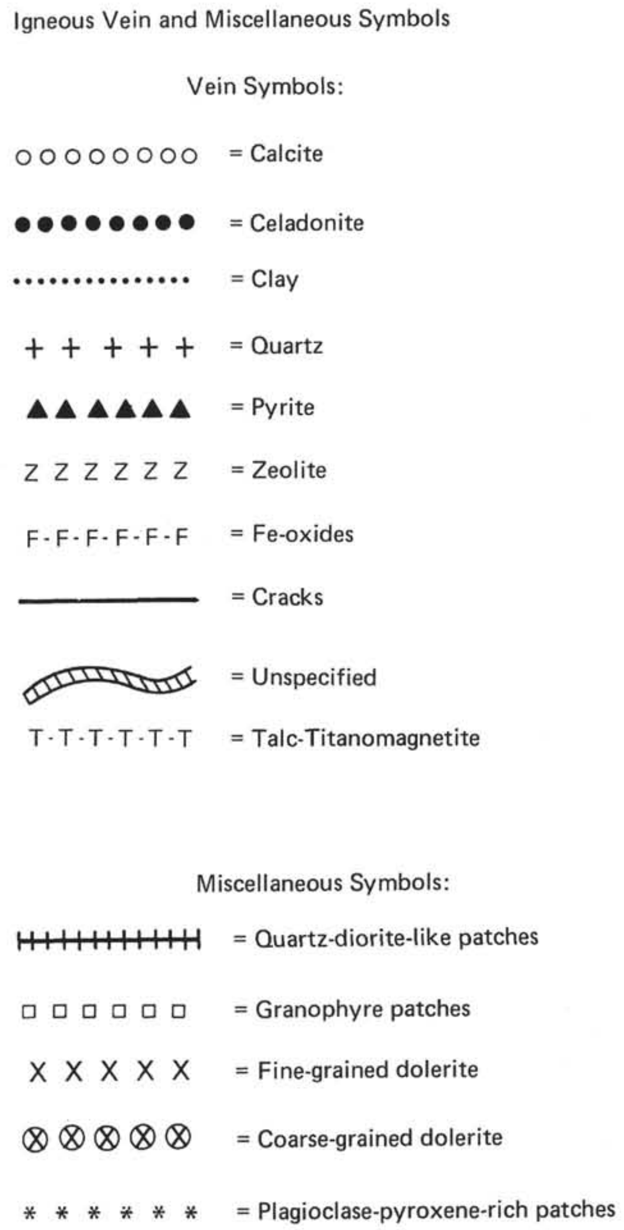

Figure 7. Vein and miscellaneous symbols used in the igneous "graphic representation column."

SPECIAL STUDIES

Carbonate Bomb

Per cent $CaCO_3$ was also determined aboard ship by the "Carbonate Bomb" technique (Müller and Gastner, 1971). In this simple procedure, a sample is powdered and treated with HCl in a closed cylinder. Any resulting CO_2 pressure is proportional to the $CaCO_3$ content of the sample. Application of a calibration factor to the manometer reading ($\times 100$) yields percent $CaCO_3$. Error can be as low as 1% for sediments high in $CaCO_3$, and in general an accuracy of ± 2 to 5% can be obtained. Accuracy degrades to 2% for low-$CaCO_3$ data (J. Bode, personal communication).

These data are presented on the core forms (sample code = o). The sample interval is designated by three

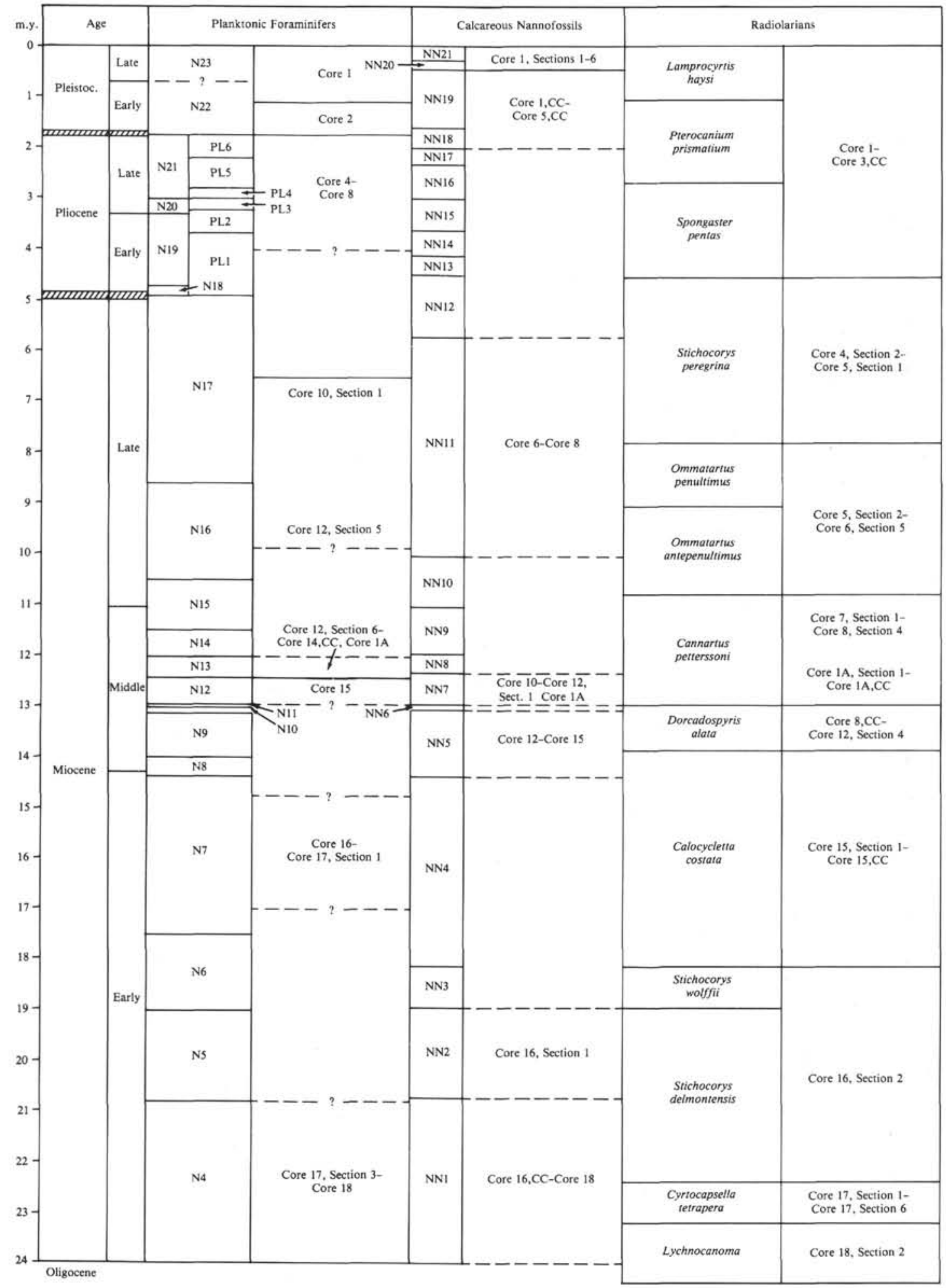

Figure 8. Neogene biostratigraphy.

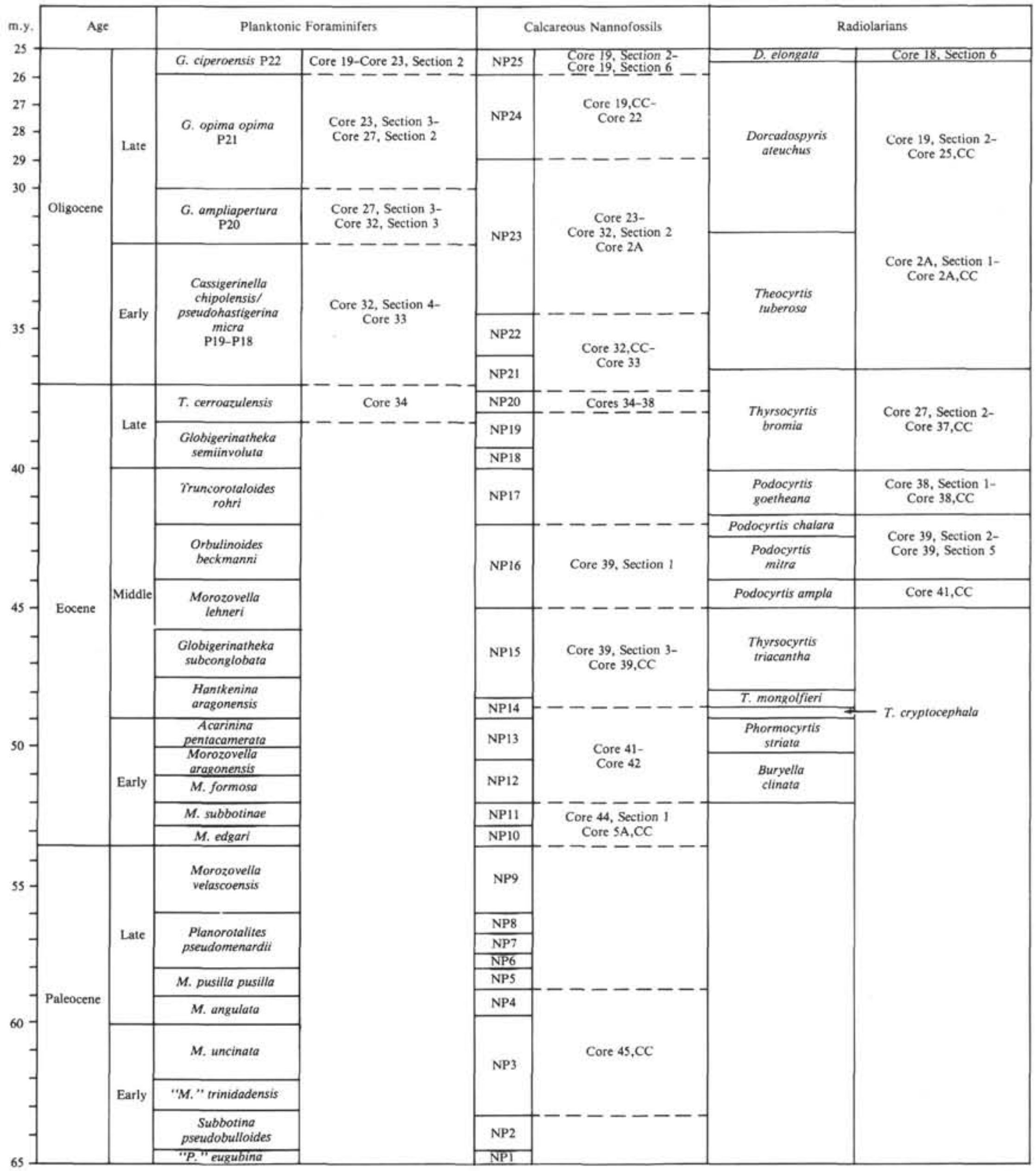

Figure 9. Paleogene biostratigraphy.

numbers: the section number followed by the top and bottom of the sample interval. For example, a sample from Section 2, 11 to 12 cm, with 90% calcium carbonate, will be presented on the core form as follows:

$$\frac{\text{Carbonate Bomb (\% CaCO}_3\text{)}}{\text{2, 11–12 cm: 90}}$$

X-ray Diffraction

X-ray-diffraction data were determined in the shore-based laboratories by Nasel et al. Methods and discussions of the data are in Nasel et al. (this volume).

Physical Properties

Compressional-sound velocity (km/s) was measured parallel and perpendicular to bedding, on undisturbed samples. From the same sample, a 2-minute Gamma Ray Attenuation Porosity Evaluator (GRAPE) count was taken to calculate wet-bulk density (g/cm^3), and a wet-water-content sample was also taken. Porosity, bulk density, and wet-water content were determined by gravimetric methods, on 20-g/cm samples, salt corrections being applied to the wet-water-content and porosity values. Detailed methods, calculations, and calibrations are discussed in Appendix I of this volume.

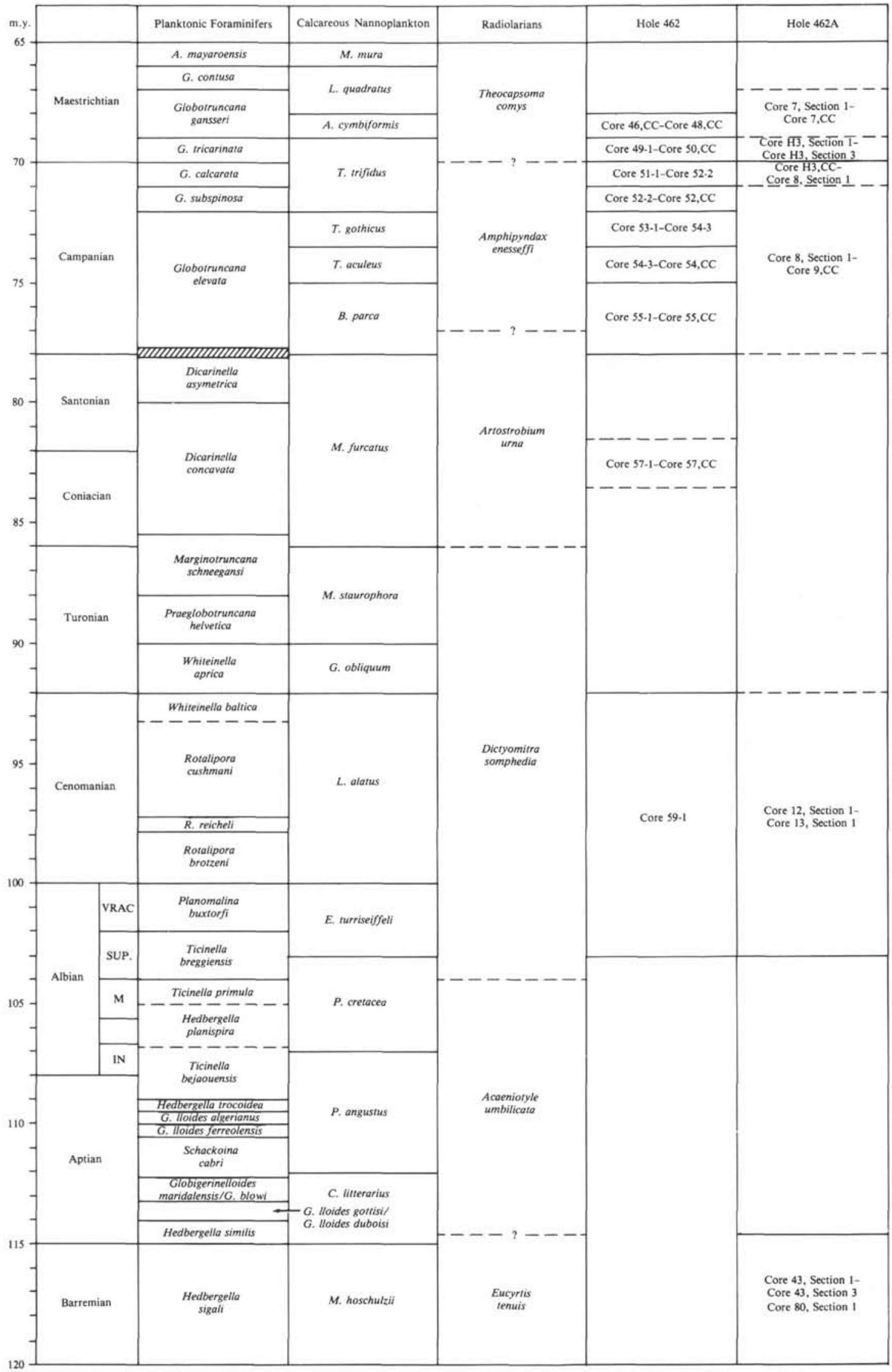

Figure 10. Cretaceous biostratigraphy.

Continuous analog GRAPE wet-bulk-density data are presented in this volume. The diameter and offset from the gamma-ray beam were measured; in addition, the material surrounding the solid sediment-rock core was noted. Adjustments and calculations were applied according to the procedures in Boyce (1976). The unadjusted raw data (solid lines) are presented with the fully adjusted data (dotted lines). This presentation will allow investigators to manipulate the data. Detailed equations used and parameters for these equations are discussed in Appendix I of this volume.

Heat-conductivity values were determined using the Quick Thermal Conductivity Meter (QTM). This instrument and calibration are discussed in Appendix I of this volume.

Only a few measurements of vane shear strength were obtained, as the cores were either disturbed or too hard to perform the test without the sample breaking. A modified Wykeham Farrance Laboratory Vane Apparatus was used (see Appendix I, this volume, for details). The measurement was taken parallel to bedding, with a 1.6 × 1.6 cm vane in a split core, the stress applied at 89 degrees per minute. Only undisturbed, clayey-type, fine-grained sediment samples were selected.

Well Logs

A suite of Gearhart-Owen well logs were attempted. These logs include the following Gearhart-Owen tools on a single wire-line lowering or run (see Appendix I, this volume, for a detailed discussion of the Legs):

1) Sonic log (bore-hole compensated), caliper, and gamma ray.

2) Density log (bore-hole compensated), caliper, and gamma ray.

3) Induction log, 16″ normal log.

4) Laterolog-3, neutron log (free in hole, thermal neutron detection), and gamma ray.

5) High-resolution temperature log (HRT) (2 runs).

6) Gamma-ray and neutron log, run singly in Hole 462A, with the drill pipe in the hole.

X-Ray Fluorescence

X-ray-fluorescence studies of selected igneous samples were performed on ship by J. Bijon.

Paleomagnetism

Natural remanent magnetization, alternating-field demagnetization, and susceptibility measurements were all performed aboard ship by M. Steiner. Methods and a discussion of results are found in Steiner (this volume).

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