1. INTRODUCTION, BACKGROUND, AND EXPLANATORY NOTES, DEEP SEA DRILLING PROJECT LEG 94, NORTH ATLANTIC OCEAN[1]

Shipboard Scientific Party[2]

BACKGROUND

In the late 1970s the advent of hydraulic piston coring from *Glomar Challenger* provided for the first time a means of extending the fine-scale Quaternary stratigraphy, established from conventional piston coring, through the Neogene. As a result, it became possible to analyze in detail, using paleontological, chemical, and lithological parameters, paleoenvironmental changes spanning millions to tens of millions of years.

Leg 94 represents the last of four transects of sites set up by the Ocean Paleoenvironment Panel to examine climatic and oceanographic changes in the Pacific and Atlantic oceans. Leg 85 drilled an east–west series of sites in the central equatorial Pacific. Legs 86 and 90 drilled latitudinal transects in the northwest and southwest Pacific, respectively.

During Leg 94, a transect of six holes aligned roughly in a south–southwest/north–northeast direction were drilled in the North Atlantic from 37° to 53°N (Fig. 1; Table 1). The principal objective of this transect was to document the magnitude and spectral character of the surface-ocean response to high-latitude climatic change in the northern hemisphere during the Neogene. Changes in the modes of oceanic response in this highly sensitive region could then be traced from the late Quaternary record, documented from piston coring, back into times of significantly different climatic boundary conditions (no northern hemisphere ice sheets, an open Panamanian Isthmus, a closed Gibraltar Isthmus, a smaller Antarctic ice sheet). Ancillary paleoclimatic objectives included the recovery of both a faunal and an isotopic record of deep-water variations at water depths ranging from 2393 to 3871 m.

Other major targets sought as well as the basic paleoclimatic objectives included ascertaining (1) the Neogene history of accelerated sediment deposition on the Feni Ridge in Rockall Trough and the Gardar Ridge on the east flank of the Mid-Atlantic Ridge; and (2) the tectonic history of the King's Trough complex north of the Azores. In addition, rotary or extended core barrel drilling at Site 608 below the upper Neogene hydraulic piston coring objectives attempted to fill gaps in the global DSDP stratigraphic array of Eocene–Oligocene sediment cores. Other significant objectives included establishing (1) a record of Neogene paleomagnetic stratigraphy including detailed polarity transitions; (2) sequences defining variations in the input of continental detritus, particularly by ice rafting; and (3) a Neogene $CaCO_3$ dissolution history for the North Atlantic.

CRUISE OBJECTIVES

Neogene Paleoclimatology

The surface North Atlantic from 40° to 50°N has been the most thermally reactive oceanic area in the world during the late Quaternary, undergoing glacial–interglacial oscillations of sea-surface temperature (SST) in excess of 12°C (Fig. 2). The frequency characteristics of this response change dramatically across the 1800-km span of latitudes cored on Leg 94. South of 45°N, the dominant periodicities are 23,000 and 100,000 yr.; north of that latitude, they are 100,000 and 41,000 yr. (Figs. 2 and 3). The concentrations of spectral power in the SST records at these three orbital frequencies are as high as any observed on the face of the Earth.

The North Atlantic is a region critically located for climatic interactions, both with the surrounding ice-age ice sheets and with the overlying atmosphere. Several climatic theories call on this part of the ocean for important feedback interactions that amplify global climatic changes initially driven by orbital variations.

The interactions and feedbacks typical of the last several hundred thousand years of the Quaternary can be expected to have been different in the geologic past, both during the smaller pre-Brunhes oscillations of the Northern Hemisphere ice sheets and during the early Pliocene and late Miocene ice-free conditions in the Northern Hemisphere. This leg was designed to detect both the changes in boundary conditions (ice-sheet size, as determined from oxygen isotopes and ice-rafted detritus) and in oceanic response (as determined from planktonic microfossils).

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[1] Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94: Washington (U.S. Govt. Printing Office).

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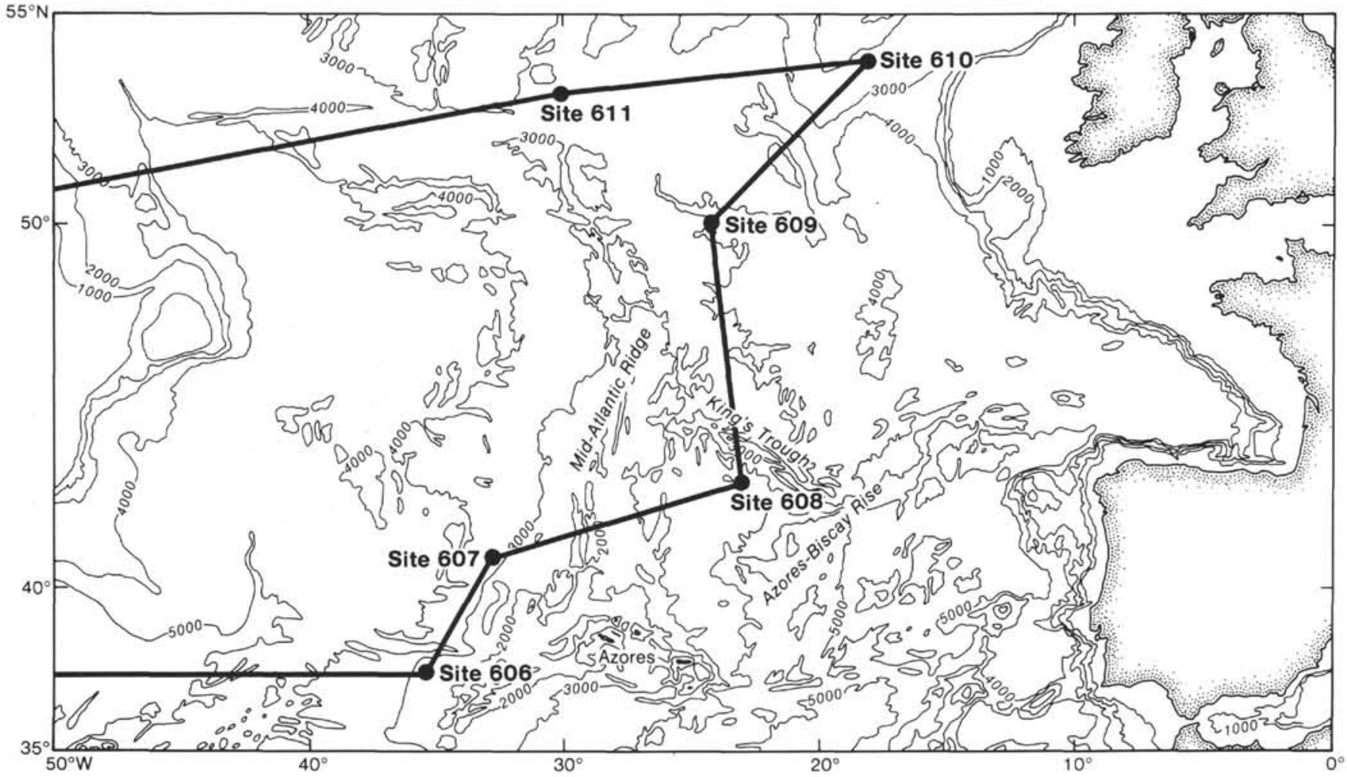

Figure 1. Leg 94 track and site locations; bathymetry in meters (after Kidd et al., 1982).

Table 1. Summary of Leg 94 drilling.

Hole	Dates (1983)	Latitude	Longitude	Water depth[a]	Penetration	No. of cores	Meters cored	Meters recovered	Percent of recovery
606	2-4 July	37°20.32'N	35°29.99'W	3007	165.8	18	165.8	154.1	93
606A	4-5 July	37°20.29'N	35°30.02'W	3007	178.4	19	178.4	156.3	88
607	6-9 July	41°00.07'N	32°57.44'W	3427	284.4	30	284.4	248.2	87
607A	9-11 July	41°00.07'N	32°57.44'W	3427	311.3	26	226.6	205.0	91
608	13-17 July	42°50.21'Q	23°05.25'W	3526	530.3	59	530.3	428.0	81
608A	17-18 July	42°50.21'N	23°05.25'W	3526	146.4	16	146.4	144.0	98
609	22-23 July	49°52.67'N	24°14.29'W	3884	399.4	42	399.4	301.2	75
609A	23 July	49°52.67'N	24°14.29'W	3883	43.0	2	19.2	17.9	93
609B	23-26 July	49°52.67'N	24°14.29'W	3883	354.7	38	354.7	308.4	87
610	28-31 July	53°13.30'N	18°53.21'W	2417	723.0	27	259.2	179.3	69
610A	31 July-1 Aug.	53°13.30'N	18°53.21'W	2417	201.0	21	201.0	191.4	95
610B	1-2 August	53°13.30'N	18°53.21'W	2417	146.8	16	146.8	136.3	93
610C	2-3 August	53°13.30'N	18°53.21'W	2417	118.2	6	48.4	43.9	91
610D	3 August	53°13.47'N	18°53.69'W	2445	386.8	7	66.0	54.2	82
610E	3-4 August	53°13.47'N	18°53.69'W	2445	327.2	7	67.2	53.3	79
611	6-7 August	52°50.47'N	30°18.58'W	3203	125.8	14	125.8	112.2	89
611A	7-8 August	52°50.47'N	30°18.58'W	3201	132.0	14	132.0	99.4	75
611B	8 August	52°50.15'N	30°19.10'W	3228	8.9	1	8.9	8.9	100
611C	8-11 August	52°50.15'N	30°19.10'W	3230	511.6	47	434.8	344.1	79
611D	11-12 August	52°50.47'N	30°18.58'W	3195	244.1	14	124.8	122.3	98
611E	12 August	52°50.47'N	30°18.58'W	3195	25.7	2	19.2	19.2	100
							3939.3	3327.6	84

[a] At sea level.

The six-site transect shown in Figure 1 was positioned in such a way as to span the major part of the region of large-scale ice-age thermal response (Fig. 2). The three southern sites are in the region now dominated by the 23,000- and 100,000-yr. response, with the amplitude building from around 6°C at the southernmost site (Site 606) to over 12°C at the next two sites to the north (Sites 607 and 608). The three northernmost sites are in regions now dominated by 100,000- and 41,000-yr. cycles, with the largest amplitude (13°C) at Site 609 (49°52′N) and somewhat diminished amplitudes at Sites 610 and 611 farther to the north.

Because of the thick sequences of carbonate ooze and interbedded glacial marine sediments deposited at rapid rates (30–100 m/m.y.) in the area, Leg 94 retrieved a valuable record of late Neogene stratigraphy, with one

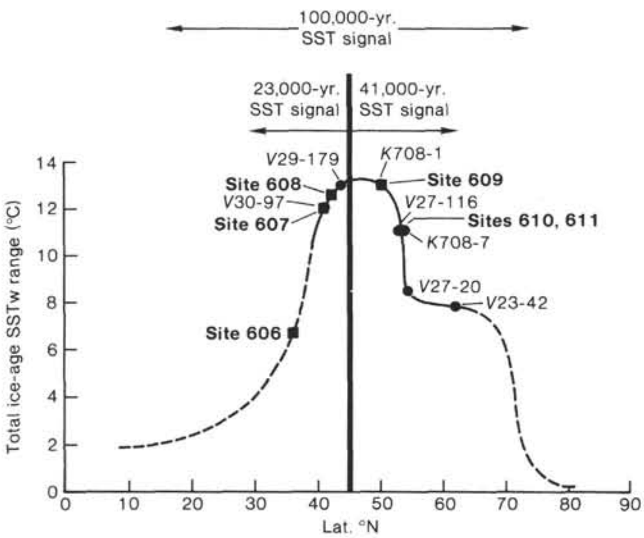

Figure 2. Placement of Leg 94 sites along a north–south transect showing: (1) total amplitude of glacial–interglacial sea-surface temperature (SST) change during the late Quaternary (Brunhes Epoch), and (2) relative apportioning of that change among the three orbital periodicities (23,000, 41,000, and 100,000 yr.) that dominate these records. (Piston cores are shown from *Vema (V)* and *Conrad (K)* cruises; SSTw—sea-surface temperature, winter.)

site (Site 608) reaching back to Eocene sediments. Finally, with coring across a 1000-km-long transect and over a water depth range of 1500 m, these sediments should contain significant information on deep-water flow based on $\delta^{18}O$, $\delta^{13}C$, and benthic foraminiferal assemblages. Four holes are situated on the eastern flank of the Mid-Atlantic Ridge and two high on the west flank (Fig. 1).

Sediment Deposition on Feni and Gardar Ridges

Site 552 drilled during Leg 81 on the edge of Hatton Drift was the first hydraulic-piston core site with a high-resolution stratigraphy to be taken from a region of positive sediment accumulation controlled by bottom currents. Site 610, located on the crest of Feni Ridge in Rockall Trough, was targeted to recover a Miocene-to-Quaternary sequence of current-deposited sediments in order to improve the present constraints on the date of initiation of drift sedimentation in that area. The site was also targeted to allow us to detect hiatuses caused by accelerated bottom flow and to characterize lithologies typical of the most rapidly accumulating sediments of a large sedimentary drift. Site 611, located on the southern tip of Gardar Ridge but still within an area of sediment waves that are the common ornamentation on the surface of major drifts, had similar stratigraphical and sedimentological objectives.

Tectonic History of King's Trough

Site 608 is located near the King's Trough complex, a positive bathymetric region marked by a long chain of parallel ridges and basins (Fig. 1). The most plausible of several hypotheses put forward to explain this unusual topographic feature postulates (1) formation of the crust, between 56 and 21 Ma, by development of an aseismic

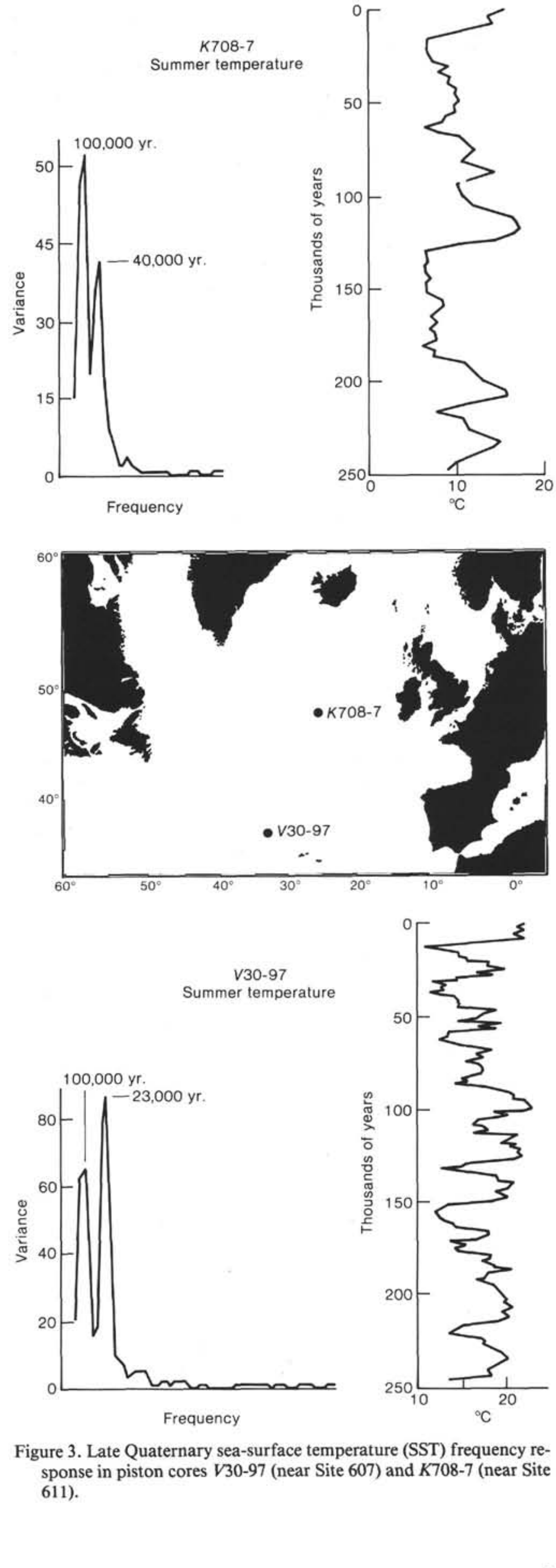

Figure 3. Late Quaternary sea-surface temperature (SST) frequency response in piston cores *V*30-97 (near Site 607) and *K*708-7 (near Site 611).

ridge from a portion of the Mid-Atlantic Ridge made anomalously shallow by the presence of a hot spot; (2) a sudden uplift of up to 2 km at roughly 32 Ma; (3) rifting with extensional downdropping of 2 to 4 km at roughly 16 to 20 Ma, and (4) normal subsidence to the present.

Continuous coring at Site 608 on the western flank of King's Trough away from the region of vertical tectonics was expected to recover a stratigraphic sequence in which nearby volcanic episodes and tectonically produced hiatuses could be detected. This would provide a comprehensive stratigraphy into which dredge and rock core data obtained in the central tectonic zone could be placed.

EXPLANATORY NOTES

Drilling Techniques

There are several types of coring systems on the *Glomar Challenger*: (1) the standard DSDP rotary-coring system, which cuts about 9.5-m-long cores and has been used since Leg 1; (2) the Extended Core Barrel system (XCB), which has been used extensively since Leg 90 (see Kennett, von der Borch, et al., 1986), and (3) the Hydraulic Piston Coring system (HPC), used since Leg 64 (Fig. 4). This coring system is described in Prell, Gardner, et al. (1982). A variation on the HPC system is the Variable Length Hydraulic Piston Coring system (VLHPC), which has been used since Leg 85 (see Mayer, Theyer, et al., 1985), and the Advanced Piston Coring system (APC), used first on Leg 94.

The APC takes a 9.5-m core and utilizes the same technology as the Variable Length Hydraulic Piston Corer (VLHPC) (Fig. 4). The APC, however, incorporates a simplified seal system that results in a piston corer capable of 80% greater coring force (up to 28,000 lbf—pounds force), but that is about half as mechanically complex as the VLHPC. The main difference is the use of the dynamic seal acting between the scoping core barrel section and a special honed-bore drill collar.

The APC consists of two basic sections. The top sub, piston rod, and piston head comprise the static section. The scoping core barrel section is initially pinned to the static section with from one to three shear pins.

The APC is lowered down the drill pipe to land and seal on the special drill collar. When the drill string above the seal is pressurized, the pressure acts on the scoping section through the speed control holes in the top sub, into which set screws can be added or removed to control coring velocity.

Other features include: (1) An optional breakaway piston head to minimize core disturbance in those instances where the APC fails to achieve full stroke. (2) The ability to withstand safely tensile loads of up to 100,000 lbf. In stiff or adhering formations a large suction force resists tool withdrawal. Several times the VLHPC has been literally pulled apart with 80,000 lbf over-pull. (3) An axial groove has been machined down the length of the piston rod. This engages a key in the scoping core barrel section to prevent the core barrel from rotating as it injects into the formation. (4) The APC is about 38 feet long compared to the 70-foot-long VLHPC. The shorter length makes it much easier to handle, and opens up the possibility for piston coring with the Heave Compensator in-line.

The APC was used on Holes 606 and 606A. Aside from some initial start-up problems inherent with any new tool, the APC was very successful on Hole 606. In particular, the tool was much easier to handle; we were able to penetrate further than would have been possible with the VLHPC in the stiff, sticky nannofossil ooze encountered. In Hole 606A, 100,000 lbf. over-pull was needed to retrieve Core 18. While attempting to retrieve Core 20, the piston rod connection broke at 40,000 lbf. over-pull. The failure was probably due to fatigue initiated during the previous high pull. The failure is being studied with the intention of strengthening this weak link. In any event, even if a limitation of 50,000 lbf. over-pull is imposed, the APC is a capable successor to the VLHPC.

No further APC coring was possible at the later Leg 94 sites because of the loss of the lower section.

Handling of Cores

A core is normally cut into 1.5-m sections, sealed, labeled, and then brought into the core laboratory for processing. Continuous wet-bulk density determinations are made using the GRAPE before splitting the plastic liner.

The cores are then split longitudinally into "working" and "archive" halves. Samples are taken from the "working" half, including those for determination of sonic velocity by the Hamilton Frame method, wet-bulk density by a static GRAPE technique, water content by gravimetric analysis, calcium-carbonate percentage (carbonate bomb), geochemical analysis, paleontological studies, and so on.

Smear slides (thin sections for lithified sedimentary and igneous rocks) from each major lithology and most minor lithologies are prepared and examined microscopically. The archive half is then described and photographed. Physical disturbances, color, texture, structures, and composition of the various lithologies are noted on standard core description forms (Fig. 5). All prime data are routinely microfilmed and some are digitized for computer retrieval.

After the cores are sampled and described, they are maintained in cold storage aboard the *Glomar Challenger* until they are transferred to the DSDP repository. Core sections of sediments removed for organic geochemistry study are frozen immediately aboard ship and kept frozen. All Leg 94 cores are presently stored at the DSDP East Coast Repository (Lamont-Doherty Geological Observatory of Columbia University).

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 is 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 (above one hole), moving the ship 100 m or more from the previous hole, and then drilling another hole.

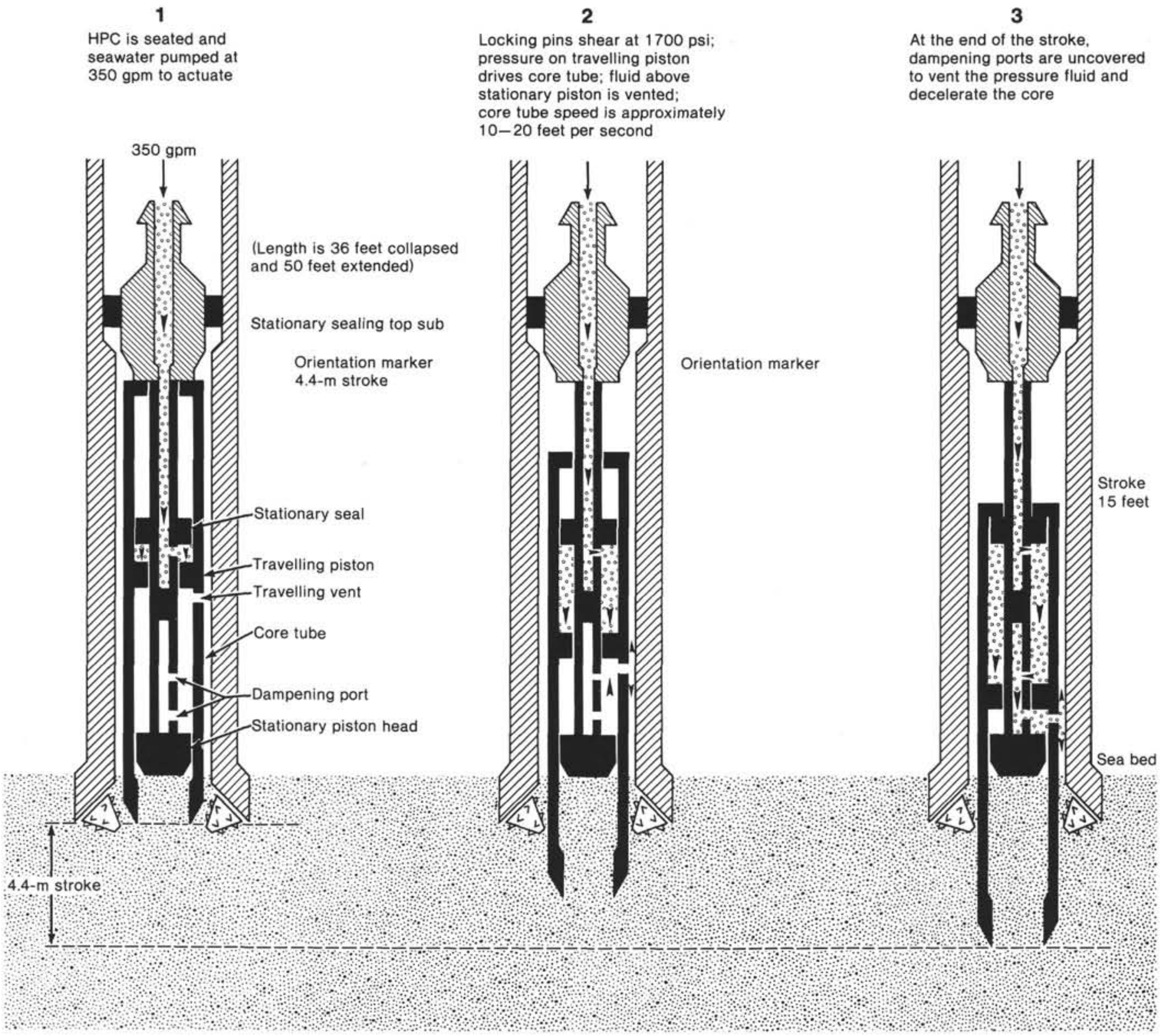

Figure 4. Operational sequence for the Serocki-Storms-Cameron DSDP Hydraulic Piston Corer.

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 on. It is important, for sampling purposes, to distinguish the holes drilled at a site, because recovered sediments or rocks from different holes usually do not come from equivalent positions in the stratigraphic column.

The cored interval is measured in meters below the seafloor. The depth interval of an individual core spans from the depth below seafloor at which the coring began to the depth at which coring ended. The nominal coring interval is 9.5 m long during rotary drilling and for the long barrel of the VLHPC. It is 5 m for the short barrel. In practice, these nominal coring intervals may be shorter or slightly longer.

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": that is, the core barrel is in place, but does not recover sediment. This is achieved by pumping water down the pipe at high pressure, which washes the sediment out of the way of the bit, up the space between the drill pipe and the wall of the hole. During this procedure it is possible to get "spotty" sampling of resistant layers, and thus recover a cored interval greater than 9.5 m.

When full, a core normally recovers 9.28 m of sediment or rock in a plastic liner of 6.6-cm I.D. In addition, about 0.2 m of sample (no plastic liner) is in the core catcher. (The core catcher is a device at the bottom

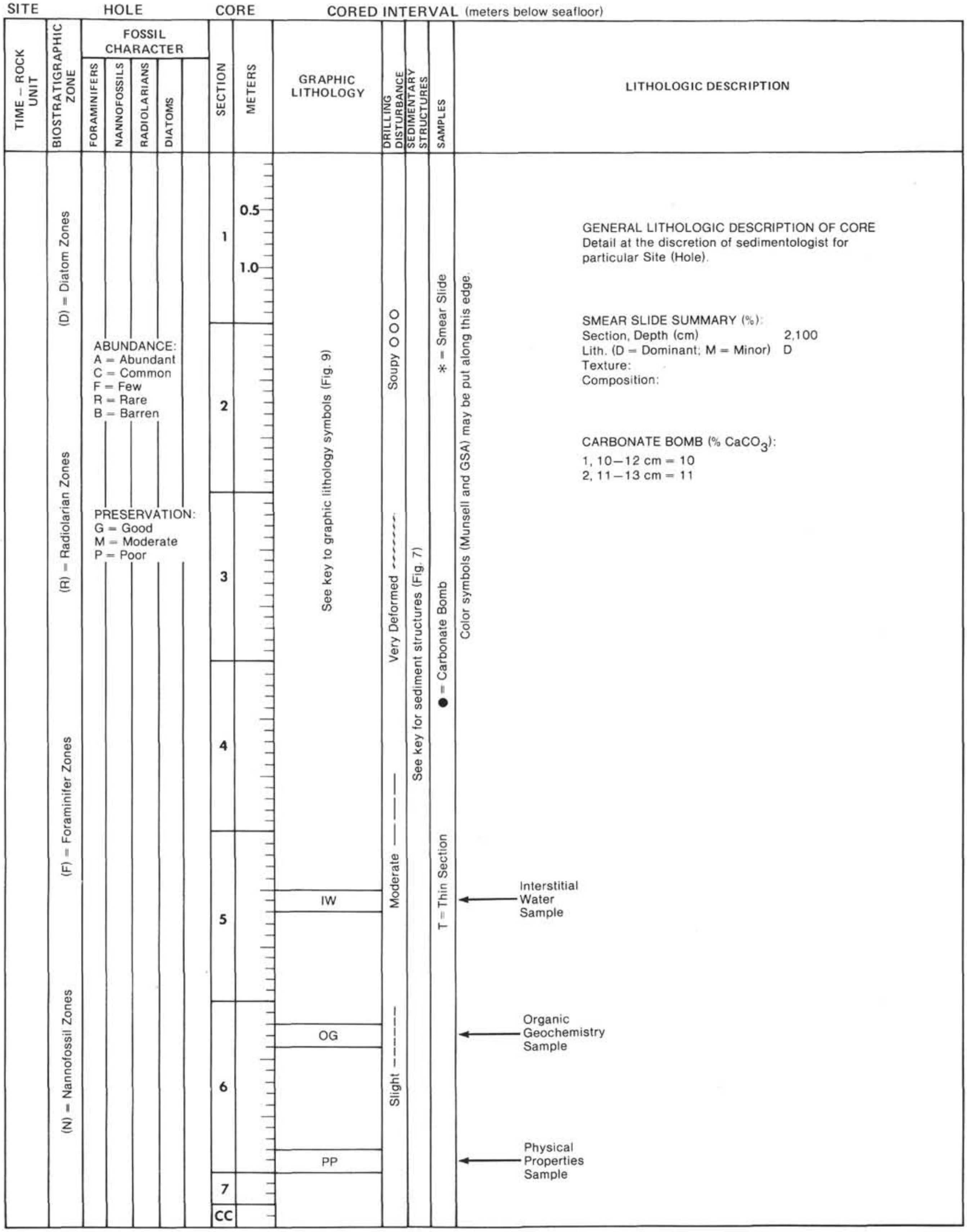

Figure 5. Standard core description form (sediment).

of the core barrel that prevents the cored sample from sliding out when the barrel is being retrieved from the hole.) With the short barrel of the VLHPC, about 4.75 m are collected when it is full, and about 0.2 m of core-catcher sample.

Each core is then cut into 1.5-m-long sections, which are numbered serially from the top of the core (Fig. 6). When there is full recovery, the sections are numbered 1 through 7 for the rotary-drilled and long-barrel-of-the-VLHPC cores, and 1 through 4 for short-barrel-of-the-VLHPC cores (the last section being 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.

In the case of partial recovery, the original stratigraphic position of the sediment in the cored interval is unknown. If the recovered rocks and sediments are contiguous, the top of this material becomes the top of the cored interval. Sections are numbered serially from the top, beginning with Section 1 (Fig. 6), to accommodate the length of the recovered sediment. For example, 4 m of sediment are divided into three sections—two upper 1.5-m-long sections and a lower 1-m section. If the sediment is determined to be discontinuous by the shipboard scientists, sections are divided and numbered serially, but gaps are labeled "voids" (Fig. 6) or marked with spacers in igneous sections.

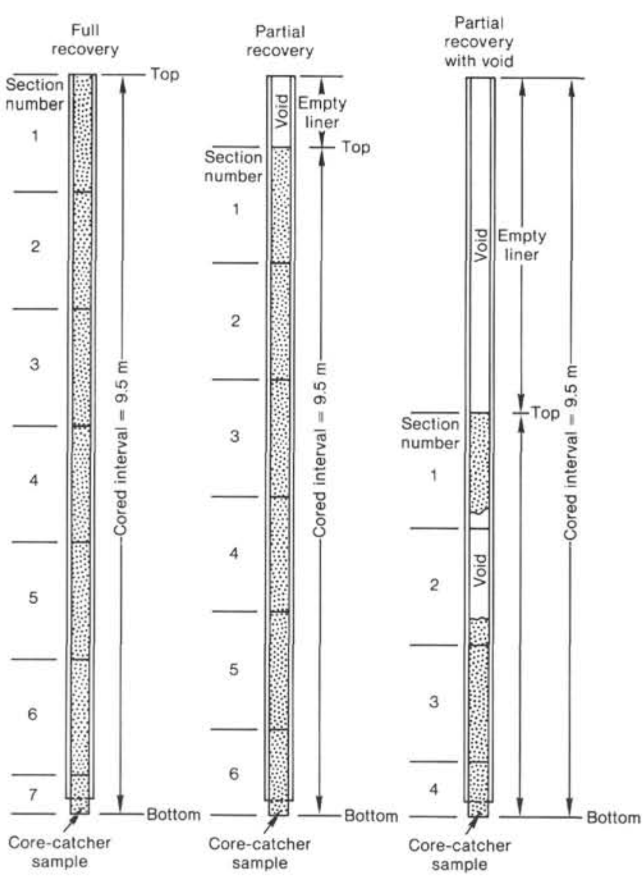

Figure 6. Diagram showing procedure for cutting and labeling core sections.

Cores taken from a hole are numbered serially from the top of the hole downward. Thus core numbers and their associated cored interval in meters below the seafloor are normally unique for a hole; however, problems may arise if an interval is cored twice.

A sample is designated by the interval in centimeters that it spans as measured from the top of the section from which it is taken. A full identification number for a sample consists of the following information: leg-site (or hole)-core number-section number, interval in centimeters from the top of the section. For instance, a sample identification number of "85-610A-12-3, 12–14 cm" is interpreted as follows: this sample was taken between 12 and 14 cm from the top of Section 3 of Core 12, from the second hole drilled at Site 610 during Leg 94. A sample from the core catcher of this core is designated as "94-610A-12,CC."

Obtaining Samples

Potential investigators who desire to obtain samples should refer to the DSDP-NSF Sample Distribution Policy (see the Table of Contents). Sample request forms may be obtained from the Curator, Ocean Drilling Program, Texas A&M University, College Station, Texas 77843. Requests must be as specific as possible and include site, core, section, interval within a section, and volume of samples required.

Core Description Forms

The notes below explain the standards used by the Leg 94 sedimentologists in describing the cores and filling out the core description forms for each site.

Core Disturbance

Recovered rocks and particularly soft sediments may be extremely disturbed as a result of coring techniques. The following categories of disturbance are used for soft to firm sediments: (1) slightly deformed—bedding contacts are slightly bowed; (2) moderately deformed—bedding contacts are extremely bowed and firm sediment is fractured; (3) very deformed—bedding is completely disturbed or is homogenized by drilling and may show diapirlike structures; (4) soupy—water saturated intervals that have lost all aspects of original bedding; (5) drill biscuits: firm sediments may be broken into discrete pieces that are probably rotated but maintain their stratigraphic integrity relative to one another; these blocks are often surrounded by brecciated or flowed sediments. These categories are listed on the core description forms in the column headed "Drilling Disturbance" (Fig. 5).

Sedimentary Structures

It is often extremely difficult to distinguish natural structures from those created by coring. Description of sedimentary structures is optional. Locations and types of these structures appear as graphic symbols in the column headed "Sedimentary Structures" (Fig. 7).

Bioturbation is difficult to recognize in monotonous white to pale gray oozes. Where obvious, the degree of burrowing was noted and occasionally the type of burrow was included in the lithologic description portion of

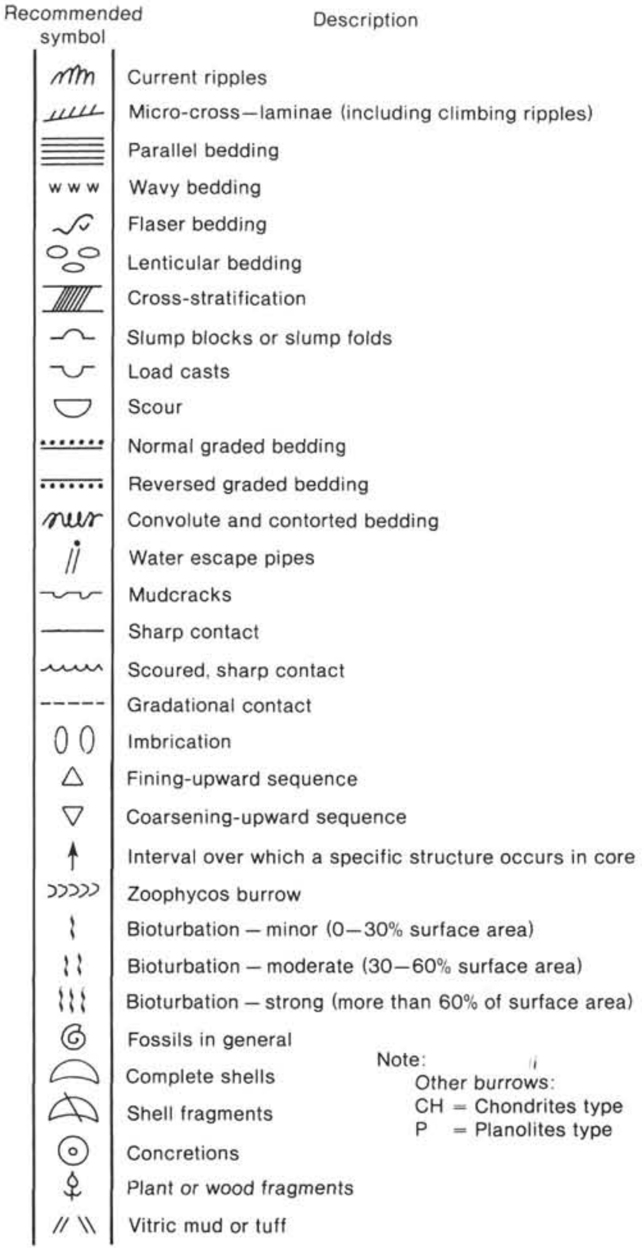

Figure 7. Symbols for sedimentary structures noted on core descriptions forms (sediment).

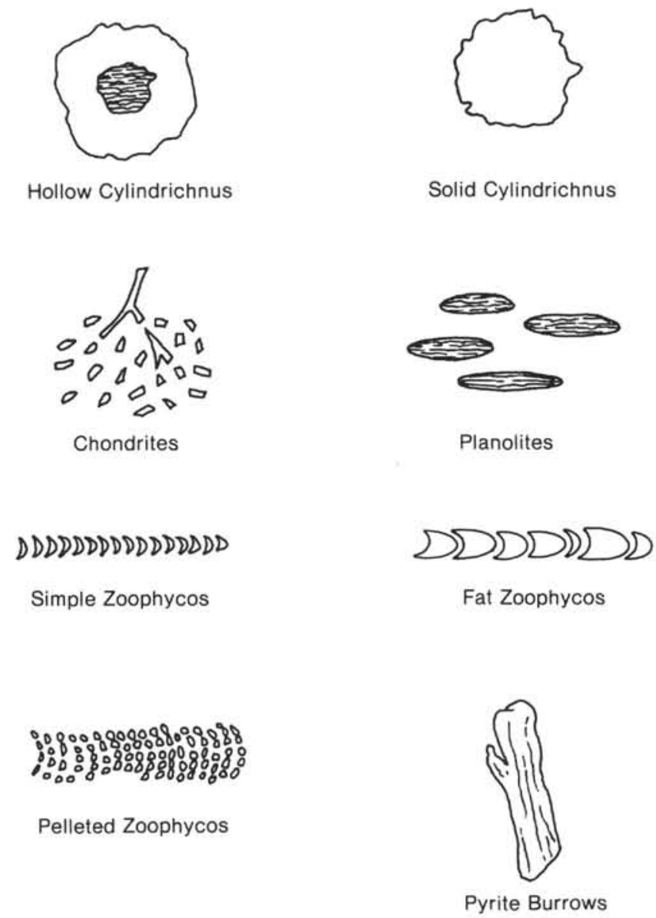

Figure 8. Common trace fossils in DSDP cores.

the core description forms. The types of burrows are illustrated in Figure 8.

Color

Sediment and rock color is determined using a Munsell or Geological Society of America rock-color chart. Colors were determined immediately after the cores were split and still wet.

Lithology

The graphic column presented on the core description form represents the lithology by means of one or more patterns. The symbols correspond to end-member sediment constituents such as clay or nannofossil ooze. The pattern for terrigenous constituent(s) appears on the left-hand side of the column. The pattern for the biogenic constituent(s) appears on the right-hand side of the column. The abundance of any component approximately equals the percentage of the width of the graphic column its symbol occupies. For example, the right 20% of the column may have a nannofossil ooze symbol, whereas the left 80% of the column may have a mud symbol—indicating sediment composed of 80% mud and 20% nannofossils.

Because of the difference in the length-to-width ratio between the sediment core and the graphic lithologic column it is not possible to reproduce structures as they appear in the core because they become highly flattened and distorted. The same is true for rock fragments or pebbles in the cores. As a result, the locations of pebbles are shown by a solid square and the depth of small "patches" of ash or other lithologic changes is given by a triangular inset of the appropriate lithologic symbol on the right side of the lithologic column (Fig. 9). This convention applies only to lithologies which do not extend across the entire core.

The assignment of sediment name is controlled by the DSDP mandatory graphic lithologic column scheme (Figs. 5, 7-9). Colors and additional information such as structures (Fig. 7) or texture (Fig. 9) are included in the text portion of the core description. The descriptive portions of the core description forms were written in-

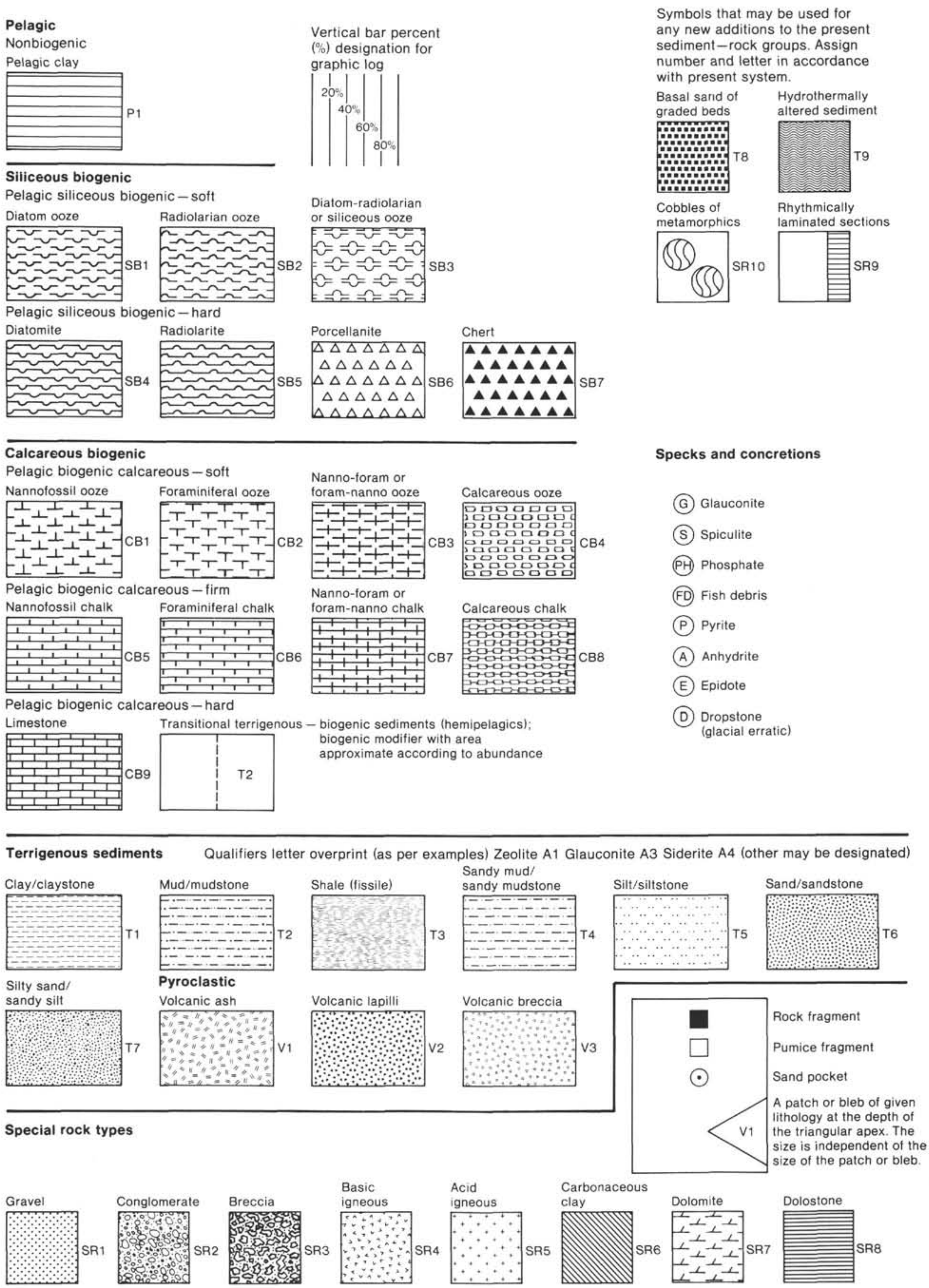

Figure 9. Symbols used in graphic lithology column of core description forms (sediments).

dependently by different sedimentologists. However, attempts were made to be consistent throughout Volume 94.

Smear-slide percentages, thin-section descriptions, and carbonate content (% $CaCO_3$) determined aboard ship are listed below the core description on these forms, where two numbers separated by a comma refer to the section and centimeter level of the sample, respectively. The locations of these samples in the core and a key to the codes used to identify these samples are given in the column headed "Samples" (Fig. 5). Locations and intervals of full round samples for organic geochemistry (OG), interstitial water (IW), and physical properties (PP) are given in the lithologic column.

Lithologic Classification of Sediments

Most sediments recovered during Leg 94 (see section below) consist of either pelagic carbonate oozes or terrigenous mud. Colors are generally white to pale gray for the carbonate oozes and olive brown to gray for the terrigenous muds.

The basic classification system used was devised by the JOIDES Panel on Sedimentary Petrology and Physical Properties (SPPP) and was adopted for use by the JOIDES Planning Committee in March 1974. For the sake of continuity the Leg 94 shipboard scientists have used this basic classification. It is descriptive rather than genetic, and divisions between sediment types are arbitrary. A brief outline of the conventions and descriptive data used to classify sediments recovered on Leg 94 follows.

For the original JOIDES classification, see Volume 42, Pt. 2, of the *Initial Reports* (Ross, Neprochnov, et al., 1978, pp. 14–15).

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 come principally from shipboard visual estimates of smear slides using a petrographic microscope and are obtained by estimating the areal abundance and the size of components on the slide. The data are less reliable than shore-based analyses of grain size, carbonate content, and mineralogy (see specialty chapters, this volume), but provide rapid shipboard estimates for descriptive purposes. From past experience, quantitative estimates of distinctive minor components are accurate to within 1 or 2%, but for major constituents accuracy is poorer (±10%) (Hsü, Montadert, et al., 1978). All smear-slide estimates were done aboard ship. The carbonate percentage of selected samples was determined using the carbonate bomb technique of Müller and Gastner (1971) as a check on the accuracy of smear-slide estimates for the descriptive logs. These values are listed on the core description forms below the lithologic description.

Grain size (texture) of terrigenous samples was estimated from smear slides and listed as percent sand–silt–clay in the smear-slide summary on the core description forms. These estimates generally include terrigenous components only.

Where applicable, one or two modifiers were used in naming sediments. In all cases, the dominant component appears last in the name; minor components precede this, the least common being listed first. A minor constituent is included in the name if it represents at least 10% of the sediment. If a minor constituent of less than 10% is deemed significant it may be included in the name of the sediment or mentioned in the lithologic description.

Induration of Sediments

We recognize three classes of induration or lithification for calcareous sediments and sedimentary rocks in which the carbonate content is greater than 50%, and two classes for other sedimentary types.

For calcareous sediments and sedimentary rocks (carbonate >50%), the three classes (after Gealy et al., 1971) are (1) soft—ooze (has little strength and is readily deformed under pressure of finger or broad blade of spatula); (2) firm—chalk (partially lithified and readily scratched with fingernail or edge of spatula); (3) hard—limestone, dolostone (well lithified and cemented).

For terrigenous sediments (terrigenous components > 50%), the classes are (1) soft—sand, silt, clay, or combinations of these (readily deformed by finger or broad blade of spatula); (2) hard—sandstone, siltstone, claystone, and so on, that is, the suffix "-stone" is added (core must be cut with a band saw or diamond saw).

Leg 94 Sediments

Three main sediment types were recovered on Leg 94. These sediments were classified as follows:

Pelagic Biogenic Calcareous Sediments

This sediment category is classified:

more than 30%	$CaCO_3$
less than 30%	terrigenous components
less than 30%	siliceous microfossils

Principal components are nannofossils and foraminifers with qualifiers used as follows:

Foraminifers (%)	Name
Less than 10	Nannofossil ooze
10–25	Foraminiferal-nannofossil ooze
25–50	Nannofossil-foraminiferal ooze
More than 50	Foraminiferal ooze

Calcareous sediments containing 10 to 30% siliceous fossils carry the qualifier radiolarian, diatomaceous, or siliceous, depending upon the siliceous component(s).

Transitional Biogenic Calcareous Sediments

The second sediment type is classified:

more than 30%	$CaCO_3$
more than 30%	terrigenous components
less than 30%	siliceous microfossils

If the carbonate content is between 30 and 60%, marly is used as a qualifier.

Terrigenous Sediments

The third sediment type is classified:

more than 30%	terrigenous components
less than 30%	$CaCO_3$
less than 30%	siliceous microfossils
less than 10%	authigenic components

Sediments in this category are subdivided into textural groups on the basis of the relative proportions of three grain-size components (sand-silt-clay). The size limits are those defined by Wentworth (1922). Textural classification is according to the triangular diagram shown in Figure 10.

Igneous Rocks

The only igneous rocks recovered on Leg 94 were the basalts underlying sediments at King's Trough, Site 608. These basalts were described in a general nature only, including several thin-section descriptions. They immediately follow the core descriptions for Hole 608.

Physical Properties Methods

Physical properties measured on sediments recovered during Leg 94 include shear strength, compressional wave velocity, continuous GRAPE wet-bulk density, as well as wet-bulk density, wet water content, dry water content, and porosity by conventional gravimetric techniques.

Shear-strength measurements were made on the sediments in split core liners using the motor-drive torvane. The axis of rotation of the vanes was perpendicular to the core axis during all measurements.

Compressional sonic velocities were measured at atmospheric pressure and at room temperature using a Hamilton Frame Velocimeter. Measurements were made perpendicular to the long core axis through the split core liner on soft sediments. Appropriate corrections were applied for an average liner thickness and the resulting traveltime. In more indurated sediments measurements were made on a piece of core taken out of the liner after splitting.

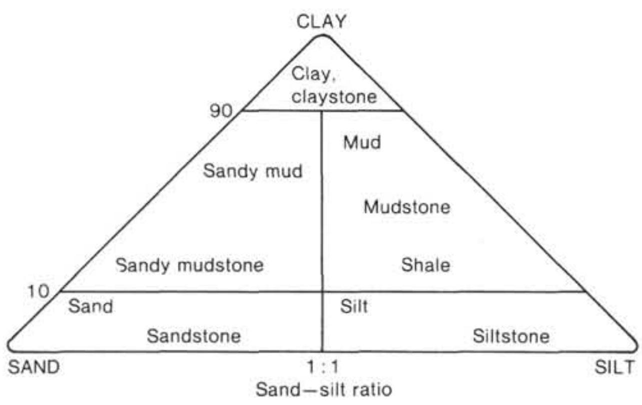

Figure 10. Textural groups of terrigenous sediments.

Continuous wet-bulk densities were measured by the GRAPE technique (Gamma Ray Attenuation Porosity Evaluation). In this technique porosity is measured by passing gamma rays through the sediment. Wet-bulk density is then calculated by assuming a value of 2.7 g/cm^3 for grain density. For description of all physical properties methods used aboard *Glomar Challenger*, see Boyce (1976a, b).

Paleomagnetic Methods

The successful recovery on Leg 94 of long, undisturbed sequences of sediment using the HPC and XCB corers yielded sections ideally suited for magnetostratigraphic study. The high sedimentation rates, averaging between 50 and 60 m/m.y., allowed a sampling interval of 1.5 m, which clearly defined the magnetic polarity chronozones, but additional sampling at a 0.75-m interval was occasionally required to further define the boundaries of subchronozones with a duration of 0.05 m.y. or less.

Paleomagnetic samples were taken by pressing oriented, 7-cm^3 plastic cubes into the split half of the core. When the sediment became too stiff to allow the use of plastic boxes, 3.5-cm-diameter cores were drilled from the split half of the core using a drill press with a diamond drill bit.

Pilot samples selected from intervals of varying lithology throughout the length of each hole were subjected to progressive alternating field demagnetization studies at increments of 5 to 10 mT. On the basis of the results of these studies, the remaining samples from the core were partially demagnetized at the field determined to be necessary to remove unstable or secondary magnetizations.

The directions and magnitude of the magnetizations of the samples were measured using a portable "Molspin" spinner magnetometer. This magnetometer was preferred over the shipboard "Digico" magnetometer, as the "Digico" exhibited a significantly higher instrumental noise level than the Molspin.

The Custer orientation tool (Weinreich and Theyer, 1985) was not used routinely on the cores taken on Leg 94. For that reason the declinations between cores were not consistent, and therefore the inclination record alone was used to determine the polarity sequence. The high latitudes of the sites (35–53°N) provided steep inclinations ± 55 to $\pm 70°$) so that normal and reversed polarity zones were readily identifiable based solely on the inclination records.

Time Scale

The time scales of Berggren, Kent, and Flynn and Berggren, Kent, and Van Couvering (in press) (Table 2, Fig. 11) were used as the chronological framework for the Leg 94 *Initial Reports*. We adhere to the most recent version of this scale by utilizing an Anomaly 5–Chron 11 correlation rather than the previous Anomaly 5–Chron 9 correlation. This results in generally younger absolute ages for late middle and early late Miocene microfossil zones and datum levels. Calibration of diatom events to magnetostratigraphy is after Barron et al. (1985).

Table 2. Revised geomagnetic polarity time scale[a] for Cenozoic and Late Cretaceous time.

Normal polarity interval (Ma)	Anomaly	Normal polarity interval (Ma)	Anomaly
0.00–0.73	1	20.88–21.16	6A
0.91–0.98		21.38–21.71	6A
1.66–1.88	2	21.90–22.06	
2.47–2.92	2A	22.25–22.35	
2.99–3.08	2A	23.27–23.44	6C
3.88–3.97	3	23.55–23.79	6C
4.10–4.24	3	24.04–24.21	6C
4.40–4.47	3	25.50–25.60	7
4.57–4.77	3	25.67–25.97	7
5.35–5.53	3A	26.38–26.56	7A
5.68–5.89	3A	26.86–26.93	8
6.37–6.50		27.01–27.74	8
6.70–6.78	4	28.15–28.74	9
6.85–7.28	4	28.80–29.21	9
7.35–7.41	4	29.73–30.03	10
7.90–8.21	4A	30.09–30.33	10
8.41–8.50	4A	31.23–31.58	11
8.71–8.80		31.64–32.06	11
8.92–10.42	5	32.46–32.90	12
10.54–10.59		35.29–35.47	13
11.03–11.09		35.54–35.87	13
11.55–11.73	5A	37.24–37.46	15
11.86–12.12	5A	37.48–37.68	15
12.46–12.49		38.10–38.34	16
12.58–12.62		38.50–38.79	16
12.83–13.01		38.83–39.24	16
13.20–13.46		39.53–40.43	17
13.69–14.08		40.50–40.70	17
14.20–14.66		40.77–41.11	17
14.87–14.96	5B	41.29–41.73	18
15.13–15.27	5B	41.80–42.23	18
16.22–16.52	5C	42.30–42.73	18
16.56–16.73	5C	43.60–44.06	19
16.80–16.98	5C	44.66–46.17	20
17.57–17.90	5D	48.75–50.34	21
18.12–18.14	5D	51.95–52.62	22
18.56–19.09	5E	53.88–54.03	23
19.35–20.45	6	54.09–54.70	23
55.14–55.37	24	66.74–68.42	30
55.66–56.14	24	68.52–69.40	31
58.64–59.24	25	71.37–71.65	32
60.21–60.75	26	71.91–73.55	32
63.03–63.54	27	73.96–74.01	
64.29–65.12	28	74.30–80.17	33
65.50–66.17	29	84.00	34

[a] From Berggren, Kent, and Flynn; and Berggren, Kent, and Van Couvering (in press).

The adoption of this time scale and the absolute age estimates of the microfossil datums is preliminary, as the biostratigraphic and paleomagnetic results of Leg 94 indicate that biostratigraphic events are often diachronous between sites. Re-evaluation of the biostratigraphic events and paleomagnetic correlation for the mid- to high-latitude North Atlantic Ocean is discussed in the biostratigraphic synthesis (Baldauf et al., this volume).

Calcareous Nannofossils

Zonation scheme: Martini (1971)

Correlation to polarity scale: Poore et al. (1984), Haq and Takayama (1984), between NN15 and NN9.

Planktonic Foraminifers

Zonation scheme: Berggren (1973, 1977), Blow (1959), Jenkins (1971), Jenkins and Srinivasan (1984).

Correlation to polarity scale: Berggren et al., 1984.

Diatoms

Zonation scheme: Burckle (1972), Baldauf (1984), Barron (1985).

Correlation to polarity scale: Burckle (1972, 1977), Barron et al. (1985).

Radiolarians

Zonation scheme: Riedel and Sanfilippo (1978) *Sphaeropyle langii* Zone (Foreman, 1975), base of zone (Casey and Reynolds, 1980).

Correlation to polarity scale: Theyer et al., 1978.

Geochemical Methods

Interstitial water samples were obtained using the hydraulic press apparatus described by Whitmarsh et al. (1974). The water samples were analyzed for salinity using an American Optical Company temperature-compensated refractometer, and pH was measured using a Corning 130 pH meter with a Markson electrode. Two Wescan Ion Chromatographs were used to determine K^+, Li^+, Ca^{2+}, Mg^{2+}, and SO_4^{2-}. New high-speed columns were used in the chromatographs to (1) make the analyses less time consuming, and (2) facilitate calibration of Mg^{2+}, which during previous legs yielded a nonlinear calibration curve.

The concentration of $CaCO_3$ in sediment samples was determined using a modified carbonate bomb (Müller and Gastner, 1971). This method involves treating a powdered sample with HC1 in a closed cylinder. The resulting pressure of CO_2 is proportional to the carbonate ($CaCO_3$) content of the sample, and this value is converted to percent $CaCO_3$, using the calibration factor of the manometer. The accuracy of this method is believed to be ±5% (Hsü, Montadert, et al., 1978).

Although carbon measurements were not a major objective of Leg 94, recent repairs to the LECO carbon analyzer required assessment. Various calibrations and cross-calibrations of the LECO system with the HP185B CHN analyzer and carbonate-bomb methods were carried out when opportunities arose.

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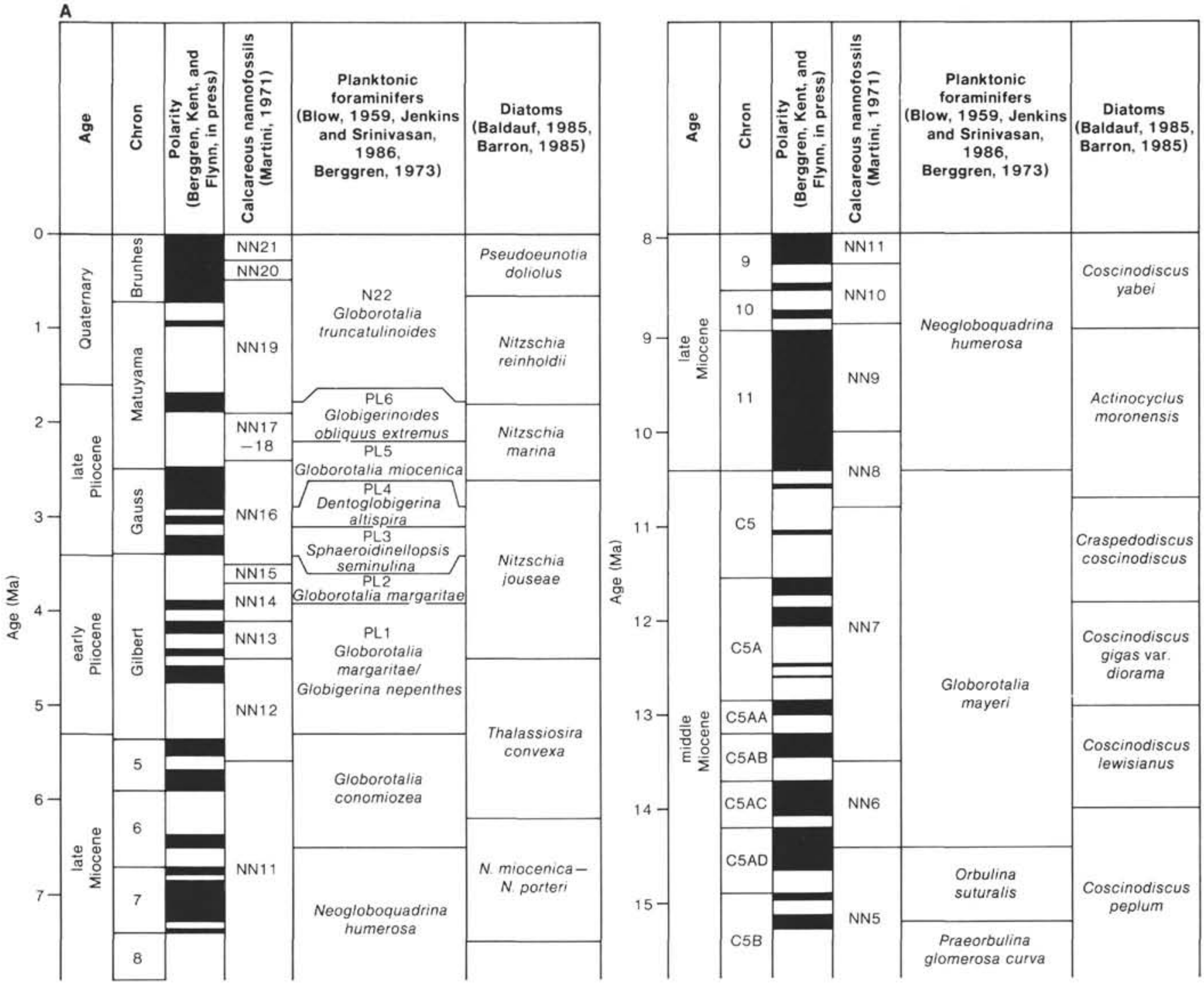

Figure 11. Time scale used during Leg 94. (See Baldauf et al. [this volume] for updated version.) A. Neogene. B. Paleogene. Note difference in scale.

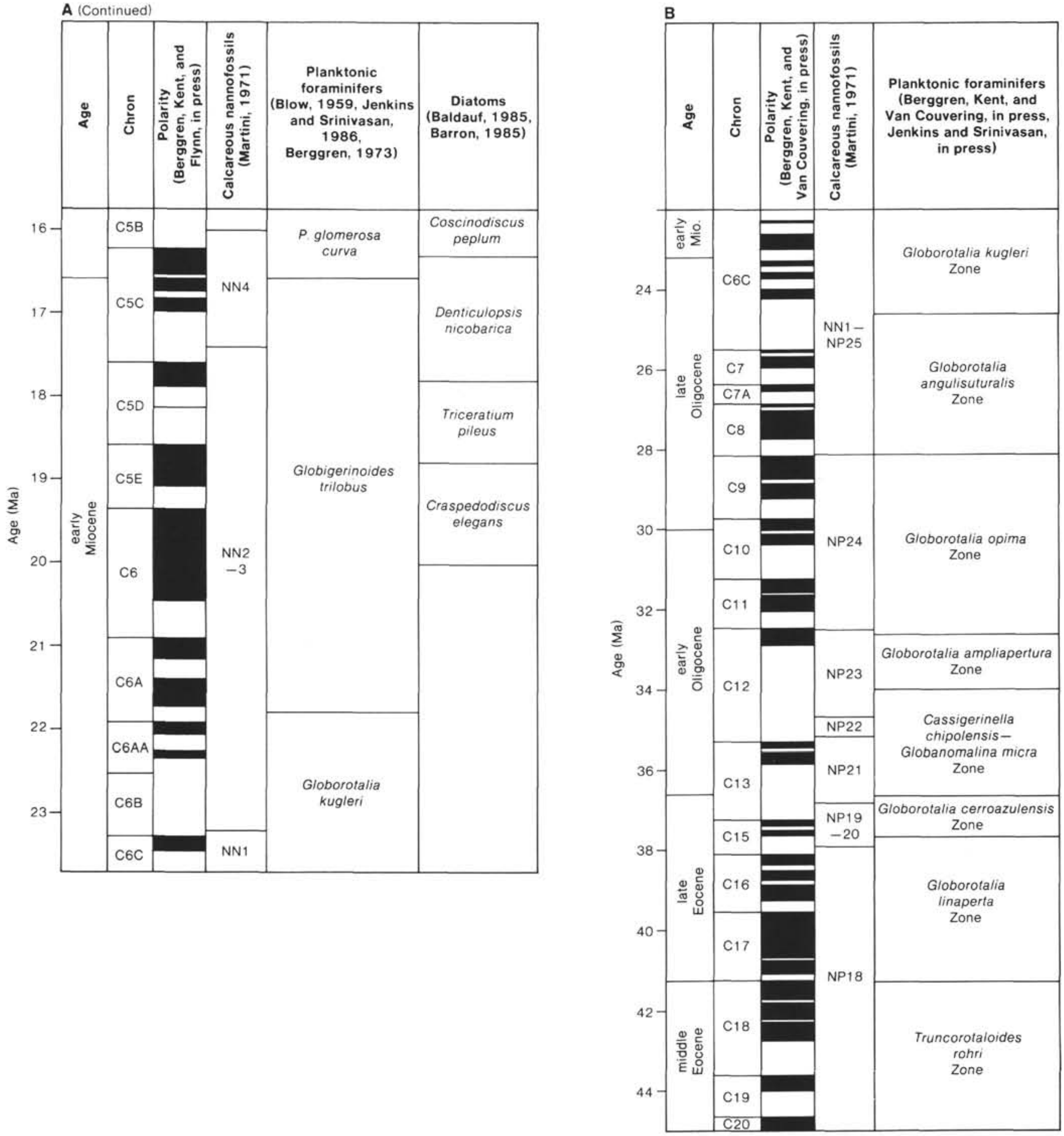

Figure 11 (continued).