1. INTRODUCTION AND EXPLANATORY NOTES[1]

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INTRODUCTION

During DSDP Leg 64 the *Glomar Challenger* drilled a total of 3462 meters (Table 1) at eight sites (474–481) in the Gulf of California region (Fig. 1). The Gulf of California presented a singular example of tectonics and sedimentation in a very young ocean, being formed by translation and oblique rifting. The sedimentation of the region is hemipelagic, rapid, and largely dominated by siliceous microfossils.

The objectives were defined by the IPOD Passive Continental Margin Panel and the IPOD Gulf of California Working Group. Three main regions, each with particular problems, were examined and these also form the organizational basis of this volume. Briefly, these are

1) Sites 474, 475, and 476. A transect from oceanic crust to continental crust at the southern tip of Baja California in order to define passive-margin subsidence during the early post-rifting phase.

2) Sites 477, 478, and 481. An investigation of the nature of young ocean crust in the Guaymas Basin, where high accumulation rates are common and variable high heat flow indicates active rifting and hydrothermal activity.

3) Sites 479 and 480. Drilling on the Guaymas Basin Slope above the proto-Gulf sequences. Interest focused on the paleoceanography of laminated, homogeneous diatom-rich, anoxic sediments within the zone of low oxygen.

In the following, some of the main results are briefly previewed.

BAJA CALIFORNIA CONTINENTAL-MARGIN TRANSECT

Site 474 (Fig. 1) is situated on oceanic crust overlain by about 500 meters of mainly diatomaceous mud and mudstone turbidites. At the base of the sediment section, Hole 474A penetrated three altered dolerite sills, before encountering a sequence of pillow basalts and intercalated sills interpreted as basement (Fig. 2).

A wide range of chemical compositions exists in the pillow-basalt sequence. The oldest sediment at this site (late Pliocene) concurs with the magnetic-anomaly age of the ocean crust, about 3.2 m.y. Much of the sediment column comprises mud turbidites with accumulation rates of 47 to 395 m/m.y. Biogenic gas was common at this site.

Sites 475 and 476 were drilled on the lower continental slope, thought to be underlain by continental crust. Drilling at both sites penetrated predominantly diatomaceous hemipelagic sediments, below which they encountered a glauconitic-phosphatic mudstone overlying conglomerate of predominantly metamorphic cobbles. The conglomerate stopped the drilling of 475, but 476, located in a more open slope environment, penetrated the conglomerate, with a thin layer of sandy clay, and bottomed in a deeply weathered granite. Rate of sediment accumulation averaged around 40 m/m.y. at both sites.

Structure of this continental margin is dominated by horst-and-graben and rotational listric faulting. Sites 475 and 476 lie in the two lowest blocks—apparently the most deeply subsided—immediately adjacent to the oldest oceanic crust generated during the present phase of spreading. We interpreted weathering of the granite and deposition of the conglomerates as subaerial, and the glauconitic-phosphatic mudstone as an isolated offshore-bank deposit. The oldest dated marine sediments over the continental crust are earliest Pliocene, but the underlying bank deposits and conglomerates could well be late Miocene. It appears then that subsidence accompanied by, or even preceded by, the first block faulting (the rifting stage) occurred before sea-floor spreading and the present phase of opening of the Gulf (the drifting stage). Probably this early subsidence was related to the formation of a proto-Gulf of California in the late Miocene.

GUAYMAS BASIN

The Guaymas Basin (Fig. 1) is an actively spreading oceanic basin, part of the system of spreading axes and transform faults which extends from the East Pacific Rise to the San Andreas Fault System.

Sites 477 and 481 were located in the south and north rifts, respectively. The recovered sediments were very late Quaternary diatom oozes and massive turbidites, intruded by basalt, dolerite, and gabbro sills of apparently very limited lateral extent. Site 477, where we measured a heat-flow of about 30 HFU in the hole, showed extensive and progressive thermal alteration of the diatomaceous and terrigenous turbidites to epidote–zoisite facies in response to deeper heat sources. Site 481, near where sea-floor hydrothermal deposits had previously been observed, showed only moderate thermal alteration adjacent to the sills, and a heat-flow of only about 4

[1] Curray, J. R., Moore, D. G., et al., *Init. Repts. DSDP*, 64: Washington (U.S. Govt. Printing Office).

Table 1. Leg 64 coring summary.

Hole	Dates	Latitude (N)	Longitude (W)	Water Depth (m)	Penetration (m)	Number of Cores	Meters Cored	Recovery (m)	Recovery (%)
474	2-4 December 1978	22°57.72′	108°58.84′	3023	182.5	20	183.0	78.0	43
474A	4-10 December 1978	22°57.56′	108°58.68′	3022	626.0	50	403.0	284.0	61
475	10-12 December 1978	23°03.03′	109°03.19′	2631	196.0	21	196.0	128.0	65
475A	12-12 December 1978	23°03.44′	109°03.83′	2545	16.0	1	9.5	0.15	1.6
475B	12-13 December 1978	23°03.36′	109°03.57′	2593	96.0	4	38.0	11.0	27
476	14-16 December 1978	23°02.43′	109°05.35′	2403	295.0	32	295.0	165.0	28
477	18-20 December 1978	27°01.85′	111°24.02′	2003	191.0	23	191.0	53.0	28
477A	20-22 December 1978	27°01.80′	111°23.93′	2003	207.0	12	121.0	16.0	13
477B	23-23 December 1978	27°01.76′	111°23.95′	2003	4.6	1	4.6	3.5	75
478	24-28 December 1978	27°05.81′	111°30.45′	1889	464.0	54	464.0	310.0	67
479	29-31 December 1978	27°50.76′	111°37.49′	747	440.0	47	440.0	271.0	62
480	31 December 1978 to 2 January 1979	27°54.10′	111°39.34′	655	152.0	31	147.0	118.0	80
481	3-4 January 1979	27°15.18′	111°30.46′	1998	52.0	31	52.0	34.0	64
481A	4-8 January 1979	27°15.18′	111°30.46′	1998	384.0	37	338.0	161.0	47
Total						180	2942.0	1632.0	

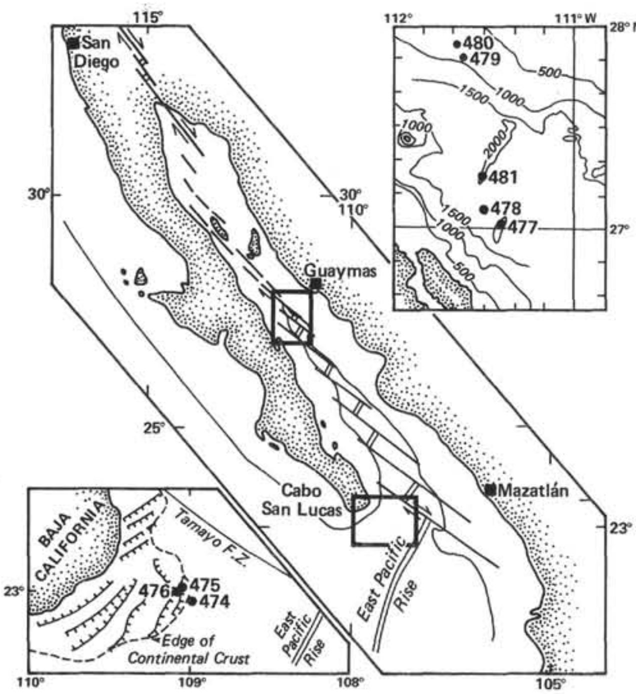


Figure 1. Location of Leg 64 sites.

HFU. Drilling at both sites was terminated while still in sediments, so depth of sediment and maximum sediment ages are unknown. Site 478 was located about half-way to the edge of the basin, 12 km from Site 477 on the basin floor, northwest of the south rift, over crust predicted by the plate-tectonic model to be not more than 400,000 years old. It had a similar section of turbidites and sills, but lower heat flow. It bottomed in a thick (>100 m) dolerite sill, but we believe that more sediment exists below this sill. All three of these sites showed biogenic gas, primarily methane. Sites 477 and 481 also contained thermogenic hydrocarbons ranging to the heptanes, derived from endogenous organic matter. Rates of sediment accumulation were extremely high at all three sites: at least 1200 m/m.y. at 478, and higher but unknown rates at 477 and 481.

The igneous rocks recovered at these sites were all emplaced as sills, mostly doleritic in texture; no pillow lavas were recovered. Mineralogically, the fine-grained margins of the sills indicate that the basaltic magma contained liquidus olivine and plagioclase, but had no pyroxene.

We envisage a model of crust formation and sea-floor spreading in the Guaymas Basin involving intrusion of basaltic magma into soft, wet, young sediments as sills, dikes, and other intrusions. Oceanic Layers 1 and 2, therefore, become completely intercalated, with a gradational contact. This type of ocean crust may be very important during the early stages of formation of ocean basins and translational continental margins (Fig. 2).

GUAYMAS SLOPE: OXYGEN-MINIMUM "VARVED" DIATOMITES

Site 479, drilled with a conventional core barrel, penetrated 444 meters into a sequence of diatomaceous oozes to laminated mudstones with thin, interbedded dolostones; two unconformities of unknown duration were encountered. Faulting and folding above the transform-fault scarp was found to be younger than 1 m.y. Hole 479 included considerable biogenic gas, and below 300 meters increasing amounts of higher-molecular-weight thermogenic hydrocarbons. Site 480 duplicated the upper 152 meters of that hole, using the hydraulic piston corer recently developed at the Deep Sea Drilling Project by engineers Serocki, Storms, and Cameron. The hydraulic piston core functioned, and we obtained over 80% recovery of essentially undisturbed laminated diatomaceous oozes and muds.

These laminated sediments are believed to comprise annual couplets, formed in response to two seasonal events: the sharply seasonal rains that introduce terrigenous clays into the region, and diatom blooms produced by seasonal upwelling and northwest winds. Preservation depends upon the oxygen minimum. The occurrence of homogeneous bioturbated sections suggest a periodic displacement of the oxygen minimum, related to Quaternary climate and sea-level fluctuations. Our undisturbed piston cores from Site 480 contain an almost complete record which may extend back as much as 250,000 years, and correlation with Site 479 carries this record back more than 1 m.y. The low-oxygen paleoenvironment at this site has persisted throughout, as shown by the abundant rhythmic laminae. The high-alkalinity, low-sulfate, ammonia-rich, anoxic sediments promote diagenetic formation of sporadic, thin dolomite beds.

EXPLANATORY NOTES

Data and Authorship

The scientific results are presented in this volume as in earlier volumes of this series. The shipboard results are collected as site chapters, under the collective authorship of the shipboard scientists. Because of the thematic organization of drilling objectives, we have collated Sites 474, 475, and 476 into a single chapter on the Southern Baja California Marginal Transect; similarly, the second site chapter includes Sites 477, 478, and 481 as the Guaymas Basin and Rifts Investigation. Sites 479 and 480 form the third site chapter, on the Guaymas Slope.

Four shipboard scientists were exchanged on 23 December, dividing Leg 64 into a Part I and Part II at Site 477. The prime contributions to the site summaries were compiled by members of the Scientific Party as follows: background and objectives by Joe Curray and Dave Moore; operations by D. Moore; sediment lithology by Kerry Kelts, Jeff Niemitz, Miriam Kastner (Part II), and Eduardo Aguayo (Part II); inorganic geochemistry by Joris Gieskes; organic geochemistry by Bernie Simoneit; biostratigraphy by Marie-Pierre Aubry (calcareous nannofossils), Y. Matoba (foraminifers), Adolfo Molina-Cruz (radiolarians), Hans Schrader (diatoms), and Jaime Rueda-Gaxiola (Part I, palynology); physical properties by Gerhard Einsele; heat flow and conductivity by Mitch Lyle (Part I) and Vic Vacquier (Part II); paleomagnetism by José Guerrero (Part I) and Vic Vacquier (Part II); igneous petrology by Andy Saunders and Dan Fornari; correlation of seismic data with lithology by J. Curray; summary and conclusions by J. Curray and D. Moore.

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 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, because recovered sediments or rocks from different holes usually do not come from equivalent positions in the stratigraphic column.

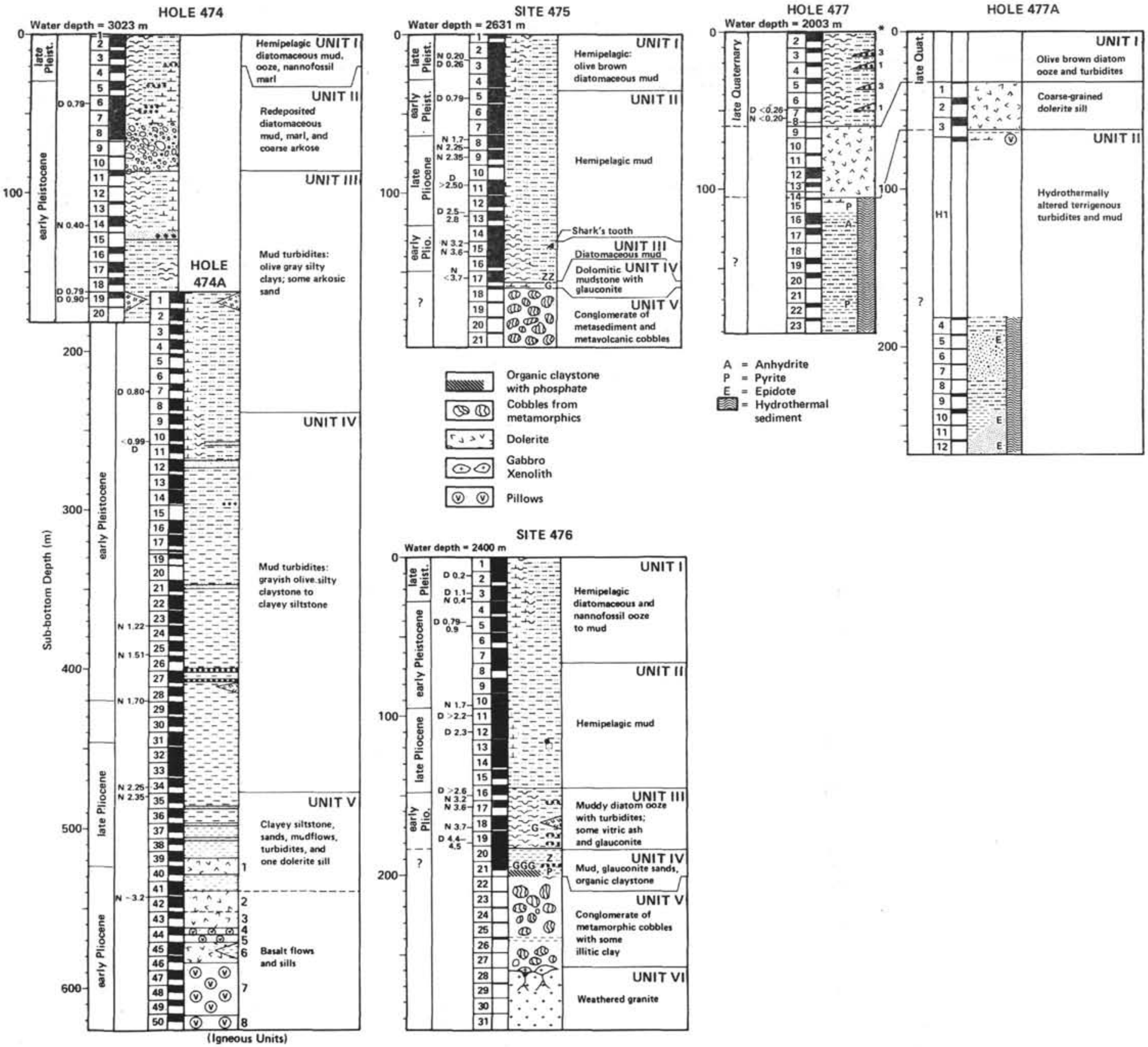
The cored interval is measured in meters below the sea floor. The depth interval of an individual core is the depth below sea floor that the coring operation began to the depth that the coring operation ended. Each coring interval is generally 9.5 meters long, which is the nominal length of a core barrel; however, the coring interval may be shorter, or sometimes 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" 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 a cored interval greater than 9.5 meters thus is possible.

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 occurs, the core number is assigned a suffix, such as "S" for supplementary. 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 ID), 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 core is then cut into 1.5-meter-long sections and numbered serially from the top of the core (Fig. 3). When we obtain full recovery, the sections are numbered from 1 through 7, the last section 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. In special cases, some cores may also have a letter designation; for example, H = "washed interval but recovered material in the core barrel."

In the case of 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 sections serially from the top, beginning with Section 1 (Fig. 3). This technique differs from the labelling systems used on Legs 1 through 45, which had a designation called "zero section," but did not have a "number 7 section." There are as many sections as needed to accommodate the length of the recovered material. For example, four meters of material are divided into three sections, two upper sections, each 1.5 meters long, and a final lower section only 1.0 meter in length. If the recovered material is not contiguous, as determined by the shipboard scientists, then sections are divided and numbered serially, as with contiguous material, and gaps are labeled as voids for sediments (Fig. 3) or marked by spacers for igneous rocks (see igneous rocks section).

Samples are designated by centimeter distances from the top of each section to the top and bottom of the


HOLE 474
Water depth = 3023 m
late Pleist.
early Pleistocene
Hemipelagic UNIT I diatomaceous mud, ooze, nannofossil marl
UNIT II
Redeposited diatomaceous mud, marl, and coarse arkose
UNIT III
Mud turbidites: olive gray silty clays; some arkosic sand
HOLE 474A
early Pleistocene
late Pliocene
early Pliocene
UNIT IV
Mud turbidites: grayish olive silty claystone to clayey siltstone
UNIT V
Clayey siltstone, sands, mudflows, turbidites, and one dolerite sill
Basalt flows and sills
(Igneous Units)
Sub-bottom Depth (m)
SITE 475
Water depth = 2631 m
late Pleist.
early Pleist.
late Pliocene
early Plio.
UNIT I
Hemipelagic: olive brown diatomaceous mud
UNIT II
Hemipelagic mud
Shark's tooth
UNIT III
Diatomaceous mud
Dolomitic UNIT IV mudstone with glauconite
UNIT V
Conglomerate of metasediment and metavolcanic cobbles
Organic claystone with phosphate
Cobbles from metamorphics
Dolerite
Gabbro Xenolith
Pillows
SITE 476
Water depth = 2400 m
late Pleist.
early Pleistocene
late Pliocene
early Plio.
UNIT I
Hemipelagic diatomaceous and nannofossil ooze to mud
UNIT II
Hemipelagic mud
UNIT III
Muddy diatom ooze with turbidites; some vitric ash and glauconite
UNIT IV
Mud, glauconite sands, organic claystone
UNIT V
Conglomerate of metamorphic cobbles with some illitic clay
UNIT VI
Weathered granite
HOLE 477
Water depth = 2003 m
late Quaternary
A = Anhydrite
P = Pyrite
E = Epidote
= Hydrothermal sediment
HOLE 477A
late Quat.
UNIT I
Olive brown diatom ooze and turbidites
Coarse-grained dolerite sill
UNIT II
Hydrothermally altered terrigenous turbidites and mud

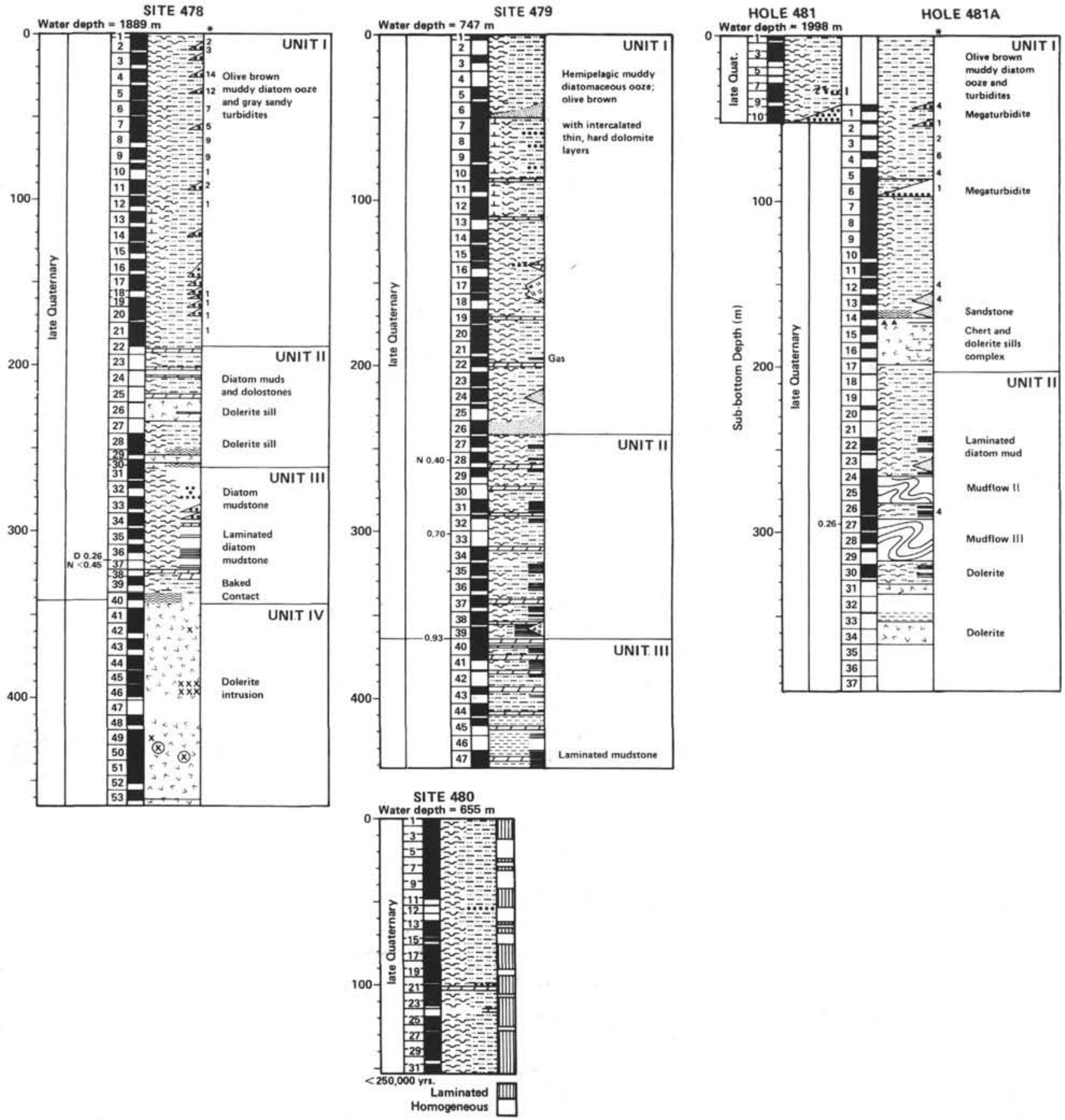


Figure 2. Lithologic columns for Sites 474 to 481.

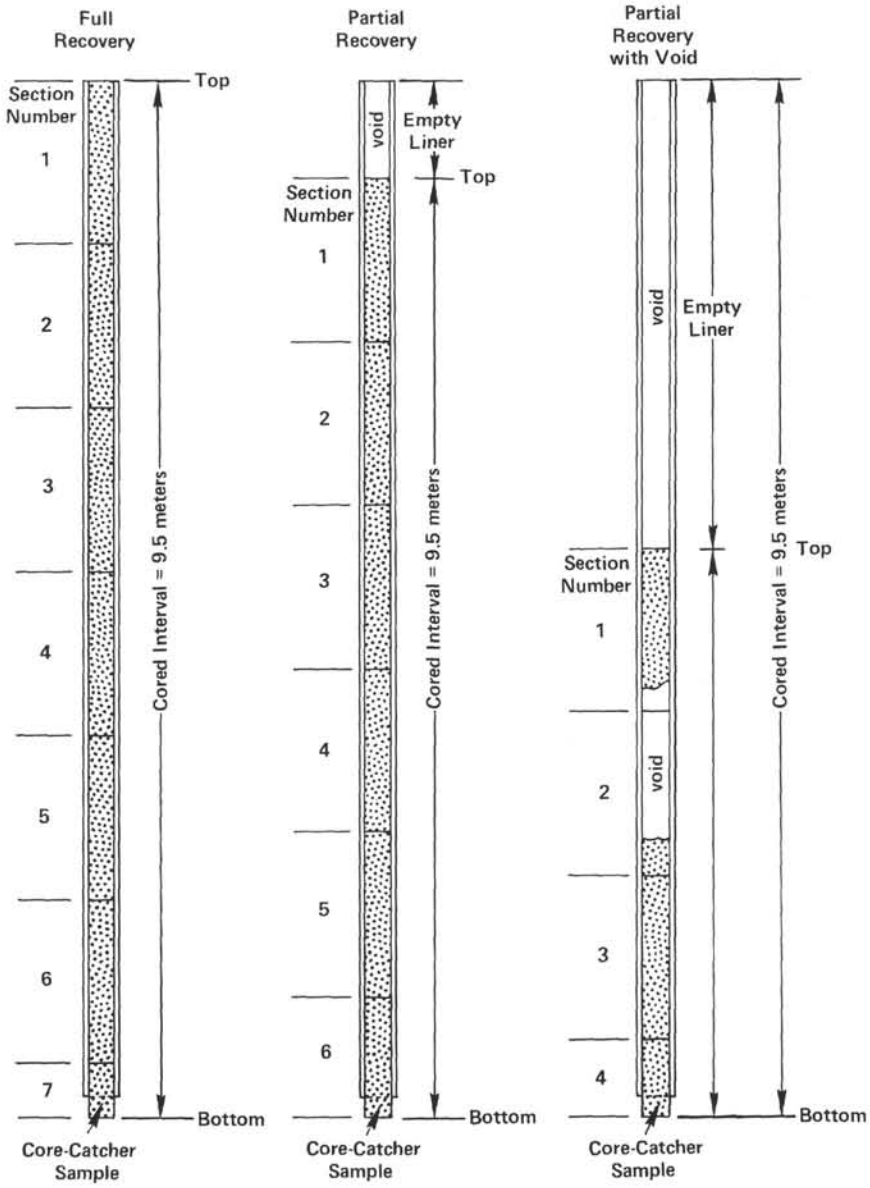


Figure 3. Diagram showing procedures in cutting and labeling of core sections.

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 the section.

For example, a sample identification number of "64-474A-9-3, 12–14 cm" is interpreted as follows: 12–14 cm designates a sample taken at 12 to 14 cm from the top of Section 3 of Core 9, from the second hole drilled at Site 474 during Leg 64. A sample from the core catcher of this core is designated as "64-474A-9,CC".

The depth below the sea floor for a sample numbered "64-474A-9-3, 12–14 cm" is the sum of the following: (1) the depth to the top of the cored interval for Core 9, which is 362 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; all of these variables add up to 365.12 meters, which theoretically is the sample depth below the sea floor. DSDP has sample listings from each leg listed on microfiche cards with assigned absolute sample depths in meters. For requests, please write to DSDP Information Handling Group.

Handling of Cores

A core was normally cut into 1.5-meter sections, sealed, and labeled, then brought into the core laboratory for processing. Gas analyses and continuous wet-bulk-density determinations using gamma ray attenuation porosity evaluation (GRAPE) were made before splitting sections.

The cores were then split longitudinally into "working" and "archive" halves. Samples were taken from the "working" half, including those for determination of grain-size distribution, mineralogy by X-ray diffraction, 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 (Karbonate Bomb), geochemical analysis, paleontological studies, and others.

Smear slides (thin-sections for lithified sedimentary and igneous rocks) 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, structures, and composition of the various lithologies were noted on standard core-description forms. All prime data are routinely microfilmed, and some are digitized for computer retrieval.

After the cores were sampled and described, they were maintained in cold storage aboard *Glomar Challenger* until transferred to the DSDP repository. Core sections of sediments removed for organic-geochemistry study were frozen immediately aboard ship, and kept frozen. All Leg 64 cores and frozen cores are stored at the DSDP West Coast Repository (Scripps Institution of Oceanography).

HPC Cores

On Leg 64, the Serocki–Storms–Cameron hydraulic piston corer (HPC) was initially used on a test (477B), and then first used successfully to recover undisturbed sediments at Site 480 and again at Site 481. HPC holes are not assigned a special letter designation, although in some informal cases a "P" might appear. The HPC operates on the principle of a 4.45-meter core barrel which is lowered inside the drill string, hydraulically ejected into the sediment, and retrieved. The pipe is then lowered those 4.45 meters to the next interval, and the procedure is repeated. At Site 480, we pulled 31 cores (Fig. 4) and obtained about 118 meters (80%) of the 152-meter section, with 2 cores empty and one core washed. Approximately the top and bottom 20 cm of a core generally showed extensive core disturbance, but most of the sections survived intact, more than 76 meters consisting of finely laminated oozes. The ocean was becalmed at Site 480, so there is no uncertainty in a core's exact depth position resulting from the ship's heave, although tidal effects are not compensated.

The HPC cores from Site 480 were subjected to special handling, and sampling was deferred to later shore-based examination in order to preserve the unique laminated record for X-radiography and "varve counts". At that time, we developed a technique of shaving the surface in 40-cm intervals with a razor to bring out structure, and to obtain interval-average trench samples without disturbing the core. Other special procedures are discussed in the special studies section on the Guaymas Slope sites.

Sediments and Sedimentary Rocks

Core Description Forms

Disturbance

Recovered rocks, and particularly the soft sediments, may be extremely disturbed. This mechanical disturbance is the result of the coring technique, 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:

1) Slightly deformed: bedding contacts are slightly bent.

2) Moderately deformed: bedding contacts have undergone extreme bowing; firm sediment is fractured.

3) Very deformed: bedding is completely disturbed or homogenized by drilling, sometimes showing symmetrical, diapir-like structure; firm zones may have relict "drill biscuits" in a breccia or homogeneous matrix.

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

These categories are coded on the core description form in the column headed "Drilling Disturbance" (Fig. 5).

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. Locations and types of these structures appear as graphic symbols in the column headed "Sedimentary Structures" on the core description form (Fig. 5). Figures 6 and 7 give the keys to these symbols.

Bioturbation is difficult to recognize in the monotone olive-brown hemipelagic oozes. In Holes 474/474A, several varieties of burrowing proved useful for distinguishing redeposited units. The tops of mud turbidites commonly showed *Chondrites* (CH) type burrows, whereas host sediment exhibited more frequent meniscate (M), or *Planolites* (P) types (Fig. 8). These are noted, where distinguishable, on the graphic column (Fig. 5).

Color

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

Lithology

The graphic column presented on the core-description form is based on the lithologies and represented by a single pattern, or by a group of two or more symbols. The symbols in a group correspond to end-member sediment constituents, such as clay or nannofossil ooze. The symbol for the terrigenous constituent appears on the right-hand side of the column, the symbol for the biogenic constituent(s) is on the left-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 left 20% of the column may have a diatom ooze symbol, while the right 80% of the column may have a silty-clay symbol, indicating sediment composed 80% of mud and 20% of diatoms.

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 appeared in the core; they become highly flattened and

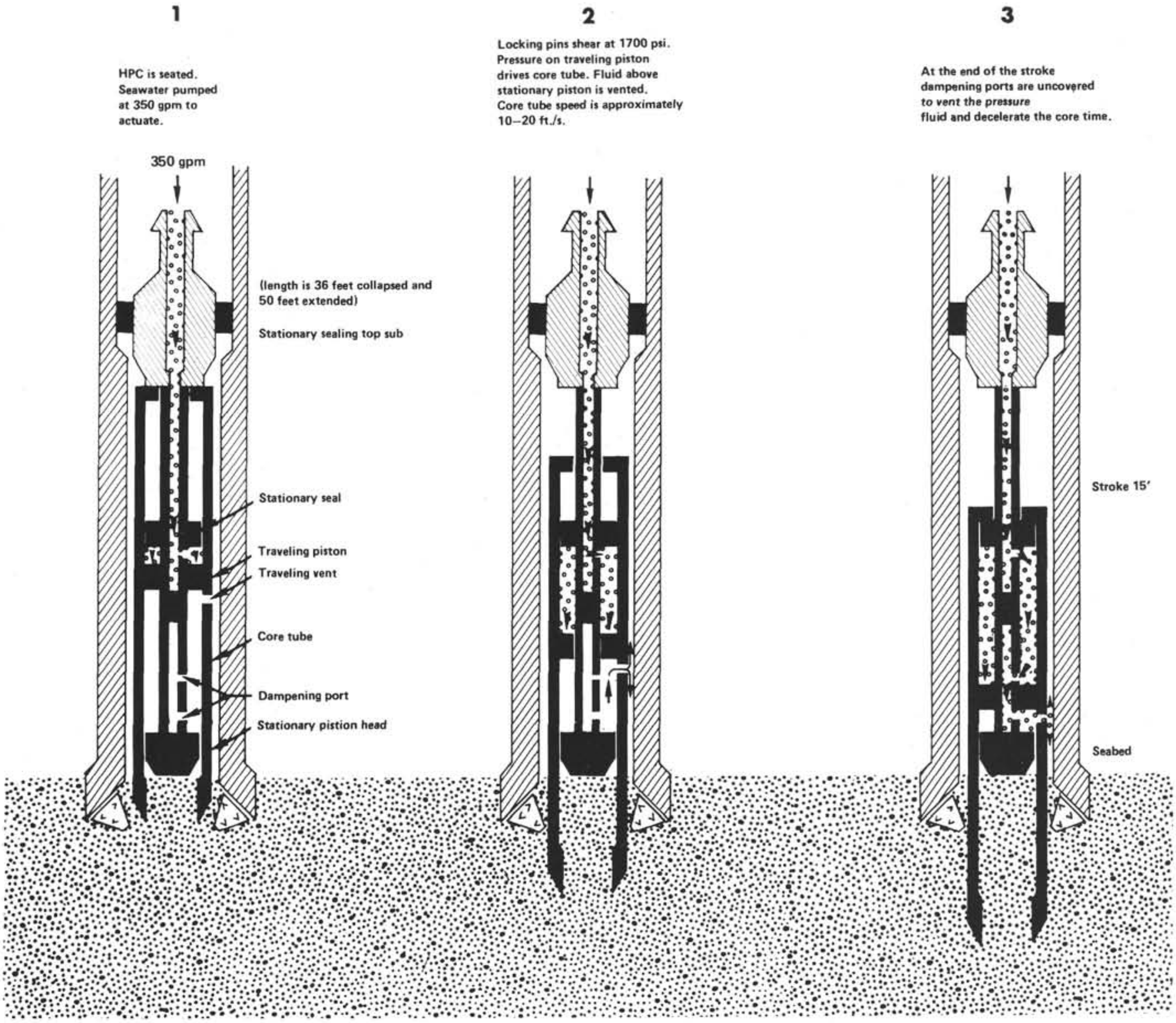


Figure 4. Operational sequence for the Serocki–Storms–Cameron DSDP hydraulic piston corer, first used successfully at Site 480.

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, the depth of small "patches" of ash or other lithologic changes are given by a triangular inset of the appropriate lithologic symbol on the right side of the lithologic column (Fig. 7). This convention applies only to lithologies which do not extend across the entire core.

Format, style, and terminology of the descriptive portion of the core-description forms (Fig. 6) are not controlled by the "Mandatory Graphic Lithologic Column Scheme" beyond the minimum assignment of a name, which is derived from the lithologic classification (described below). Colors and additional information, such as structures and texture, are included in the text portion of the core description.

Smear-slide (or thin-section) compositions, carbonate content (% $CaCO_3$), and organic-carbon content determined aboard ship are listed below the core description on these forms, where two numbers separated by a hyphen refer to the section and centimeter interval 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 organic-geochemistry (OG) and interstitial-water (IW) samples are given in the lithology column, as well as special samples for ^{14}C analysis and bacterial incubation (BACT).

Lithologic Classification of Sediments

Most sediment recovered during Leg 64 comprised hemipelagic mixtures of terrigenous and biogenic components, mostly diatomaceous. Turbidite sediments are common. Colors are generally drab olive-browns to grays.

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

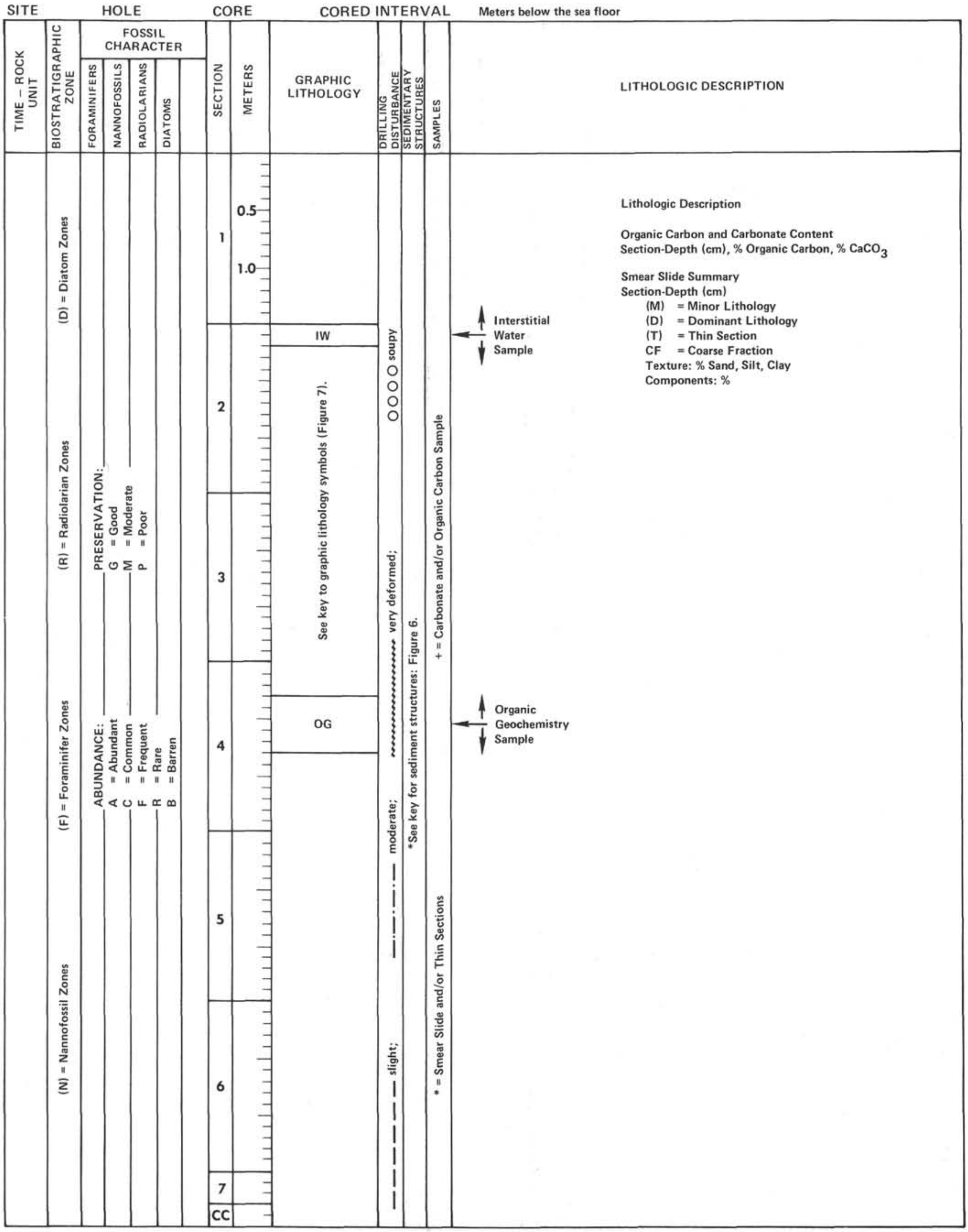


Figure 5. Sample core-description form (sediment).

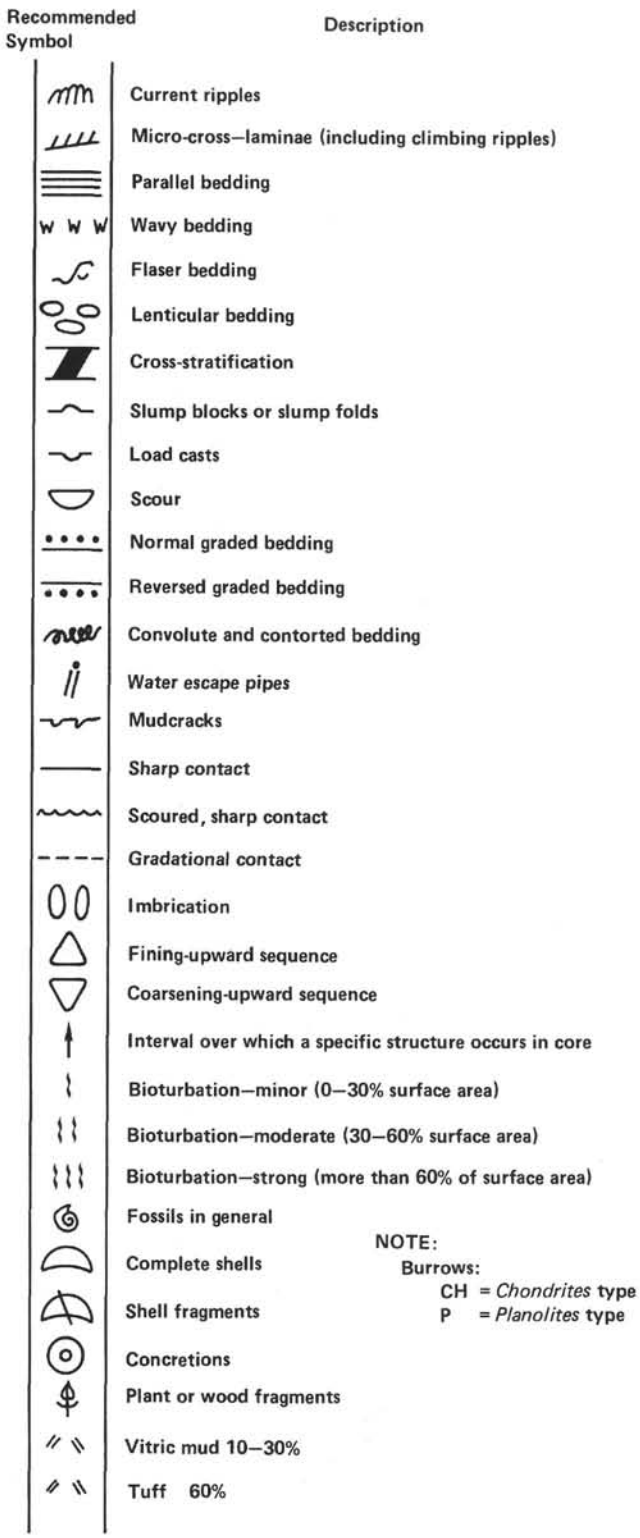


Figure 6. Symbols for sedimentary structures noted on core-description forms (sediment).

JOIDES Planning Committee in March, 1974. For the sake of continuity, the Leg 64 shipboard scientists have used this basic classification, with some minor modification. We will point out our differences from the SPPP classification when those topics are discussed. For the unadulterated JOIDES classification, see Volume 42, Pt. 2, of the *Initial Reports* (Ross, Neprochnov, et al., 1978, pp. 14–15).

This classification is descriptive, rather than genetic, and divisions between different types of sediment are somewhat arbitrary. We treat lithologic types not covered in this classification as a separate category, termed "special rock types." A brief outline of the conventions and descriptive data used to construct this classification follows.

Composition and Texture

In this classification, composition and texture are the only criteria used to define the type of sediment or sedimentary rock. Composition is most important for describing sediments deposited in the open ocean, whereas texture becomes significant for hemipelagic and near-shore sediments. These data come principally from visual estimates of smear slides, using a petrographic microscope. They are estimates of areal abundance and size components on the slide, and they may differ somewhat from more accurate analyses of grain size, carbonate content, and mineralogy (see "Special Studies" section). From past experience, quantitative estimates of distinctive minor components are accurate within 1 to 2%, but for major constituents accuracy is poorer (±10%). All smear slide estimates were done aboard ship. Carbonate content is difficult to estimate from smear slides. Therefore, for many cores we determined the percentage of carbonate using the "Karbonate Bomb" technique of Müller and Gastner (1971). This method involves treating a powdered sample with HCl 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 ±5%. Carbonate content determined in this manner is listed on the core-description forms below the lithologic description.

Textures of sediments estimated from smear slides and listed as percent sand-silt-clay in the smear-slide summary on the core description forms include all constituents. Thus, a diatomaceous ooze will have a greater percentage of silt-size particles than a nannofossil ooze, because of the different sizes of the tests of the two planktonic groups. This convention causes some confusion when naming terrigenous sediments that contain a significant number of microfossils. For example, a diatomaceous silty clay may have less silt-size terrigenous particles (e.g., quartz and feldspar) than a nannofossil silty clay, simply because many diatoms are silt-size and are included as such in the textural estimate. However, we have chosen fairly broad compositional class boundaries (see below) for mixed terrigenous and biogenic sediments, in order to minimize this effect. For this reason we preferred to replace clayey-silt or silty-clay terms simply by "mud," when used with a biogenic modifier.

Where applicable we used one or several modifiers in naming the sediment. In all cases, the dominant component appears last in the name; minor components pre-

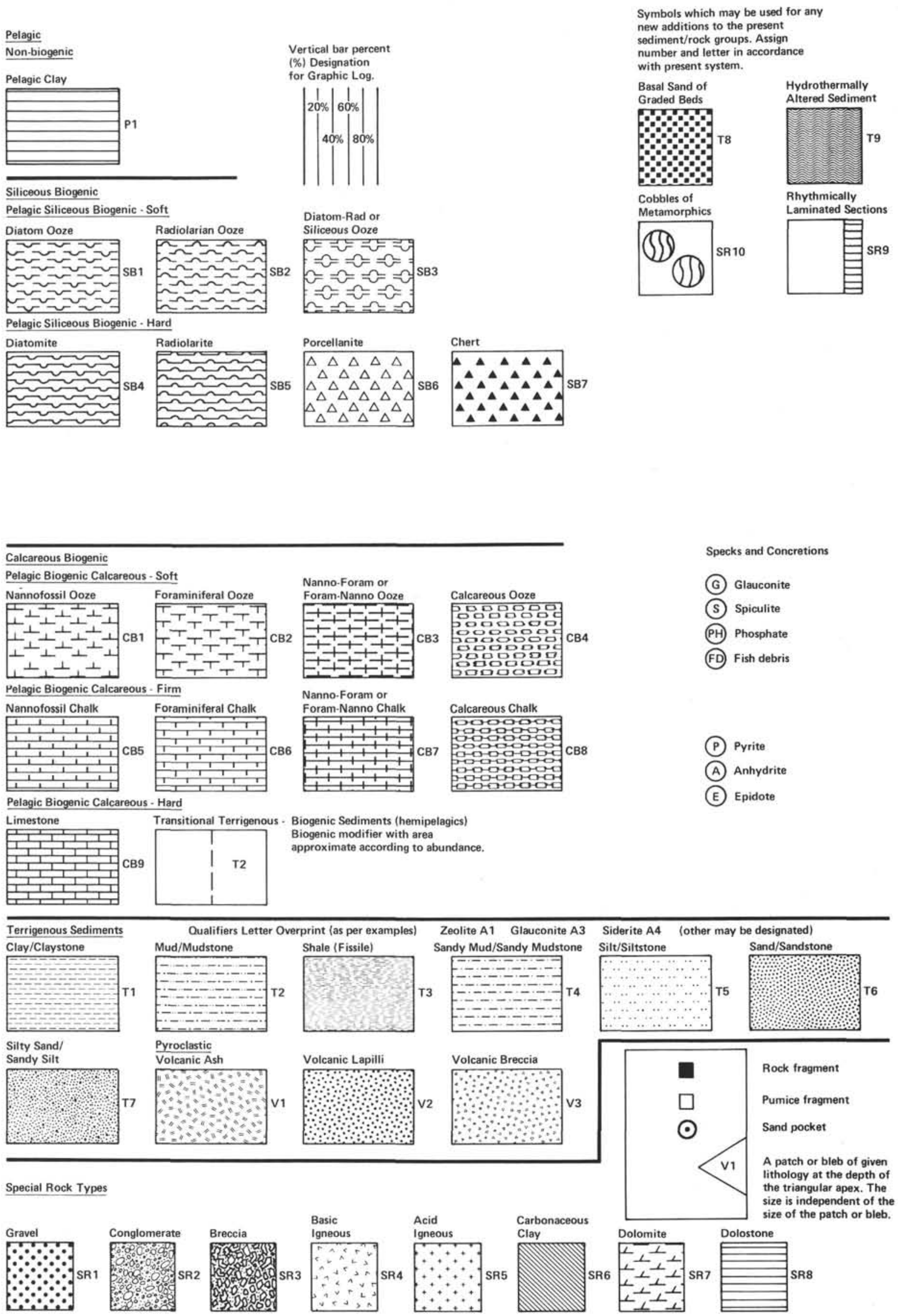


Figure 7. Symbols used in graphic lithology column of core-description forms (sediment).

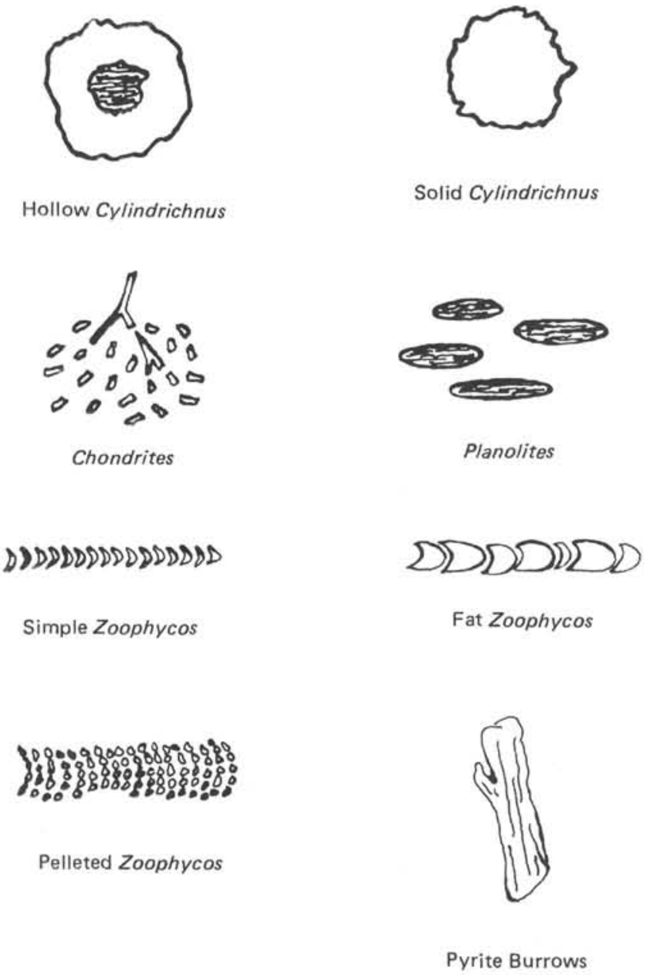


Figure 8. Common trace fossils in Deep Sea Drilling Project cores.

cede, the least common constituent being listed first. If minor constituents occur in amounts less than 10%, they are not included in the name. This convention also holds for zeolites, Fe- and Mn-micronodules, and other indicators of very slow rates of sedimentation or nondeposition, such as fish bones. Often these minerals are conspicuous, even though greatly diluted. If minor constituents are deemed important and environmentally significant—as glauconite and dolomite were on Leg 64—they are sometimes 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 only two classes for all other lithologic types.

1) Calcareous sediments and sedimentary rocks (carbonate >50%); categories after Gealy et al. (1971).
   a. Soft = ooze: has little strength, and is readily deformed under pressure of finger or broad blade of spatula.
   b. Firm = chalk: partially lithified and readily scratched with fingernail or edge of spatula.
   c. Hard = limestone, dolostone: well lithified and cemented; resistant or impossible to scratch with fingernail or edge of spatula.
2) Siliceous sediments (silica >50%).
   a. Soft = ooze: readily deformed by finger or broad blade of spatula.
   b. Hard = radiolarite, diatomite, chert, or porcellanite: core must be cut with band saw or diamond saw.
3) Terrigenous sediments (terrigenous components >50%).
   a. Soft = sand, silt, clay (or combinations of these): readily deformed by finger or broad blade of spatula.
   b. Hard = sandstone, siltstone, claystone, etc. (i.e., suffix "-stone" added): core must be cut with band saw or diamond saw; claystones may have soft, waxy texture, but show fissile partings.

Types of Sediments and Compositional Class Boundaries

We distinguish four basic types of sediments: siliceous biogenic sediments, calcareous biogenic sediments, terrigenous sediments, and volcanogenic sediments and pyroclastic rocks. Each type of sediment is discussed briefly below. An additional category, "special rock types," is also included.

Siliceous Biogenic Sediments

These are sediments in which biogenic silica or authigenic silica (opal-CT and/or quartz) compose at least 30% of the sediment. If the siliceous component is between 30 and 60%, then the terrigenous (mud), calcareous biogenic, or volcanogenic modifier is retained. For example, "muddy diatomaceous ooze" describes a soft sediment with at least 30% clayey silt and between 30 and 60% diatoms. If the siliceous component exceeds 60%, then the modifer(s) are dropped. A radiolarian ooze would have <10% clay or carbonate and >60% radiolarians. If the siliceous biogenic component is between 30 and 60%, then the names for terrigenous or calcareous biogenic sediments or pyroclastic rocks apply, with the dominant siliceous constituent as a qualifier. Silica in amounts <10% is not acknowledged in the name. These terms apply to soft sediments (Fig. 8).

For hard siliceous rocks, siliceous microfossils often are absent. If they have been dissolved and replaced by opal-CT and/or quartz, and if these minerals make up >50% of the rock, then the terms porcellanite and chert apply.

Chert is a hard, conchoidally fracturing, varicolored sedimentary rock with semi-vitreous, vitreous, or waxy luster; it consists mostly of silica.

Porcellanite is a siliceous sedimentary rock with a dull or matte luster, resembling that of unglazed porcelain. It is less hard, dense, and vitreous than chert, and it commonly has a lower silica content.

If two modifiers are used, 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.

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

Biogenic Siliceous Fossil Particles (%)	Clay (%)	Lithology	
<10	>90	clay	soft
		claystone	hard
30 to 10	70 to 90	diatomaceous mud	soft
		diatomaceous mudstone	hard
60 to 30	40 to 70	muddy diatomaceous ooze	soft
		muddy diatomite	hard
100 to 60	0 to 40	diatomaceous ooze	soft
		diatomite	hard

Mud is used to group silty clays and clayey silts.

Calcareous Biogenic Sediments

These are sediments in which biogenic carbonate or carbonate of indeterminate origin (cement or recrystallized carbonate) constitute at least 30% of the sediment. If the carbonate component is between 30 and 60%, then the terrigenous, siliceous biogenic, or volcanogenic modifiers are retained. For example, "muddy nannofossil ooze" describes a soft sediment with at least 10% clay and between 30 and 60% calcareous nannofossils. If the calcareous component exceeds 60%, then the modifiers are dropped. A nannofossil ooze would have <10% clay or silica, and 60% calcareous nannofossils. If the calcareous biogenic component is between 30 and 60%, then the names for terrigenous, or siliceous biogenic sediments, or pyroclastic rocks apply, with the dominant calcareous constituent as a qualifier. Carbonate less than 10% is not acknowledged in the name. These terms apply to soft sediments.

For firm and hard calcareous rocks with carbonate contents >50%, the terms chalk, limestone, and dolostone apply, respectively. If the carbonate content is between 30 and 60% the terrigenous modifier is retained. For example, a clayey limestone has at least 10% clay, and 30 to 60% carbonate. The modifiers are dropped when the carbonate content exceeds 60%. If the carbonate content is less than 30%, the terrigenous, siliceous biogenic, or volcanogenic names apply, with the dominant carbonate type retained as a qualifier. Carbonate is not acknowledged in the name if it is present in amounts <10%. Note that we use the qualifier "calcareous" to designate carbonate of indeterminate origin. Dolostone is used for hard calcareous beds where subsequent X-ray diffraction studies showed 50% or more dolomite.

Terrigenous Sediments

The textural classification of terrigenous sediments follows that of Shepard (1954) (Fig. 9), with grain size limits as defined by Wentworth (1922). Sediments and sedimentary rocks are assigned terrigenous names according to their textural classification when these components exceed 30%. If the terrigenous component is between 30 and 60%, the biogenic or volcanogenic modifier is retained. For example, a nannofossil mud contains >10% calcareous nannofossils and 30 to 60% silty clay, the sand-silt-clay proportions being 0 to 20%, 25 to 50%, and 50 to 75%, respectively. The biogenic or volcanogenic modifier is dropped when that component is less than 10%. For hard terrigenous sediments, the suffix "-stone" is added. Characteristic components are noted in smear-slide or coarse-fraction descriptions.

Within the textural and the component groups, the modifiers are listed in order of increasing abundance.

Sand is commonly part of a graded bed with transitional textures. Such beds are noted on the sediment structures column and the approximate limits are given on the lithological column based on estimates of the maximum grain size.

Volcanogenic and Pyroclastic Sediments

We arbitrarily distinguish pyroclastic rocks from volcanogenic sediments, using 50% as the pivotal percentage, pyroclastic rocks having >50% volcanic components, and volcanogenic sediments <50%. Textural groups are:

>32 mm, volcanic breccia; 4–32 mm, volcanic lapilli (lapilli tuff when indurated); <4 mm, volcanic ash (tuff when indurated).

Rhyolitic and basaltic ash are distinguished on the basis of bed color, sorting, and refractive index of glass shards. Rhyolite ash is medium gray, with a refractive index <1.54. In Leg 64 sediments, volcanic glass is a generally minor component where it does not occur as a discrete bed.

The compositional breakdown is vitric, crystalline, or lithic, according to the most common constituent. Qualifiers are used when volcanic components are between 50 and 90%. For example, a clayey vitric ash contains >10% clay and 50 to 90% ash composed mainly of glass shards. Terrigenous and biogenic modifiers are dropped if <10%.

When the volcanic component is <50%, the terminology and class boundaries for terrigenous (and, less often, biogenic) sediments apply. The modifier "tuffaceous" encompasses both ash and lapilli when either or both of these components occur in amounts between 10 and 50%. Thus, a tuffaceous clayey sand(stone) contains 10 to 50% ash and/or lapilli and 50 to 90% clayey sand.

Hemipelagic Sediments

Hemipelagic sediments are distinguished by a terrigenous component in excess of 30%, a total non-biogenic component in excess of 40%, and a biogenic-silica content in excess of 10%. Besides the terrigenous component, hemipelagic sediments are usually rich in biogenic silica (usually diatoms because of coastal upwelling). The classification of these sediments in terms of the dominant components can be represented by a pyramid in which the peak and each corner represents 100% of a specific component: 100% sand at the peak; 100% silt and 100% clay at diagonal corners of the base; and 100% biogenic silica and 100% ash at the other diagonal corners of the base. As such, Shepard's textural classifi-

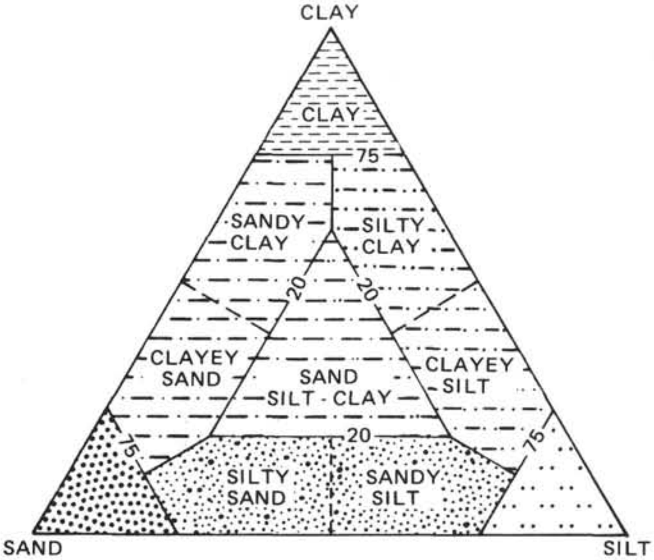


Figure 9. Textural classification of terrigenous sediments (after Shepard, 1954).

cation (1954; Fig. 9) would be represented by the plane passing through the points for 100% sand, 100% silt, and 100% clay.

The plane of the base of the pyramid (Fig. 10) shows the classification of sediments with less than 10% sand. Such sediments are the dominant type on most continental margins; thus, the classification in Figure 10 is broadly applicable. The percentage silt and clay used in the diagram (Fig. 10) refers to only terrigenous components. Authigenic minerals, ash, and biogenic particles are not included.

For biogenic opal contents greater than 10%, the dominant siliceous biogenic component should be used in the name. Because diatoms predominate in these sediments, we have used the terms "diatomaceous" and "diatomite" in the diagram (Fig. 10). However, where other biogenic siliceous components dominate, the terms radiolarian, radiolarite, spicular, etc., may be used.

Terms such as sand, diatoms, radiolarians, spicules, ash, etc., may be used as qualifiers to the original sediment description if these components amount to 10 to 30% of the sediment; for example: clayey vitric diatomaceous ooze; diatomaceous sandy silty claystone; diatomaceous vitric silty clay; diatomaceous mud.

As biogenic components increase the intermediate silt–clay mixtures, they are not readily distinguished; therefore, they generally are referred to merely as "mud."

Special Rock Types

Special rock classifications (Fig. 7) from Leg 64 include the following:

1) *Phosphatic organic claystone:* used to designate some sediments at the base of Hole 476 which contained scattered glauconite pellets, a few thin phosphate (collophane) laminae, pyrite, and layers containing up to 8% organic carbon. The very high organic contents are localized in only a few laminae. They are typical of sediments forming on protected offshore banks, within the oxygen-minimum zone of upwelling regions.

2) *Hydrothermal sediments:* used to designate the suite of terrigenous sediments cored below dolerite sills at Site 477. The sediments show high-temperature alteration, approaching green schist facies metamorphism. Hydrothermal minerals include anhydrite, dolomite, large pyrite crystals, pyrrhotite, zeolites, euhedral quartz, feldspar overgrowths, epidote, and clinozoisite. Organic matter has been subjected to temperatures up to 300°C, and it delineates the contact aureole around dolerite sills.

3) *Rhythmically laminated "varved" sediments:* used to designate long sequences of finely laminated rhythmic couplets of light and dark sediment rich in diatoms and terrigenous material found at several of the sites in the Guaymas basin. In particular, Site 480 was hy-

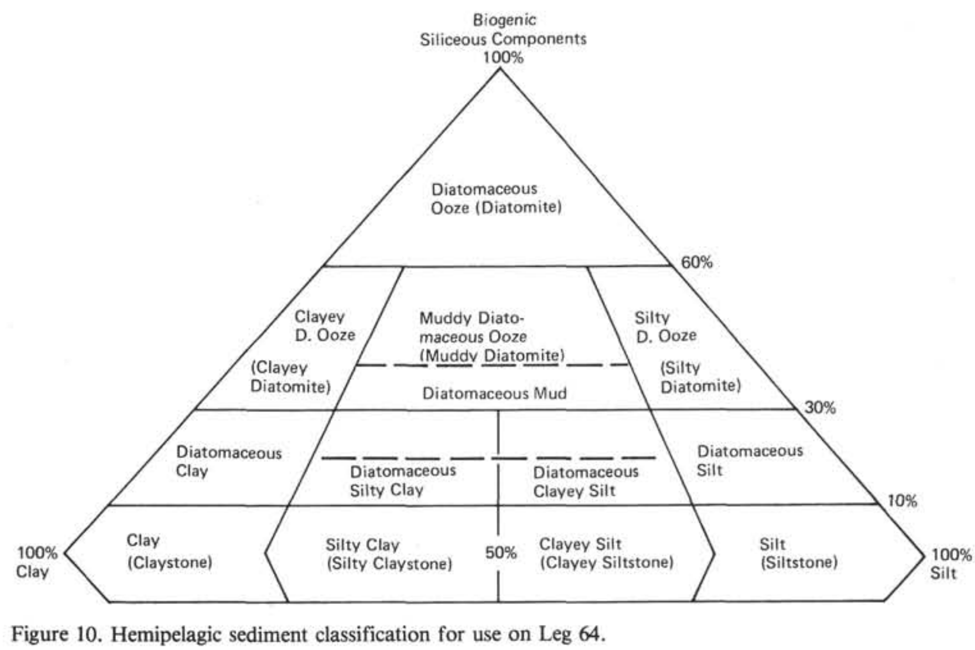


Figure 10. Hemipelagic sediment classification for use on Leg 64.

draulic-piston cored and collected an undisturbed suite with very regular couplets ranging from 10 to 30 couplets per centimeter. These are assumed to represent annual cycles. The detailed composition of these laminae cannot be shown on the graphic lithology column and is therefore represented as an average.

4) *Metamorphic cobble conglomerate:* used to designate basal conglomerates in both Sites 475 and 476, having clasts almost exclusively derived from a metamorphic terrain, but including abundant acidic volcanics. Granitic components are rare.

5) *Dolostone* (Dolomite): used to designate thin diagenetic calcareous beds intercalated in muddy diatom oozes of the Guaymas region containing more than 30% rhombic to anhedral dolomite as cement and replacement mineral. Primary sedimentary structures and diatom frustules commonly are well preserved. The dolomitic composition was confirmed by later X-ray-diffraction analysis.

X-Ray Diffraction

Samples selected for routine X-ray-diffraction analyses were run at the Institut für Sedimentforschung, Heidelberg, Federal Republic of Germany, and are presented in Appendix I (this volume, Pt. 2).

Organic Carbon and Carbonate Content

Samples have been analyzed on board by a Hewlett-Packard CHN Analyzer (see Simoneit, "Shipboard Geochemistry," this volume, Pt. 2), and others were analyzed at the DSDP Sediment Laboratory on a Leco WR-12 carbon analyzer (Boyce and Bode, 1972). The data are combined with other available analyses and presented in Appendix II (this volume, Pt. 2) with the exception of the 900 samples from surface scrape samples from HPC Hole 480 (Le Claire and Kelts, this volume, Pt. 2).

Igneous Rocks

Visual-Core-Description Forms

All igneous rocks were split with a rock saw into working and archive halves described and sampled aboard ship. Figure 11 shows a composite visual-core-description form used for the description of igneous rocks recovered on Leg 64. On this form, each section of a core is described under a set of five column headings: (1) piece number, (2) graphic representation, (3) orientation, (4) shipboard studies, and (5) alteration (Fig. 11).

In the graphic-representation column, each piece is accurately drawn, and various features, such as texture, glassy margins, or vesicles, are coded according to the symbols given in Figure 12. Two closely spaced horizontal lines in this column indicate the location of styrofoam spacers taped between pieces inside the liner. Each piece is numbered sequentially from the top of the section, beginning with the number 1 (piece-number column). Pieces are labeled on the rounded surface, rather than the flat slabbed face. Pieces which fit together before splitting are given the same number, but are consecutively lettered as 1A, 1B, 1C, etc. Spacers were placed only between pieces which did not fit together: those pieces were given different numbers. In general, spacers may or may not indicate missing material (not recovered) between pieces. All cylindrical pieces longer than the diameter of the liner have arrows in the "orientation" column, indicating that top and bottom have not been reversed as a result of drilling and recovery. Arrows also appear on the labels of these pieces on both archive and working halves.

The column marked "Shipboard Studies" designates the location and the type of measurements made on a sample aboard ship. The column headed "Alteration" gives the degree of alteration, using the code given in Figure 12. Below each set of five descriptive columns is the designation for core and section to which these data apply.

Figure 11 gives the outline for core descriptions of igneous 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 recovered depth interval are listed, followed by the major and minor rock types and a short description. Thin-section data are tallied below this, then shipboard data.

Classification of Igneous Rocks

We informally classified igneous rocks recovered on Leg 64 according the mineralogy and texture determined from visual inspection of hand specimens and thin-sections. Standard rock names, such as basalt and dolerite, come from texture and mineralogical compositions. Textural terms follow Williams et al. (1954).

Physical Properties

Boyce (1976) has described in considerable detail the equipment, methods, and corrections routinely used by shipboard scientists to measure physical properties of sediments and rocks recovered at Deep Sea Drilling sites. On Leg 64, we determined saturated bulk density using the gamma ray attenuation porosity evaluator (GRAPE) and the gravimetric technique, porosity calculated from GRAPE and gravimetric measurements, water content from gravimetric measurements, sonic velocity using the Hamilton frame velocity meter, and shear strength of undisturbed sediments (see discussion in Einsele, this volume, Pt. 2). For density and porosity calculations, we assume grain densities of 2.70 g/cm^3 for sediments and 2.90 g/cm^3 for igneous rocks, and a corrected pore fluid density of 1.128 g/cm^3. Listings of these corrected data are available on request from Deep Sea Drilling.

Down-hole Logs

Table 2 lists the specifications of the Gearhart-Owen International wire-line well logging tools used on Leg 64. All logs were run in the open hole filled with water-base mud. Lynch (1962) discusses the general theory and

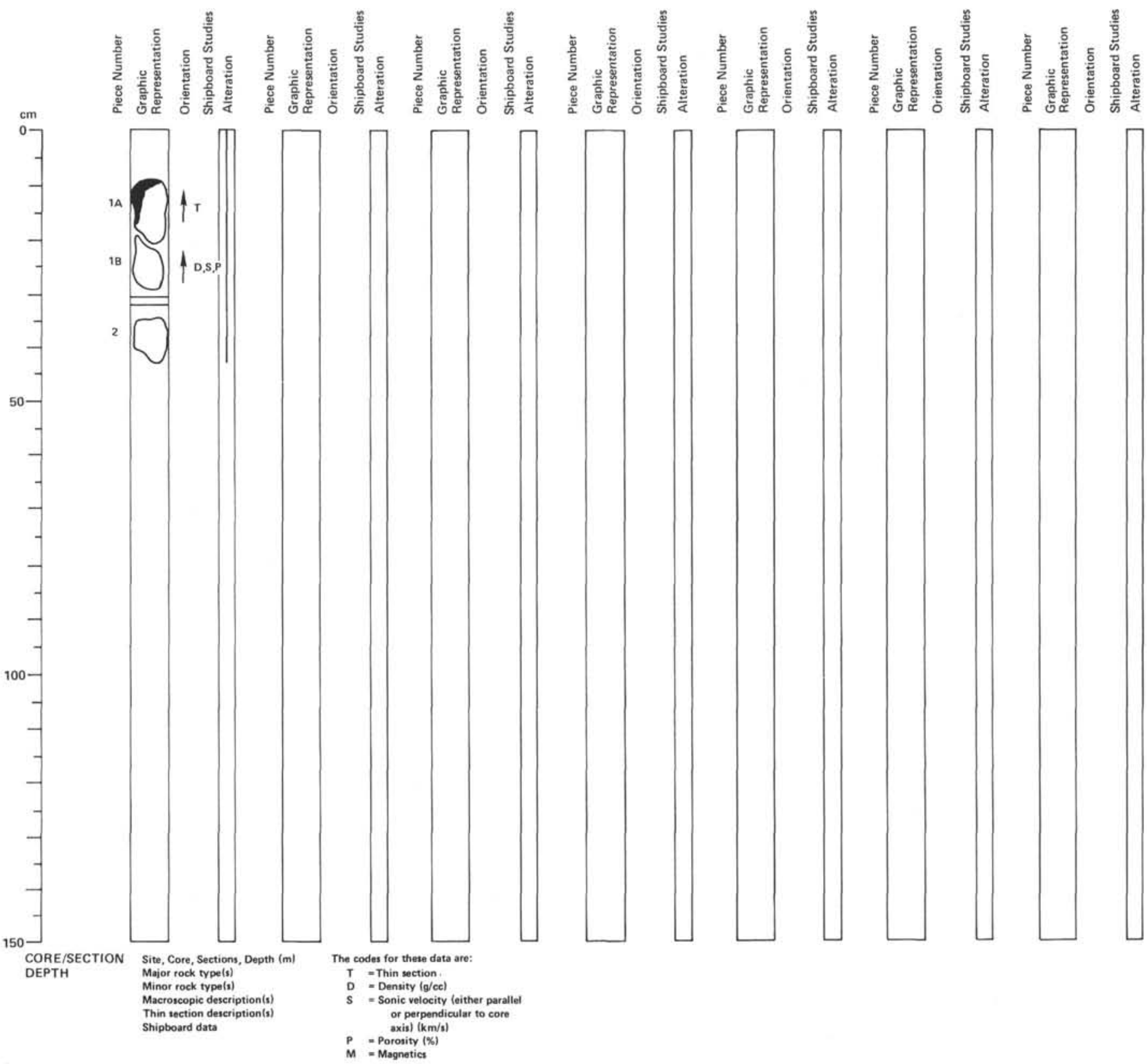


Figure 11. Visual-core-description form (igneous rocks).

applications of the various well-logging instruments. Further detailed treatments are in Gearhart-Owen (1978). Logging operations were performed in six holes at five sites, using the complete set of available tools in five combinations. Table 3 gives a summary of the logging operations during Leg 64.

The basic feature of the logging system used on Leg 64 is digitized logging data with a laser recorder that allows signals to be scaled, converted, or corrected. Tapes are stored at the Deep Sea Drilling Project.

There is a conditionary note for the compensated sonic log in formations of low velocity (1.5–2.0 km/s). Because this is a two-layer seismic-refraction experiment with a centered tool, velocities below about 1.7 to 1.8 km/s become unmeasurable as the formation's velocity approaches that of the fluid. In the soft, porous sediments that leads to low velocities. Further inaccuracy is introduced by the variable enlargement of the hole. Thus, for example, in Hole 479, any velocities less than 1.65 km/s are obviously that of the fluid in the bore hole.

The induction electrical-logging tool measures conductivity in medium- to high-porosity formations, with about 1.6-meter resolution. The guard log generates and records a signal which is a function of formation conductivity. The density log is a radiation well log for measuring bulk density. It utilizes a highly collimated cesium-137 gamma-ray source and two detectors. The gamma rays emitted by the source are reflected by the formation and picked up by the two separate and shielded detector pads. The gamma ray-CCL neutron tool can be used to determined lithologies and formation poros-

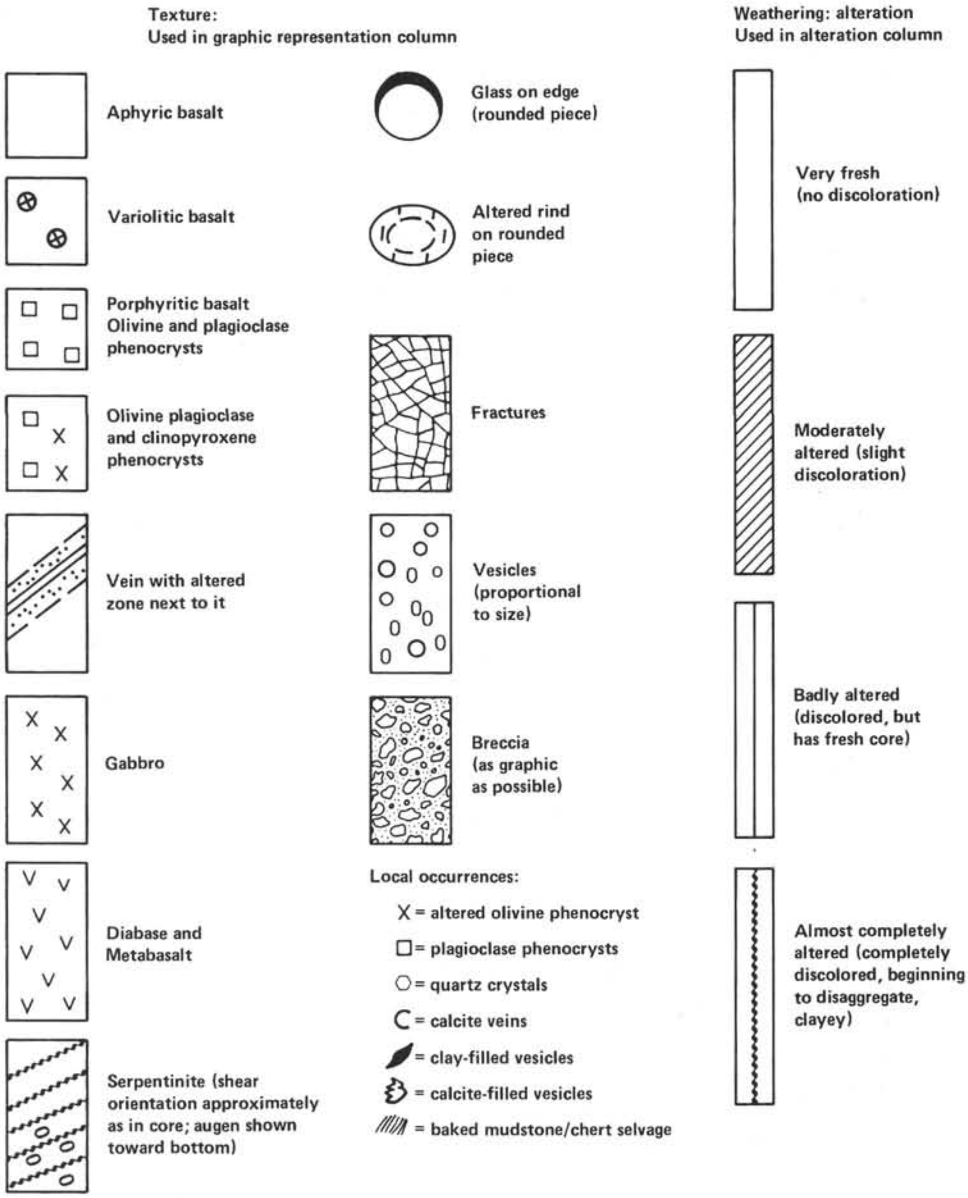


Figure 12. List of symbols for igneous rocks.

Table 2. Summary of specifications of Gearhart-Owen well-logging tools, Leg 64.

Tool	Tool Specifications: Diameter (in.)	Length (ft)	Minimum Hole Size (in.)	Maximum Pressure (PSI)	Maximum Temperature (°F)	Log Rate (ft/min)	Units	Purpose/Remarks
Induction log with gamma ray (IL/GR)	3.5	20–5	6	15,000	325	60	ohm-m (IL)	Resistivity/conductivity
Deep laterlog (LL) (with GR)	3.5	20–5	6	15,000	325	35	ohm-m	Resistivity/conductivity
Neutron log (NL) (epithermal, non-compensated; with GR)	3.5	F	4.5	15,000	300	30	API units (cts/s)	Porosity
Temperature log (TL)	7/8	2–5	2	15,000	300	40	°C	Temperature
Compensated density log (CDL)	4	8–5	5	20,000	303	30	g/cm^3	Saturated bulk density
Compensated sonic velocity log (CSVL) with seismic spectrum (SS) and sonic formation amplitude log (SFAL)	3.5	11–6	6	15,000	300	35	volts/ft	Continuous compressional-wave velocity measured over 2-ft interval; fracture information from attenuation of SS
Caliper log (CL)	3.5	6–11	4.5	15,000	300	30	cm	Hole diameter

Table 3. Leg 64 logging summary.

Hole/ Run No.	Water Depth from Rig Floor (m)	Total Depth from Rig Floor (m)	Open Ended Pipe at (m)	Fluid in Hole	Total Time for Logging (hr)	Logs Recorded	Depth from–to (m) (rig floor)	Observations
474A								No logging
1	3043	3669	3718	Mud 8.9	27.25	*Density	3585–3179	
						Gamma-Ray	3585–3179	
						Caliper	3585–3179	
						Temperature	3178–3585	Recorded going down
2						*Sonic	3580–3180	
						Gamma-Ray	3580–3180	
						Caliper	3580–3180	
3						Variable density	3580–3180	
						Gamma-Ray	3580–3180	
4						*Guard	3668–3180	
						*Neutron	3668–3180	
						*Gamma-Ray	3668–3180	
5						Induction	3669–3180	Misrun because of gamma-ray
						Gamma-Ray	3669–3180	
6						*Temperature	3669–3180	Recorded going up
475								
	2680	2846						No logging requested
475A								
	2591	2607						No logging requested
475B								
	2629	2725						No logging requested
476								
	2429	2723.5						No logging—impossible to release core bit
477								
1	2020	2211		Seawater	6.00	*Gamma-Ray	2204–2020	Logging through drill pipe with bottom plug in bottom hole assembly
						*Neutron	2204–2020	Mud in annulus
2						*Temperature	2202–2020	
477A								
1	2020	2287	2122	Mud 1.32	20.25	*Density	2284–2122	
						*Gamma-Ray	2284–2122	
						*Caliper	2284–2122	
						*Temperature	2122–2284	
2						*Sonic	2122–2284	
						Gamma-Ray	2122–2284	
						Caliper	2122–2284	
3						*Guard	2282–2021	
						*Neutron	2282–2021	
						Gamma-Ray	2282–2021	
4						Induction	2281–2121	
						Gamma-Ray	2281–2121	
5						Gamma-Ray	2122–2021	
						*Neutron	2122–2021	
6						*Temperature	2284–2100	
477B								
	2020	2024.5						No logging requested
478								
1	1913	2377	2026	Mud 1.32	18.5	*Density	2377–2027	
						*Gamma-Ray	2377–2027	
						*Caliper	2377–2027	
						*Temperature	2377–1900	
2						*Sonic	2377–2253	Tool stuck in hole at 2250 meters
						Gamma-Ray	2377–2253	Parted line at tool connection
						Caliper	2377–2253	Tried to fish—failed—abandoned logging
3		2250	2007			*Guard	2245–2008	For runs 3 and 4—impossible to record below stuck sonic
						*Neutron	2245–2008	
						Gamma-Ray	2245-2008	
4		2250	2007			*Induction	2245–2008	
						Gamma-Ray	2245–2008	
479								
1	766	1206	859	Mud 1.32	13.0	*Density	1194–860	
						*Gamma-Ray	1194–860	
						*Caliper	1194–860	
						*Temperature	860–1194	Recorded going down
2						*Sonic	1194–860	
						Gamma-Ray	1194–860	
						Caliper	1194–860	
3						*Guard	1194–860	
						*Neutron	1194–860	
						Gamma-Ray	1194–860	

Table 3. (Continued).

Hole/ Run No.	Water Depth from Rig Floor (m)	Total Depth from Rig Floor (m)	Open Ended Pipe at (m)	Fluid in Hole	Total Time for Logging (hr)	Logs Recorded	Depth from–to (m) (rig floor)	Observations
479								
4						*Induction	1194–860	
						Gamma-Ray	1194–860	
5						*Temperature	860–1194	Recorded going down Thirty minutes on bottom
480								
	674.5	826.5						No logging requested
481								
	2016.5	2064						No logging requested
481A								
1	2016.5	2400.5	2111	Mud 1.32	20.0	*Density	2395–2111	
						Gamma-Ray	2395–2111	
						Caliper	2395–2111	
						*Temperature	2111–2397	
2						*Sonic	2395–2111	
						Gamma-Ray	2395–2111	
						*Caliper	2395–2111	
3						Guard	2395–2111	Misrun
						Neutron	2395–2111	Tool did not work
						Gamma-Ray	2395–2111	
4						*Guard	2395–2111	Number 3 repeat run
						*Neutron	2395–2111	Ok
						*Gamma-Ray	2395–2111	
5						*Induction	2395–2111	
						Gamma-Ray	2395–2111	
6						*Temperature	2395–2111	

* Indicates logs which are illustrated in site chapters.

ity, rather than the natural gamma ray. This tool actually detects the secondary electron emission existing in most formations by decay of certain elements in the radioactive families of uranium, thorium, and potassium (^{40}K). Shales commonly have the greatest concentrations of such elements. The neutron logging tool uses a ^3He-filled detector which responds to thermal neutrons from a source. Neutron capturing is more pronounced in formations containing hydrogen (oil, water, gas), so that higher neutron count rates indicate lower porosities. The bore-hole dimensions are monitored by a four-arm caliper tool. Temperature is logged with a linear thermistor probe with 0.1°C accuracy.

The excellent set of logs obtained on Leg 64 were not subjected to detailed interpretation or calculation of formation factors. Original tapes are available from the DSDP Information Handling Group. The logs have been scaled and correlated with the lithologic columns and physical properties in a series of illustrations in each site chapter. These provide significant information on the depth relationships of sills and their sub-unit boundaries, the position and thickness of various mass flow beds, the onset of diagenesis, the width of contact zones around sills, and clues to hard and soft lithologies that for some reason or another were not recovered or at least not undisturbed.

At Site 477, exceptionally high temperatures, beyond the tool limits, which were encountered only 260 meters sub-bottom (>150°C) quickly terminated the logging runs. In addition, there were no aluminum liners aboard ship which could withstand those temperatures, although this had been recommended in advance by the Ocean Crust Panel. The plastic liners melted above 87°C.

Photography

As supplements to the core descriptions, sets of color and black-and-white slides and photographs of whole cores are available for consultation at both repositories. In addition, negatives in color and black and white for close-up documentation of special structures are archived at the Deep Sea Drilling Project. Table 4 lists those from Leg 64. The undisturbed hydraulic piston cores from Holes 480 and 481 subsequently have been filmed in black-and-white and color on a very detailed level by T. Chase, U.S. Geological Survey, Menlo Park, using a continuous-feed microfilm camera. Hemipelagic sediments recovered on Leg 64 were highly disturbed, generally showing drab brownish to olive hues, and therefore appear very dark on the black-and-white whole-core photographs at the end of each site chapter. They are, however, presented as a visual record of the type and quality of the archived cores.

Biostratigraphic Conventions

The oldest datable sediments recovered during Leg 64 are less than 5 m.y. old. Microfossil abundances varied considerably owing to dissolution, biogenic productivity, and redeposition. Precise age assignments were hampered by the high sedimentation rates, young sequences, and provinciality of some of the forms. Diatoms are most abundant. In the Guaymas Basin, accumulation rates are so rapid than zonal boundaries were rarely encountered. In order to derive as much age information as possible, a modified biographical zonal scheme (Fig. 13) was applied which emphasizes a datum-level ap-

Table 4. Leg 64 detailed core negatives.

Negative Number	Detailed Core Description
Black and White	
1	474-4-3, 55–70 cm
2	474-6, 110–120 cm
3	474-6-5, 120–130 cm
4	474-6-6, 45–60 cm
5	474-6-6, 85–95 cm
6	474-10,CC, 0–10 cm
7	474A-9-4, 50–60 cm
8	474A-9-4, 75–85 cm
9	474A-9-4, 120–130 cm
10	474A-13-2, 80–100 cm
11	474A-13-3, 75–95 cm
12	474A-14-5, 75–95 cm
13	474A-21-5, 0–30 cm
14	474A-21-5, 30–60 cm
15	474A-21-5, 60–90 cm
16	474A-21-5, 90–120 cm
17	474A-22-3, 10–30 cm
18	474A-22-3, 30–55 cm
19	474A-23-2, 45–75 cm
20	474A-33-2, 115–150 cm
21	474A-36-1, 0–25 cm
22	474A-36-2, 50–75 cm
23	474A-38-1, 0–40 cm
24	474A-38-1, 40–80 cm
25	474A-38-1, 70–80 cm
26	474A-39-3, 135–150 cm
27	474A-39-3, 135–150 cm
28	474A-40-2, 60–80 cm
29	474A-41-1, 15–25 cm
30	474A-41-1, 75–85 cm
31	474A-41-3, 15–25 cm
32	474A-41-5, 125–135 cm
33	474A-42-2, 100–110 cm
34	474A-42-2, 100–120 cm
35	475-15-3, 30–40 cm
36	475-15-3, 45–65 cm
37	475-15-3, 80–100 cm
38	475-17-5, 10–40 cm
39	475-17-5, 30–40 cm
40	476-7-2, 85–120 cm
41	476-20-7, 5–35 cm
42	476-21-4, 10–20 cm
43	476-21-4, 45–75 cm
44	476-25-1, No. 4 and No. 5
45	476-29-1, No. 6
46	477-3-1, 40–60 cm
47	477-3-2, 0–20 cm
48	477-7-2, 0–10 cm
49	477-11-2, 60–75 cm
50	477-16-4, 10–25 cm
51	477-19-2, 65–75 cm
52	477A-1-1, No. 1, View No. 1
53	477A-1-1, No. 1, View No. 2
54	477A-1-1, No. 1, View No. 3
55	477A-2-3, No. 9
56	477A-2-3, No. 9
57	477A-7-1,CC
58	477A-11-1, 0–12 cm
59	478-2-2, 85–100 cm
60	478-2-2, 120–135 cm
61	478-2-3, 15–30 cm
62	478-2-6, 50–60 cm
63	478-8-4, 120–135 cm
64	478-11-6, 35–60 cm
65	478-16-2, 15–30 cm
66	478-35-1, 0–65 cm
67	478-35-1, 10–30 cm

Table 4. (Continued).

Negative Number	Detailed Core Description
Black and White	
68	478-35-1, 55–65 cm
69	478-38,CC, No. 2 and 3
70	478-39-1, 60–64 cm
71	478-40-2, 120–150 cm
72	478-42-2, No. 1G
73	478-42-3, No. 3B
74	478-44-1, No. 1E
75	478-44-5, No. 1D, 70–80 cm
76	478-44-6, 85–95 cm
77	479-5-1, 95–105 cm
78	479-13,CC, 0–10 cm
79	479-17-4, 50–65 cm
80	479-27-5, 123–135 cm
81	479-27,CC
82	479-29-1, 0–20 cm
83	479-29-3, 110–120 cm
84	479-34-5, 140–150 cm
85	479-35-3, 95–110 cm
86	479-38-4, 25–35 cm
87	479-38-4, 25–35 cm
88	479-38-4, 25–35 cm
89	479-38-5, 110–120 cm
90	479-39-1, 25–40 cm
91	479-39-2, 130–140 cm
92	479-47-2, 125–145 cm
93	479-47-3, 15–45 cm
94	479-47-3, 45–75 cm
95	479-47-3, 75–105 cm
96	479-47-3, 105–135 cm
97	479-47-5, 50–60 cm
98	480-P3-2, 70–85 cm
99	480-P5-3, 105–130 cm
100	480-P8-3, 65–80 cm
101	480-P-10-3
102	480-P13-2, 60–80 cm
103	480-P13-2, 60–80 cm
104	480-P13-3, 15–35 cm
105	480-P14-1, 110–125 cm
106	480-P18-2, 25–50 cm
107	480-P19-1, 0–30 cm
108	480-P19-1, 30–60 cm
110	480-P19-1, 90–120 cm
111	480-P19-1, 120–150 cm
112	480-P19-2, 0–30 cm
113	480-P-19-2, 30–60 cm
114	480-P19-2, 60–90 cm
115	480-P19-2, 90–120 cm
116	480-P19-2, 120–150 cm
117	480-P19-3, 0–30 cm
118	480-P19-3, 30–60 cm
119	480-P19-3, 60–90 cm
120	480-P19-3, 90–120 cm
121	480-P20-1, 0–30 cm
122	480-P20-1, 30–60 cm
123	480-P20-1, 60–90 cm
124	480-P20-1, 90–120 cm
125	480-P20-1, 120–150 cm
126	480-P20-2, 0–30 cm
127	480-P20-2, 30–60 cm
128	480-P20-2, 90–120 cm
129	480-P20-2, 120–150 cm
130	480-P20-3, 0–30 cm
131	480-P20-3, 30–60 cm
132	480-P21-2, 0–30 cm
133	480-P21-2, 30–60 cm
134	480-P21-2, 34–45 cm
135	480-P26-2, 50–60 cm

Table 4. (Continued).

Negative Number	Detailed Core Description
Black and White	
136	480-P29-3, 85–135 cm
137	480-P29-3, A
138	480-P29-3, B
139	480-P29-3, C
140	480-P29-3, D
141	481-P2-2, 0–20 cm
142	481-P8-1, 75–105 cm
143	481-P8-2, 40–55 cm
144	481-P8-3, 0–15 cm
145	481-P8-3, 25–40 cm
146	481-P8-3, 30–70 cm
147	481-P8-3, 110–125 cm
148	481-P10-2, 90–105 cm
149	481A-14-4, 50–100 cm
150	481A-14-4, 55–65 cm
151	481A-14-4, 80–100 cm
152	481A-14-4, 95–135 cm
153	481A-14-4, 100–115 cm
154	481A-14-4, 120–135 cm
155	481A-15-1, 45–55 cm
156	481A-15-2, 15–30 cm
157	481A-17-1, 15–25 cm
158	481A-33-1, 50–70 cm
Color	
1	477A-1-1, No. 1
2	477A-1-1, No. 1
3	477A-1-1, No. 1
4	477A-1-1, No. 1
5	478-44-1, No. 1E
6	479-47-3, 8–52 cm
7	479-47-3, 38–82 cm
8	479-47-3, 68–112 cm
9	479-47-3, 88–142 cm
10	479-47-4, 1–36 cm
11	479-47-4, 24–65 cm
12	479-47-4, 55–96 cm
13	479-47-4, 84–125 cm
14	479-47-5, 1–37 cm
15	479-47-5, 24–66 cm
16	479-47-5, 44–125 cm
17	479-47-5, 50–60 cm
18	479-47-5, 55–96 cm
19	479-47-5, 114–150 cm
20	479-47-6, 1–37 cm
21	479-47-6, 27–68 cm
22	479-47-6, 57–98 cm
23	479-47-6, 85–127 cm
24	479-47-6, 98–140 cm
25	480 P3-2, 70–85 cm
26	480-P3-2, 70–85 cm
27	480-P5-3, 105–130 cm
28	480-P13-2, 60–80 cm
29	480-P18-2, 25–50 cm
30	480-P19-1, 0–30 cm
31	480-P18-1, 60–90 cm
32	480-P19-1, 90–120 cm
33	480-P19-1, 120–150 cm
34	480-P19-2, 0–30 cm
35	480-P19-2, 30–60 cm
36	480-P19-2, 30–60 cm
37	480-P19-2, 60–90 cm
38	480-P19-2, 90–120 cm
39	480-P19-2, 120–150 cm
40	480-P19-3, 0–30 cm
41	480-P19-3, 30–60 cm
42	480-P19-3, 60–90 cm

Table 4. (Continued).

Negative Number	Detailed Core Description
Color	
43	480-P19-3, 90–120 cm
44	480-P20-1, 0–30 cm
45	480-P20-1, 30–60 cm
46	480-P20-1, 60–90 cm
47	480-P20-1, 90–120 cm
48	480-P20-1, 120–150 cm
49	480-P20-2, 0–30 cm
50	480-P20-2, 30–60 cm
51	480-P20-2, 60–90 cm
52	480-P20-2, 90–120 cm
53	480-P20-2, 125–150 cm
54	480-P30-2, 0–30 cm
55	480-P20-3, 30–60 cm
56	480-P21-2, 0–30 cm
57	480-P21-2, 30–60 cm
58	480-P21-2, 35–45 cm
59	480-P20-2 and P21-2 (24–62 cm)
60	480-P29-3, 85–135 cm
61	481-P2-2, 0–20 cm
62	481-P8-3, 0–15 cm

proach representing unique events in progressive floral and faunal evolution. Generally these define the initial (FAD: first appearance datum) and terminal (LAD: last appearance datum) occurrence of a species.

The accuracy of datum levels may be spurious, because ages are commonly determined by interpolation from magnetic stratigraphy, and microfossil events may be subject to locally diachronous paleoenvironmental shifts. It is based on the geomagnetic time scale of La Brecque et al. (1977) which was modified by Mankinen and Dalrymple (1979). General microfossil zonations (0–10 m.y.) are partly adopted from Barron et al. (1980), Martini (1971), and Riedel and Sanfilippo (1978).

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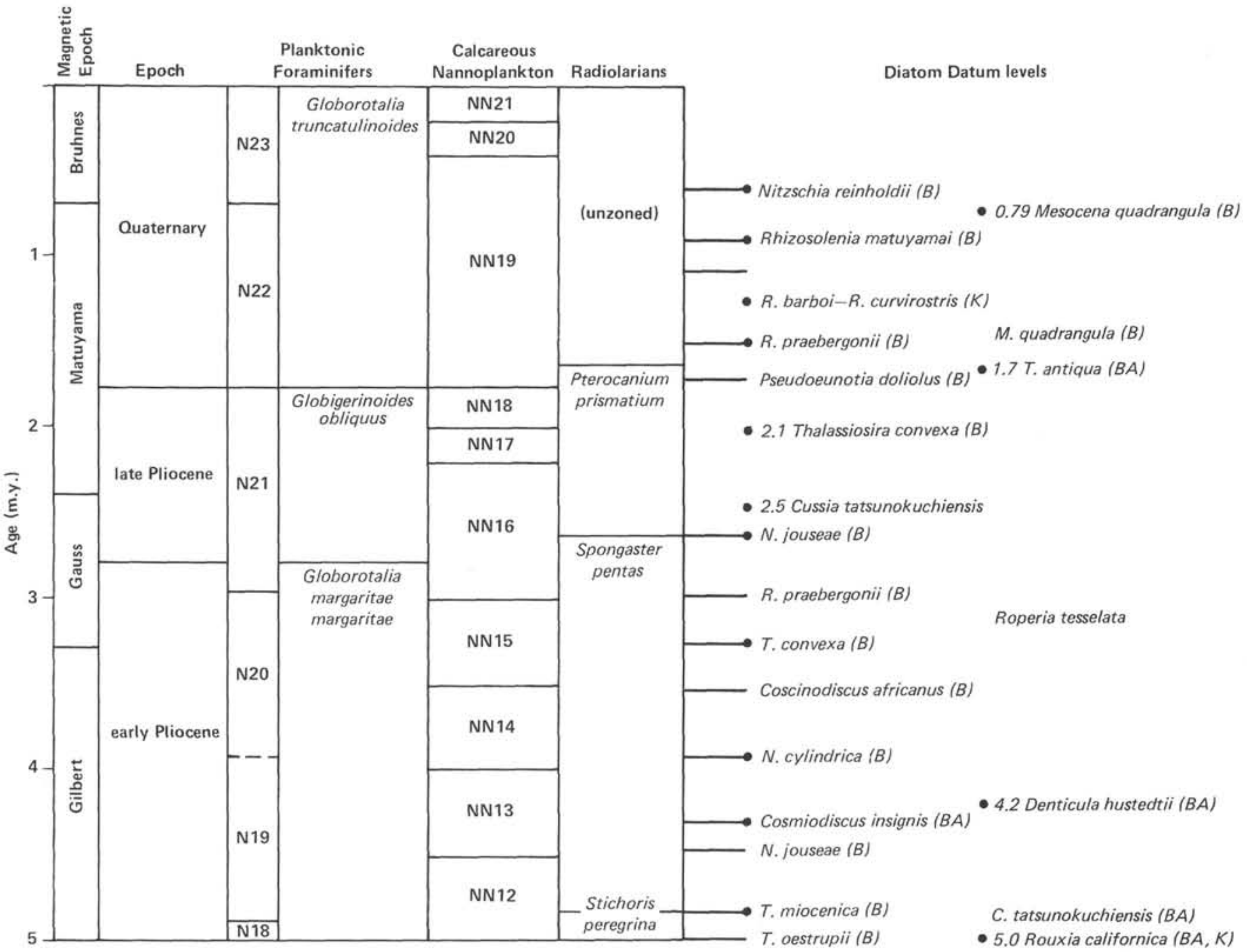

Figure 13. Summary diagram of biostratigraphic zonal schemes used on Leg 64. Only the diatom levels have been correlated directly with the paleomagnetic scale (LaBrecque et al., 1977). Radiolaria after Riedel and Sanfilippo (1978); nannoplankton after Martini (1971); diatom datum levels as established by Burckle (B) (1977, 1978), Barron (BA), and Koizumi (K) (both in Barron [1980]). (Large dots indicate last occurrences, bars indicate first occurrences. Numbers before species names indicate absolute dates, in m.y., of diatom datum levels.)