1. INTRODUCTION

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GENERAL OBJECTIVES

Leg 27 of the D/V *Glomar Challenger* was the sixth cruise of the drilling ship in the Indian Ocean in Phase III of the Project's operation. The ship sailed from Fremantle, Western Australia, on 1 November 1972 and returned to Fremantle 9 December 1972.

The primary objectives of this cruise were to study:

(1) The oceanic basement in the far Eastern Indian Ocean, believed by some to be the most ancient in the Indian Ocean.

(2) The paleo-oceanic environment of this area.

(3) The relationship of the oceanic and continental geologic record in this area.

Earlier in the year the *Glomar Challenger,* on Leg 22, crossed the eastern Indian Ocean from east to west at the latitude of north Australia. Later in the year she crossed, on Leg 26, from west to east essentially at the latitude of southern Australia. Leg 27 was to provide the link between these other two cruises in the eastern Indian Ocean. This Initial Report is being written while the Initial Reports of Legs 22 and 26 are being prepared; thus, there has been little opportunity for the authors of the three reports to compare their preliminary conclusions.

Sites were chosen (see Figure 1) to fulfill the primary objectives of the cruise within the time available and in a manner that would, hopefully, complement the holes drilled on adjacent legs. Where the age of basement was the primary goal, sites were located where the overlying sediments were relatively thin. North of Fremantle four sites were drilled through the sediments overlying the oceanic crust and, south of Timor, one site was drilled through sediments believed to overlie continental crust. Other sites were planned on the eastern Wallaby Plateau, to learn whether that Plateau was a microcontinent, and on the Naturaliste Plateau because Leg 26 was unable to drill as deep as planned at Site 258. These two sites were not attempted because of a mechanical malfunction which forced a premature termination of drilling operations on Leg 27 at Site 263.

Summary stratigraphic columns of the five sites drilled are shown in Figure 2. Of the four oceanic sites drilled, basalt was reached on three, and on the fourth (Site 263) basement was believed to be within a few meters when the hole was abandoned. The basalt encountered at Site 260 is thought to be a sill. Table 1 shows the ages of the oldest sediments at each site.

The thick, acoustically transparent sediments which drape the basement throughout the eastern Indian Ocean were found to be Cretaceous, especially Lower

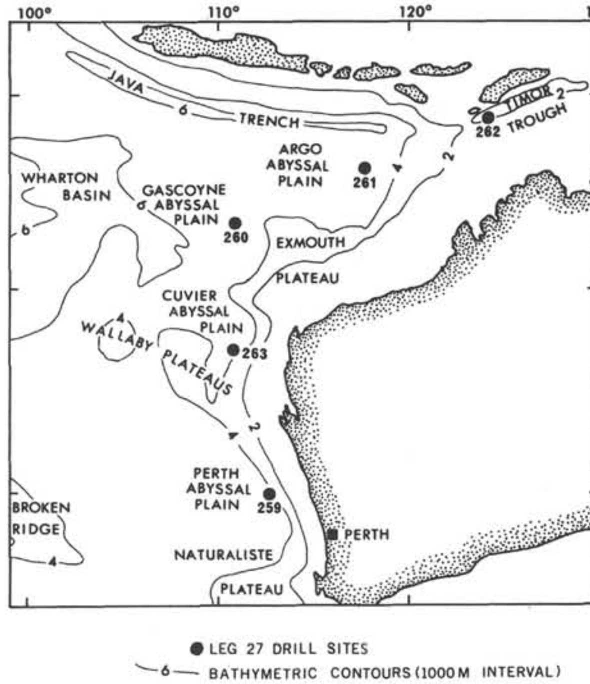


Figure 1. *Location of Leg 27 drill sites in the eastern Indian Ocean.*

Cretaceous. These sediments and, to a lesser extent, the overlying well-stratified horizontal turbidites were samples extensively and subsequently studied by a variety of techniques.

The results of this cruise showed that the eastern Indian Ocean basement off Australia is late Jurassic. Hence, the basement in this area is the oldest thus far reported from the Indian Ocean, and is, in fact, as old as the oldest known oceanic crust found anywhere in the world's oceans.

At Site 262, in the Timor Sea, 442 meters of sediment were penetrated and cored nearly continuously to obtain a complete section into the Pliocene. High salinity of interstitial water at this site suggests that the site is on or near a salt body.

OPERATIONS

The *Glomar Challenger* was at sea 38 days, traveling about 8000 km (3736 n.m.) with an average underway speed of 16.6 km/hr (9.5 kts). Table 1 shows the location, water depth, and recovery from each of the sites.

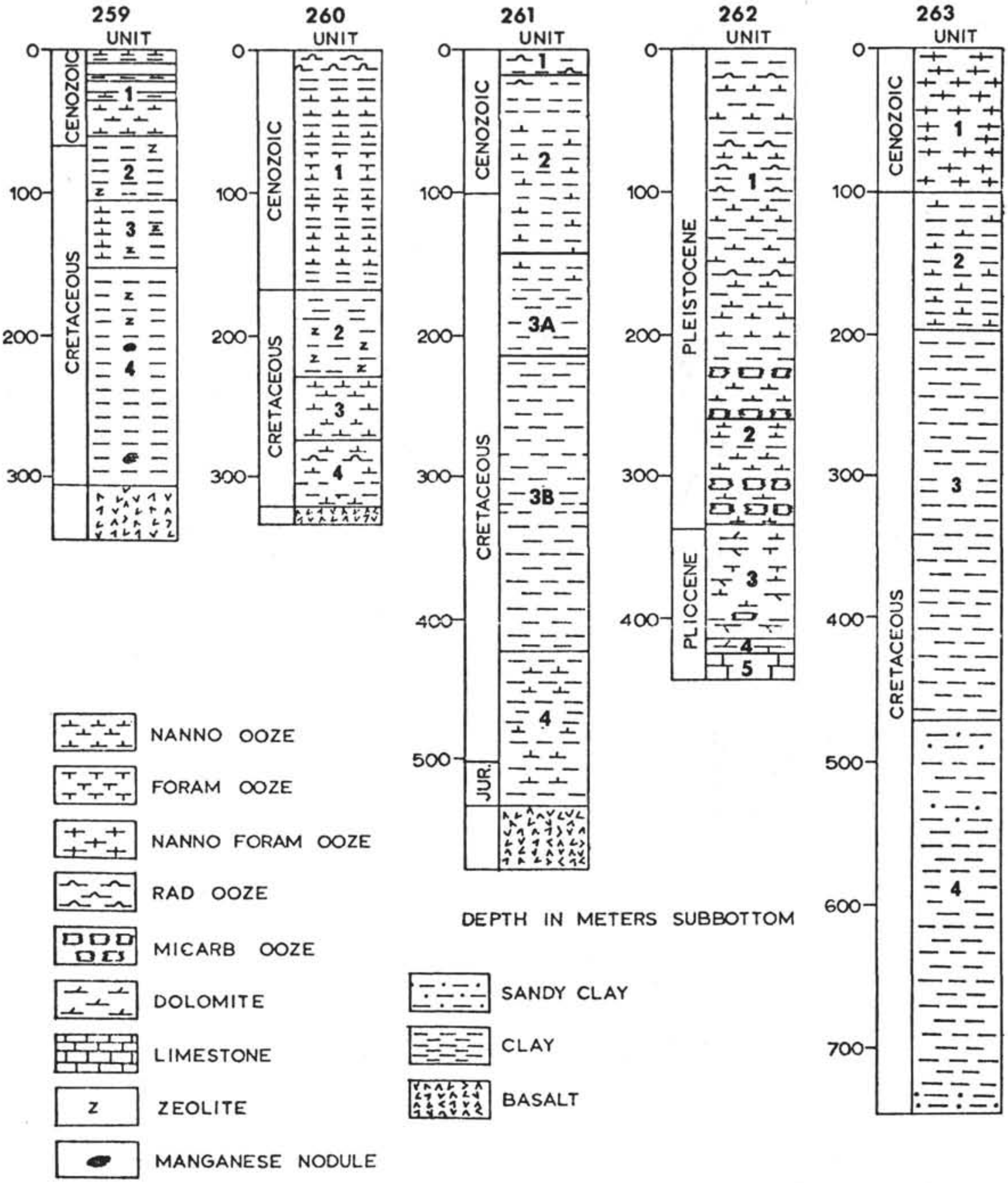


Figure 2. *Generalized stratigraphic columns from Leg 27 drill sites. Numbers refer to sedimentary units recognized at each site.*

Accounts of the ship's operations are reported in local time. All other records are expressed in GMT.

EXPLANATION OF SHIPBOARD TECHNIQUES

Site Numbering and Depth Conventions

Each site number represents a hole or group of holes drilled at essentially the same location. On Leg 27 only one hole was drilled at each site.

Cores were taken by dropping a core barrel down the drill string and coring for a maximum of 9.5 meters as measured by lowering the drill string. The core was contained in a plastic liner 9.28 meters long and a 0.20-meter core catcher attached to the base of the core barrel. Core recovery was variable and the core liner was seldom completely full.

After removal from the core barrel the plastic liner was cut into 1.5-meter sections beginning from the lowest occurrence of sediment within the liner. The 1.5-meter sections were labeled from 1 to (as many as) 6, beginning at the top of the core. When partial recovery occurred the recovered material was assumed to represent the top of the cored sequence, and the core catcher was assumed to contain material from immediately below the lowest sediment.

TABLE 1
Coring Summary of Sites Drilled on Leg 27

Site	Date (1972)	Latitude	Longitude	Water Depth (m)	Penetration (m)	No. of Cores	Cored (m)	Recovered (m)	Oldest Sediment
259	3-7 Nov	29°37'S	112°42'E	4712	346	41	346	249.0	Earliest Aptian
260	11-14 Nov	16°09'S	110°18'E	5709	331	20	169	56.7	Middle Albian
261	17-22 Nov	12°57'S	117°54'E	5687	579	39	342	125.8	Late Oxfordian
262	24-26 Nov	10°52'S	123°51'E	2315	442	47	442	365.5	Pliocene
263	1-6 Dec	23°20'S	110°58'E	5065	746	29	271	163.5	Barremian or middle Albian
				Totals:	2444	176	1570	960.5	

Handling of Cores

After the core was cut into sections the sections were sealed, labeled, and brought into the core laboratory for processing. Routine physical measurements were carried out on selected core sections as follows:

(1) All full core sections were weighed for mean bulk density determinations.

(2) GRAPE analysis for bulk density and porosity was carried out on most sections.

(3) Sonic velocity measurements were conducted on undisturbed cores using a Hamilton Frame.

After completion of the physical measurements the core liner was cut and the core split into halves. Soft sediments were split with a cheese cutter; indurated materials were cut with a band saw or diamond saw.

One of the core halves was designated as a working half; the other an archive half. Samples for grain size, carbon-carbonate analyses, X-ray mineralogy, interstitial water chemistry, and shore-based studies by individual scientists were taken from the working half. Larger samples were taken at approximately 50-meter intervals for organic geochemical analyses. The working half was then sent to the paleontology laboratory where it was sampled for post-cruise paleontologic studies.

The archive half was cleaned and smoothed with a spatula to bring out the natural colors and sedimentary structures. The colors, textures, structures, and compositions of each lithologic unit were recorded on a standard visual core-description sheet. At least one smear slide was taken from each section, usually at 75 cm if the core was uniform. In heterogeneous cores, a smear slide was taken from each major unit. After the description was completed, the core was photographed, sealed, and deposited in cold storage.

Shipboard Geochemical Techniques

Aboard ship only analyses of *p*H, alkalinity, and salinity were conducted routinely. A 6-cm length of whole core was taken at approximately 50-meter intervals of subdepth, except at Site 262 where samples were taken at 10-meter intervals. Enough sample was squeezed to yield approximately 20 ml of millipore-filtered interstitial water, through utilization of a stainless steel squeezer (developed at Woods Hole Oceanographic Institution, Woods Hole, Massachusetts) mounted in a Carver lab press.

Except for a very small volume used in shipboard analyses, this water was packaged in 2 aliquots (one in a fused glass ampoule and one in a fused polyvinyl tube), and stored at 4°C. In addition, a 1-ml sample in a glass ampoule was sent to Dr. Irving Friedman, U.S.G.S., Denver, Colorado. At Site 262 samples were retained by P. J. Cook for subsequent shore analysis.

The squeezed sediment was heat-sealed in a plastic bag and stored at 4°C.

The standard samples from all sites (the two water samples and squeezed sediment), were shipped to Scripps Institution of Oceanography, La Jolla, California, for archive storage.

A small quantity of interstitial water, removed from the bulk prior to Millipore filtration, was allowed to equilibrate to laboratory temperature (20° to 23°C) and was then used for *p*H, alkalinity, and salinity determinations.

*p*H was determined on all samples by inserting interstitial water into a glass capillary electrode with a disposable syringe. This is referred to as the "flow-thru" *p*H. In the softer sediments a "punch-in" *p*H was also determined by inserting *p*H electrodes directly into the sediment before squeezing. The *p*H electrodes for both methods are plugged into an Orion digital millivoltmeter.

These readings are converted to *p*H using the following formula:

$$pH = 7.41 + \frac{EMF_{7.41\ buffer} - EMF_{sample}}{\frac{\Delta EMF}{\Delta pH}}$$

$$\frac{\Delta EMF}{\Delta pH}\ (slope) = \frac{EMF_{4.01\ buffer} - EMF_{7.41\ buffer}}{pH^{1}_{7.41\ buffer} - pH^{1}_{4.01\ buffer}}$$

[1]Temperature corrected value.

Alkalinity was measured by potentiometric titration of a 1-ml aliquot of interstitial water with a standard (assumed to be 0.1 N) HCl solution, using a methyl red/blue indicator.

$$\text{Alkalinity (meq/kg)} = (\text{ml HCl})\,(97.752)$$

Salinity was calculated from the fluid's refractive index, as measured on a Goldberg optical refractometer (Model 1040Z), using the ratio:

$$\text{Salinity } (^{0}/_{00}) = 0.55\,\triangle N, \text{ where } \triangle N = \text{refractive index difference} \times 10^4.$$

Local surface sea water was regularly examined by each of the above methods for reference.

Physical Properties Testing

The objectives of the physical properties program of Leg 27 were: (1) to provide those measurements of immediate interest to the onboard scientific staff; (2) to determine physical properties as thoroughly as time would allow over the full cored depth; (3) to measure the vane shear strength of the relatively undisturbed soft sediments recovered and examine the adequacy of such measurements made onboard *Glomar Challenger;* and (4) to examine the methodology and accuracy of some shipboard procedures for measuring basic sediment properties. These objectives were to be accomplished primarily through shipboard sampling and testing and supplemented with additional testing at the Naval Civil Engineering Laboratory (NCEL).

The planned at-sea testing program was to determine wet bulk density (by Gamma Ray Attentuation Porosity Evaluator [GRAPE] syringe, water-displacement, and gross section-weight methods), sound velocity, porosity, water content, vane shear strength, and residual pore pressure. All are performed in the *Glomar Challenger* sediment laboratory soon after a core has been retrieved and cut into 150-cm sections. Each of these tests measures a value which will change as time elapses and the cored sediment adjusts to its new environment. Land-based testing was for determination of grain density and Atterberg limits, and to determine water content and bulk wet density for comparison with shipboard data.

The testing program for each site was based on the site-coring plan and the type and quantity of sediments expected to be recovered. Many of the tests have a limited range of material on which they may be run. Vane shear testing is limited to the softer fine-grained sediments and was concentrated in the surface cores, the area of highest engineering significance. The syringe and section-weight bulk density tests are also more significant when made on softer materials, while density by the water-displacement method is more easily determined on stiff or semilithified sediments. At some sites noncontinuous coring was planned over the upper 100 or 150 meters if sediment was suspected to be primarily detrital. Reliable indication of the presence of detrital sediments (turbidites) was obtained from the subbottom profile record and from site and area topography.

The actual testing, however, turned out to be more dependent on the quality of the sediments recovered. The amount of relatively undisturbed materials varied from site to site and could not be predicted well in advance. The detrital sediments, while they were most often coarse and too highly disturbed to test, were often interbedded with clay and ooze layers of sufficient quality for testing. In several cores from Sites 259, 260, and 261 there were numerous layers only mildly disturbed and vane shear testing was limited only by available time. Plans made at the beginning of the cruise for shore-laboratory consolidation tests and shipboard residual pore-pressure testing had to be changed, and those tests were eliminated from the program. Insufficient quantities of undisturbed sediment were recovered for a meaningful set of consolidation tests, while equipment and time problems forced cancellation of the pore-pressure measurement attempts.

Test data, excluding vane shear results, at each site are summarized and presented in a graphical display in the text or beside core and site summary sheets. These data show properties of the sediment in the laboratory after coring and have not been corrected for sampling disturbance. Reported measurements are from tests on relatively undisturbed sediment as determined visually by only mild distortion of layers. The testing methods are described in the chapter "Physical Properties measurements and Test procedures for Leg 27." of Part IV. Vane shear data and discussion are presented in the chapter "Vane Shear Strength Measurements on Leg 27 Sediment" of Part IV.

EXPLANATORY NOTES

Organization of this Volume

Part 1 of this volume consists of an introductory section outlining the scientific objectives of Leg 27 and a brief statement of the principal results. Also included is a description of shipboard techniques and an explanation of the conventions and symbols used in this volume.

Part II consists of site reports which provide the basic geological, geophysical, and paleontological data obtained at each site. Each report is organized in a standard format as follows:

Site Summary
Background and Objectives
Site Survey
Operations
Lithology
Paleontology
Geochemical Measurements
Physical Properties
Correlation of Seismic Reflection Profile with Drilling Results
Summary and Conclusions
Core Summaries

The results of a series of underway shipboard programs including geophysical surveying, sea-water sampling, and atmospheric sampling are reported in Part III.

Part IV contains a series of reports on shore-based geophysical studies dealing with the magnetic, density, and velocity characteristics of samples from Leg 27.

Shore-based chemical investigations are discussed in Part V. These deal primarily with major and trace element composition and interstitial fluid geochemistry of recovered sediments.

Geological studies reported in Part VI deal with various aspects of the deep-sea sediments and basalts recovered from Leg 27, and with comparisons between the geology of the western Australian margin and the eastern Indian Ocean.

Part VII contains a number of papers dealing with the shore-based paleontologic studies and Part VIII contains syntheses of the lithostratigraphy, biostratigraphy, and geologic evolution of the eastern Indian Ocean.

Responsibility of Authorship

The site reports are co-authored by the entire shipboard scientific party. In general, the site surveys, summaries and background, and objectives sections were written by J. Heirtzler and J. Veevers; operations by C. Morris; lithology by A. Carter (Site 261), P. Cook (Site 263), B. McKnight (Site 260), P. Robinson (Site 259), and P. Thayer (Site 262); paleontology by H. Bolli and V. Krasheninnikov (foraminifera), F. Proto-Decima (calcareous nannoplankton), and N. Renz (Radiolaria). Shipboard geochemical measurements were made by J. Pine and summarized by P. Cook. The sections on physical properties were written by K. Rocker.

Sediment Classification

CLASSIFICATION AND NOMENCLATURE RULES

I. Rules for class limits and sequential listing of constituents in a sediment name.

A. Major constituents

1. Sediment assumes name of those constituents present in major amounts (major defined as >25%). See example in rule IA3 (below).
2. Where more than one major constituent is present, the one in greatest abundance is listed farthest to the right. In order of decreasing abundance, the remaining major constituents are listed progressively farther to the left.
3. Class limits, when two or more major constituents are present in a sediment, are based on 25% intervals, e.g., 0-25, 25-50, 50-75, 75-100.

Example illustrating rules IA and IB and the resulting sediment names:

% Clay	% Nannos	
0-25	75-100	= Nanno ooze
25-50	50-75	= Clayey nanno ooze
50-75	25-50	= Nanno clay
75-100	0-25	= Clay

B. Minor constituents

1. At the discretion of the sedimentologist, constituents present in amounts of 10-25% may be prefixed to the sediment name by the term **rich.**
   Example: 50% nannofossils, 30% radiolarians, 20% zeolites would be called a **zeolite-rich rad nanno ooze.**
2. At the discretion of the sedimentologist, constituents present in amounts of 2-10% may be prefixed to the sediment name by the term **bearing.**
   Example: 50% nannofossils, 40% radiolarians, 10% zeolites would be called a **zeolite-bearing rad nanno ooze.**

C. Trace constituents. Constituents present in amounts of <2% may follow the sediment name with addition of the word **trace.** This again is at the discretion of the sedimentologist.

II. Specific rules for calcareous and siliceous tests.

A. Nannofossil is applied only to the calcareous tests of coccolithophorids, discoasters, etc.

B. The term **calcareous** or **siliceous**, depending on skeletal composition, is applied where no attempt is made to distinguish fossils as to major subgroup. Thus, if no percentage estimate is made, a mixture of radiolarians, diatoms, and silicoflagellates would be called **siliceous ooze.** Where this distinction is made, the appropriate fossil name is used.

C. Fossil tests are not qualified by a textural term unless very obviously redeposited.

D. Abbreviations, as nanno for nannofossil, rad for radiolarian, etc., may be used in the sediment name.

E. The term **ooze** follows a microfossil taxonomic group whenever it is the dominant sediment constituent.

F. The term **chalk** is used to designate a compacted calcareous ooze.

III. Clastic sediments

A. Clastic constituents, whether detrital, volcanic, biogenous, or authigenic, are given a textural designation. When detrital[2] grains are the sole clastic constituents of a sediment, a simple textural term suffices for its name. The appropriate term is derived from Shepard's triangle diagram (see Figure 3). The textural term can be preceded by a mineralogical term when this seems warranted.

B. When the tests of a fossil biocoenosis or authigenic and detrital grains occur together, the fossil or authigenic material is not given a textural designation (as per rule IIC).

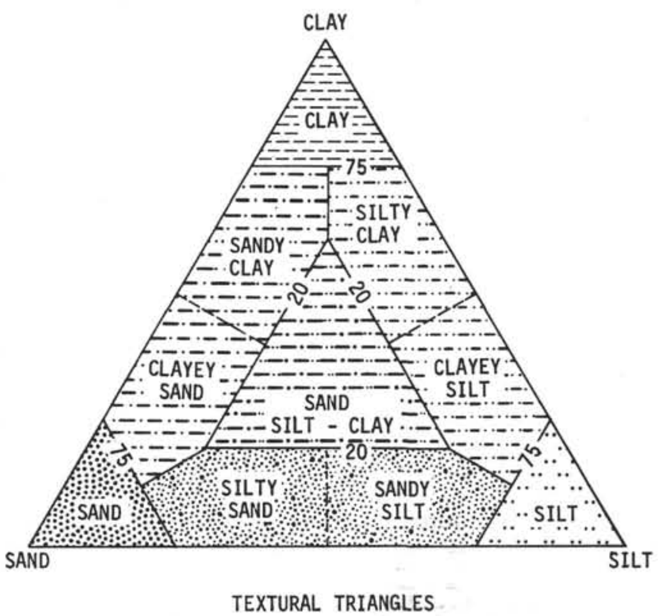


Figure 3. *Textural classification of clastic sediments, after Shepard (1954).*

IV. Volcanic and authigenic constituents

A. Volcanic constituents

Pyroclastics are given textural designations already established in the literature. Thus, **volcanic breccia** = >32 mm, **volcanic lapilli** = <32 mm to >4 mm, and **volcanic ash** = <4 mm. It is at times useful to further refine the textural designations by using such modifiers as **coarse** or **fine.** An ash wholly, or almost wholly, of glass shards is termed **vitric ash.**

[2]Detrital = all clastic grains derived from the erosion of preexisting rocks.

B. Authigenic constituents
1. Authigenic minerals enter the sediment name in a fashion similar to that outlined under rules 1A and B. Normally, as with a fossil biocoenosis, the authigenic minerals are not given a textural designation.
2. The terms **ooze** and **chalk** are applied to carbonate minerals of all types using the same rules that apply to biogenous constituents.

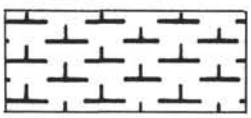
V. Color
A. Color is not formally part of the sediment name. However, its employment for sediment description is important particularly as it provides one of the criteria used to distinguish **pelagic** and **terrigenous** sediments.
B. Common usage dictates that it is no longer expedient to employ the term **red** for sediments (*usually* pelagic) which are various shades of red, yellow, and brown. The proper color designation should be used.

VI. General comments
A. Sediments are not divided into the two groups, pelagic and terrigenous, by the sediment classification.
B. The distinction between clastic and nonclastic fossil material is often not clear in the deeper pelagic realm. Therefore, fossil material receives a textural designation if, and only if, there is evidence of obvious and significant current transport. Similar consideration applies to volcanic material.

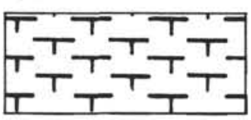
Lithologic Symbols

The lithologic symbols used on Leg 27 are as follows:

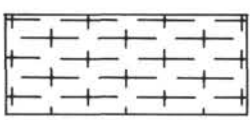
B1 Nannofossil ooze



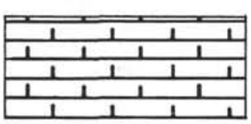
B2 Foraminiferal ooze



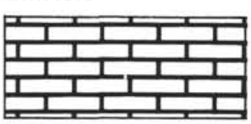
B3 Nanno-Foram or Calcareous ooze



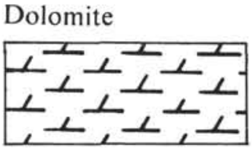
B4 Nannofossil Chalk



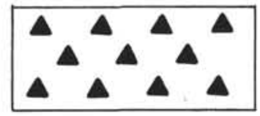
B8 Limestone



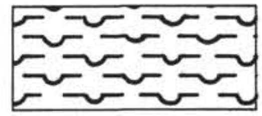
B9 Dolomite



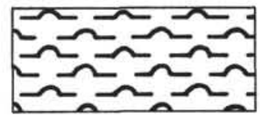
B12 Chert



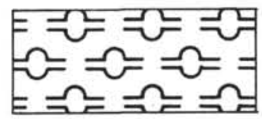
B13 Diatom ooze



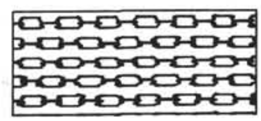
B14 Radiolarian ooze



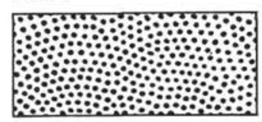
B15 Diatom-Rad or Siliceous ooze



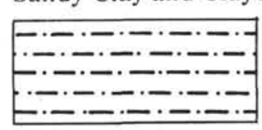
B19 Micarb ooze



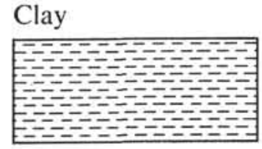
T1 Sand



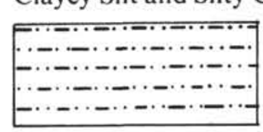
T2 Sandy Clay and Clayey Sand



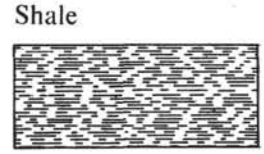
T3 Clay



T4 Clayey Silt and Silty Clay

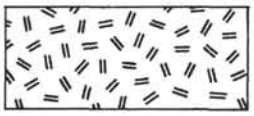


T9 Shale

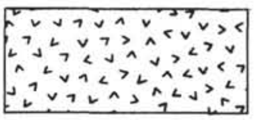


03 Breccia

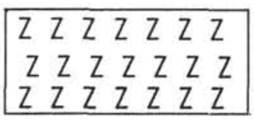
V1 Volcanic ash



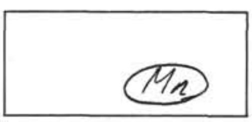
V5 Basic Igneous



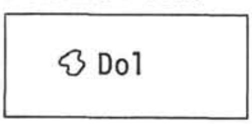
A1 Zeolite



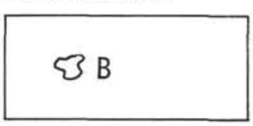
A2 Manganese Nodule



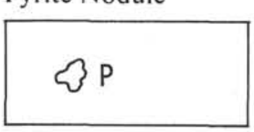
Dolomite Nodule



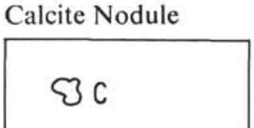
Barite Nodule



Pyrite Nodule



Calcite Nodule



For constituents present in amounts of 2-10%, a letter or symbol is sometimes sparsely overprinted over the regular lithologic symbols. The letters and symbols used in this volume are as follows:

F = Foraminifera
N = Nannofossil
D = Diatom
R = Radiolaria
Z = Zeolite
G = Glauconite
S = Sponge Spicules

These symbols have been used on some core and site summary forms. Where complex lithologies occur, each major constituent is represented by a vertical bar. The width of each bar corresponds to the percentage value of the constituent it represents in the manner shown on Figure 4. It will be noted that the class limits of the vertical bars correspond to those of the sediment classification. With this system of graphical representation, the rich portion of the major constituents and the minor constituents may be shown. In some cases it is not possible to show all major and rich constituents graphically; here the sedimentologist must make a value judgment, showing those components most geologically significant.

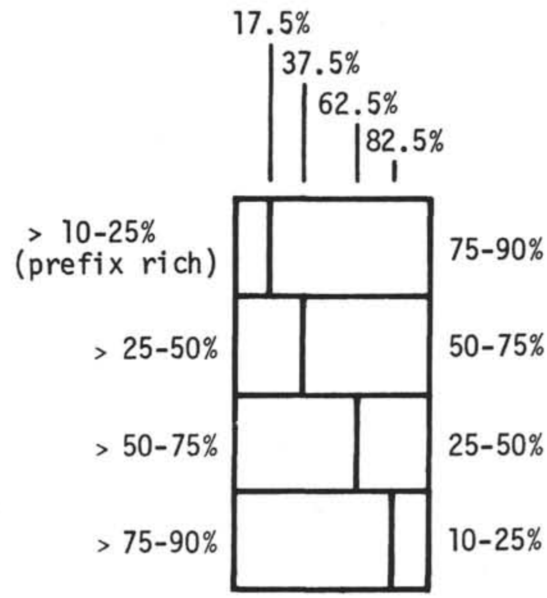


Figure 4. *Vertical bar width representations of class limits.*

Smear Slides

Smear slides were used extensively for mineral identification onboard ship. Experience from previous legs has shown that quantitative estimates of constituents in smear slides may be in error by as much as 20-30%, particularly for the major constituents. The smear slide determinations have been revised and updated using the results of shore-based studies, particularly, X-ray mineralogy and grain size data.

Core Forms

The core summary forms at the end of each site report contain the basic lithologic and paleontologic data. X-ray data are from the DSDP X-ray mineralogy laboratory. Wherever possible textures are based on the grain-size determinations of the DSDP sedimentology lab. Where these data are not available, the textures were estimated from smear slides.

The colors reported on the core forms were determined onboard ship using a Munsell or GSA color chart. The colors of carbonate sediments will often fade or disappear with time. Colors particularly susceptible to rapid fading are purple, light and medium tints of blue, light bluish gray, dark greenish black, light tints of green, and pale tints of orange. These colors change to white or yellowish white or pale tan.

Paleontologic zones are preceded by a letter designating the fossil group, i.e. N-calcareous nannofossils, D-diatom, R-radiolaria, Pm-palynomorph, F-foraminifera, Cs-calcisphaerulidae, O-ostracods, Ms-mollusks, Fd-fish debris. These letters are also used to indicate fossil groups in the "others" column. Fossil abundance and preservation are indicated by letter codes as follows:

Abundance—F, flood; A, abundant; C, common; R, rare; Preservation—G, good; M, moderate; P, poor; VP, very poor; VVP, very, very poor.

Lithologic samples collected for shore-based studies are designated XM for X-ray mineralogy and GZ for grain size. The location of each sample is indicated next to the symbol. The numbers in the lithology-sample column show the locations of smear slides used in describing the sediments. The symbol □76 indicates the position of thin sections cut onboard ship.

Four degrees of drilling deformation were noted as follows:

slightly deformed

moderately deformed

highly deformed

△△△△ drilling breccia and watery material

The degrees of deformation represent a subjective determination by the sedimentologist describing the core. In general, slight deformation reflects slight bending of the bedding planes; moderate bending defines moderate deformation. In highly disturbed cores bedding planes are completely disrupted and smeared out parallel to the wall of the core liner. Extensive deformation is most common when drilling penetrates alternating hard and soft layers.

The geologic time scale used on Leg 27 is given in Figure 5.

ACKNOWLEDGMENTS

Selection of drilling sites was based largely on unpublished seismic profiles taken by Lamont-Doherty Geological Observatory, and further interpretation of the acoustic sequence at the drill sites was made by reference to unpublished seismic profiles made by the Australian Bureau of Mineral Resources, Geology and Geophysics. We express our gratitude to these institutions for their generous cooperation.

D. A. Falvey allowed us to use, in advance of publication, the regional physiographic chart (to lat. 29°S) used in this report. The extension of the chart to lat. 35°30'S is the work of S. Robins. R. Markl made available preliminary bathymetric charts for the region 29° to 35°S.

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REFERENCE

Shepard, F. P., 1954. Nomenclature based on sand-silt-clay ratios: J. Sediment. Petrol., v. 24, p. 151.

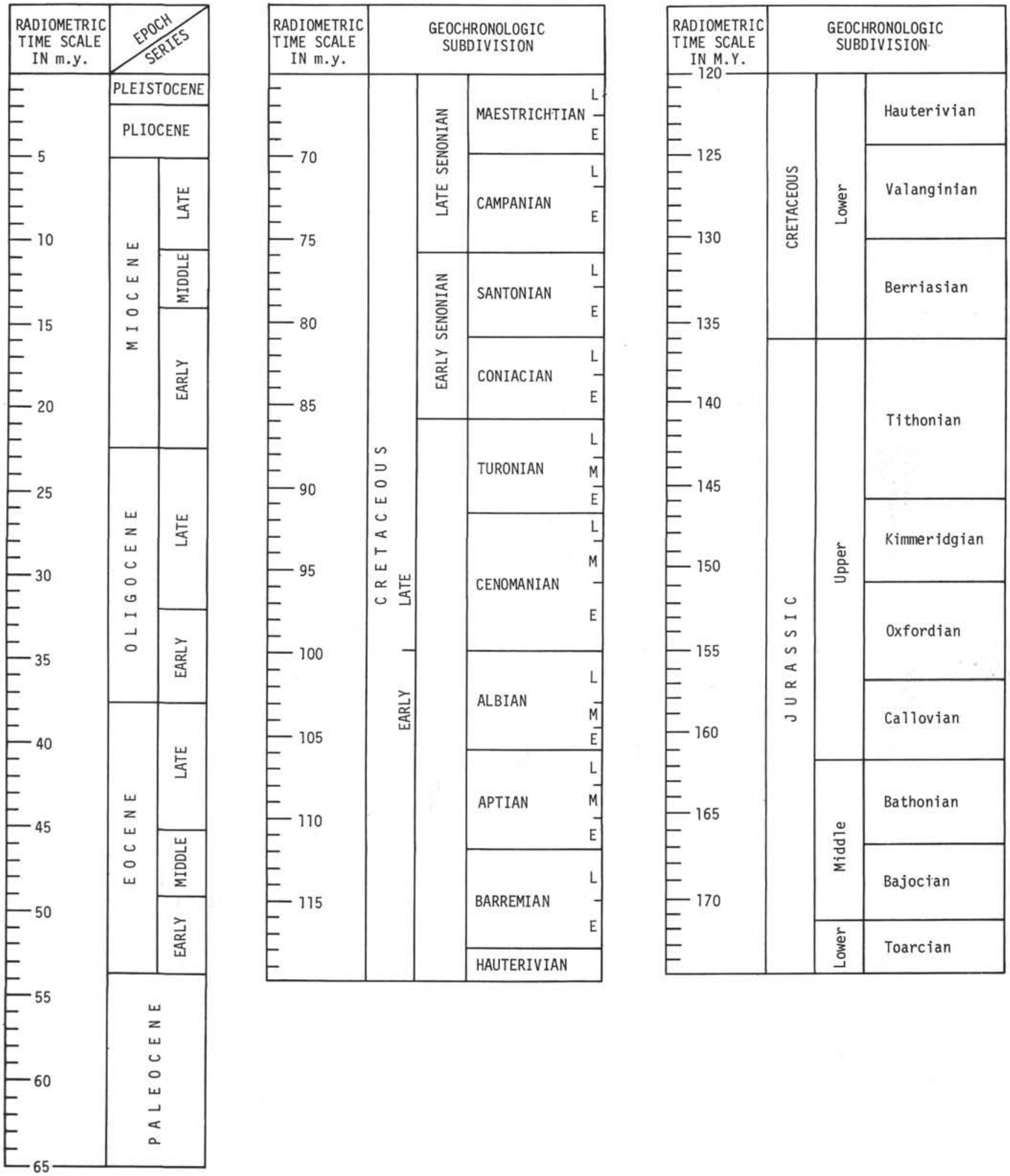

Figure 5. *Geologic time scale used on Leg 27.*