1. INTRODUCTION AND EXPLANATORY NOTES

Shipboard Scientific Party[1]

SCIENTIFIC GOALS

Four quite separate scientific problems faced us on Leg 22: (1) to find out the age and mode of formation of the Wharton Basin, (2) to obtain a detailed stratigraphic and biostratigraphic sequence on and to either side of the Ninetyeast Ridge, (3) to determine the mode of formation of the Ninetyeast Ridge, and (4) to date two of the three major unconformities in the Bengal Fan. To accomplish these goals the ship sailed from Darwin to Colombo with a plan to drill from 8 to 10 holes.

Wharton Basin

The discovery of many distinctive patterns of magnetic anomalies in the Indian Ocean had enabled McKenzie and Sclater (1971) to reconstruct the position of the southern continents back to the Late Cretaceous (Figure 1b, 1c). However, distinctive anomalies have not been recognized in the deeper portions of the Indian Ocean, in particular, the Wharton Basin east of Ninetyeast Ridge. This absence of information, combined with the complex geometry of the continents in the Late Cretaceous, make it impossible to produce exact reconstructions of the continents using only present sea-floor evidence.

In the classical reconstructions of Gondwanaland one of the major problems is the relative positions of India, Australia, and Antarctica. Smith and Hallam (1970) (Figure 1d) have demonstrated that the best geometrical fit of the continents at the 500-fathom contour is close to King's (1950) reconstruction as modified from DuToit (1937). In this geometry India abuts the northwestern flank of Antarctica, and there is a gap between northeastern India and Australia. Ahmad (1961), Crawford (1969), and Veevers et al. (1971) all prefer a reconstruction in which India is placed against northwest Australia. This fit is geometrically acceptable, but in this position the India-Australia-Antarctica combination cannot be fitted against the Africa-South America group without leaving large gaps between them. No overriding reasons exist for believing Gondwanaland to be one supercontinent, but as Smith and Hallam (1970) have pointed out, the stratigraphic unit of the Gondwana formations is evidence that all the fragments may at one time have been a single continent with few intervening gaps.

The key to the relative and changing positions of India and Australia may lie in the ocean floor between them. This sea-floor area includes the Bengal Fan, the central Indian Basin, the Ninetyeast Ridge, and the Wharton Basin. The Bengal Fan and the central Indian Basin to the south have prominent east-west magnetic anomalies that constrain the position of India relative to Antarctica (cf. McKenzie and Sclater, 1971). The Ninetyeast Ridge marks a transform fault along which India migrated northward during the Late Cretaceous and early Tertiary (McKenzie and Sclater, 1971). Only the history of the Wharton Basin is unknown, and thus the understanding of this basin may hold the key to the resolution of the relative movements of the three continents, India, Australia, and Antarctica, since upper Mesozoic times. Dietz and Holden (1971) arguing from the fit of Smith and Hallam (1970), have suggested that this basin may be pre-Mesozoic in age.

Distinctive magnetic anomalies have been recognized in the western portion of the Wharton Basin between the Ninetyeast Ridge and the Cocos-Keeling Ridge complex (Sclater and Fisher, in press). These anomalies become younger to the north and have been identified as 23 just south of the Java trench and 33 just north of a prominent bulge in the Ninetyeast Ridge at 20°S. Tentative identification has also been made of Anomalies 31 through 33 in the deep basin south of the Cocos-Keeling Ridge complex. East-west-trending anomalies were located at the site survey 22-3a at 8°30′S and 97°E and in the Argo Abyssal Plain (Falvey, 1972). All recognizable anomalies north of 20°S and west of 110°E trend east-west and provide evidence that the basin was formed by an east-west-trending ridge which spread north-south.

The depth of the Wharton Basin is generally below 5000 meters except for a region around Cocos-Keeling Island and an area including Christmas Island. From the Java trench to 20°S, the depth in general increases with increasing distance from the trench. This increase is not uniform and many prominent north-south gashes offsetting topography of different depths are shown in the Russian bathymetric chart of the area (Belousov et al., 1962).

The magnetics and topography in the basin are interpreted in the following manner:

1) The Wharton Basin is between 55 m.y.B.P. and 100 or perhaps 120 m.y.B.P. old.

2) The crust gets progressively older going southward from the trench.

3) The Wharton Deep may be 100 to 120 m.y. old.

4) The east-west magnetic lineations and general nonuniformity of the topography are evidence that the basin has been formed by an east-west-trending ridge offset by many north-south fracture zones, the three major ones being at 95°E, 98°E, and 105°E. The first two have a

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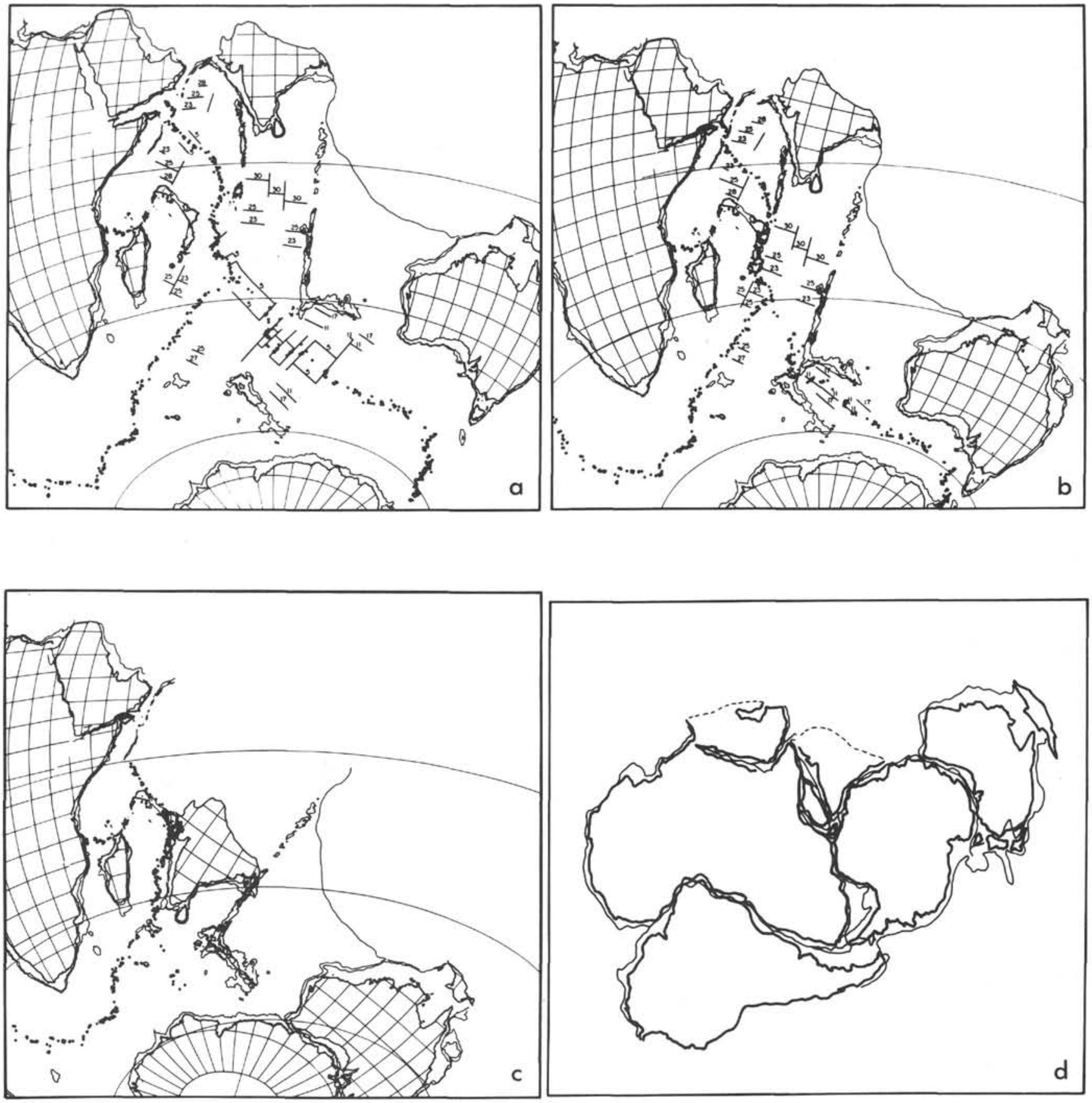

Figure 1. *Lambert equal area projection of various reconstructions of the southern continents after Laughton et al., 1970.* (a) *present,* (b) *35 m.y.B.P. reconstruction after McKenzie and Sclater (1971),* (c) *75 m.y.B.P. reconstruction after McKenzie and Sclater (1971),* (d) *Jurassic reconstruction after Smith and Hallam (1970.*

northward offset of roughly 500 km each and the third a southerly offset of almost the same amount.

5) The tectonic history of the Wharton Basin is complicated by the Cocos-Keeling complex and the bulge in the topography produced by the viscoelastic bulging of the plate as it descends into the trenth.

The Wharton Basin is thought to be younger than the Early Cretaceous. Unless spreading was very slow in the Cretaceous, almost all the present oceanic crust between India and Australia has been formed since this time. Magnetic anomalies south of Ceylon and north of Crozet Island define the exact relationship of India to Antarctica in the Late Cretaceous (Figure 1c from Laughton et al., 1972). They place India due west of Australia, separated from it by the Wharton Basin, Broken Ridge, and Kerguelen Plateau. With the east-west-trending anomalies recognized in the Wharton Basin by Sclater and Fisher (in press) it is difficult to see how India would be connected to Australia except by east-west spreading before the Cretaceous. However, such spreading would take India across the continental Kerguelen Plateau and Broken Ridge and, hence, is unlikely. Thus, this tentative interpretation of the Wharton Basin argues against fitting India close to western Australia and is rather weak evidence in favor of the position of India given by Smith ahd Hallam (1970).

Three Deep Sea Drilling sites in the Wharton Basin were chosen to test the proposed tectonic history of the basin and also to help date the oceanic crust in the regions where there are no distinctive magnetic anomalies. These sites were chosen in a triangle, with Site 211 on the ridge just south of the trench, Site 212 some 12° due south of the first site in the deepest part of the basin, and Site 213 parallel in latitude and some 17° to the east of the first site in the zone of distinctive magnetic anomalies which occurs just east of the Ninetyeast Ridge.

East-West Drilling Transect of the Ninetyeast Ridge

Among the most prominent features of the Indian Ocean are the numerous microcontinents and ridges not directly connected with active spreading centers. One such feature is the long, north-south-trending Ninetyeast Ridge which almost exactly marks the 90 degree east longitude. Tectonically, this ridge is thought to have been a major fracture zone in Late Cretaceous and early Tertiary times, marking the northward movement of India relative to a once-joined Antarctica and Australia. At the breakup of Australia and Antarctica the spreading direction in the Indian Ocean changed. McKenzie and Sclater (1971) tentatively suggested that the Ninetyeast Ridge was formed at this time by slow compression, the ridge having remained elevated ever since.

Outcropping Cretaceous and Tertiary calcareous material has been dredged and cored from the crest and flanks of the ridge (Funnell, 1971; Riedel, 1971). From this evidence it is presumed that the ridge has been above the carbonate compensation depth during much of the Tertiary.

Some important differences in depositional environment may have existed in the two basins on either side of the Ninetyeast Ridge. The Wharton Basin may be open to Deep Antarctic Bottom Water through the gap between Naturaliste and Broken ridges and via a deep fracture zone across the India-Australia Ridge. This would explain the bottom water being consistently colder to the east of the Ninetyeast Ridge. Both basins were formed by ridges spreading north-south, and anomaly 28 is found at the same latitude either side of its ridge. However, the Wharton Basin is the deeper of the two and the spreading axis was to the north, whereas in the central Indian Basin the axis was to the south. Tectonically, the Ninetyeast Ridge was a fracture zone which was active through the Cretaceous until anomaly 21 time. At this time or some time later the ridge in the Wharton Basin jumped further south to become a continuation of the ridge in the central Indian Ocean and began to separate Australia from Antarctica. At this time all motion on the Ninetyeast Ridge ceased. If this tectonic picture is correct, then sediment younger than anomaly 21 time 50 m.y.B.P. (early Eocene) should have exactly the same paleohistory on both sides of the ridge. On the other hand, if the Wharton Basin has remained fixed to Australia, older sediments in this basin would have remained more or less stationary during the period 50-75 m.y.B.P. while those in the central Indian Basin may have experienced as much as 25° of northward migration.

On Leg 22 it was decided to drill sites both on and to either side of the Ninetyeast Ridge south of the turbidite sediments from the Bengal and Nicobar fans. The first objective of these sites was to compare the biostratigraphic record on both sides of the ridge at the same latitude. A secondary objective was to obtain basement ages at all three sites and to examine the older sediments for evidence of radically different latitudes of formation.

Sites on the Ninetyeast Ridge

The third major objective of Leg 22 was to gain a better understanding of the past tectonic history of the Ninetyeast Ridge. For this purpose two or possibly three sites were planned. Distinctive east-west-trending magnetic anomalies 23 through 32 have been identified on either side of the Ninetyeast Ridge. On the west these anomalies get older northwards; to the east they increase in age to the south. The anomalies thus indicate that the Ninetyeast Ridge was an active transform fault from the Late Cretaceous (anomaly 32) until at least the early Eocene (anomaly 23). After the Eocene, two portions of the oceanic crust coalesced, India and Australia become part of the same plate, and motion on the Ninetyeast Ridge ceased. Since this time the whole region from Pakistan in the northwest to Australia in the southeast has behaved as a rigid plate moving slowly northeast with respect to Antarctica. McKenzie and Sclater (1971) and Fisher et al. (1971) have suggested that the Ninetyeast and Chagos Laccadive ridges were formed after the Eocene either by (a) slow extension along the old lines of weakness–the Chagos and Ninetyeast transform faults, or by (b) compression related to the change in spreading direction in the Eocene. The Ninetyeast Ridge has an asymmetrical bell shape with a pronounced sharp drop to a long linear deep to the east (Sclater and Fisher, in press). It is thought that this deep marks the old transform fault and that the crust to the west which includes the ridge proper has the same age as the old Indian plate. Unfortunately, most of the older portion of this plate, north of 10°S, is covered by thick sections of turbidite from the Bengal Fan. These sediments are too thick to drill through, and consequently, basement age cannot be obtained to extend the tectonic history of McKenzie and Sclater (1971) beyond anomaly 32 (75 m.y.B.P.). Thus the Ninetyeast Ridge, provides the best opportunity for determining the age of the older portions of the plate. Such ages also should help to resolve the position of India in the reconstructions of Gondwanaland.

The Ninetyeast Ridge also offered the possibility of obtaining a complete biogenic calcareous and siliceous section through most of the Cenozoic. Curray and Moore (1971) have suggested that the northern sections of the ridge are covered by Miocene abyssal fan sediments which were uplifted during the Pliocene.

Two primary sites were planned on the ridge. the northernmost, in the region suggested by Curray and Moore (1971) at 8°N, was selected to date the second phase of Bengal Fan turbidites and to obtain an age for the basement. A southern site on the ridge at 12°S was selected for a stratigraphic comparison with holes drilled close to the same latitude on either side of the ridge. A third possibility at 2°N was considered and eventually drilled to provide an additional biogenic section, to date the age of the Ninetyeast Ridge, and to obtain further information regarding formation of the ridge.

Bengal Fan Sites

The Bengal Fan, purportedly the largest fan in the world, is composed of sediments dumped into the head of the Bay of Bengal by the confluent Ganges and Brahmaputra rivers which drain the Himalayan Mountain Chain (Moore et al., 1971). Stratigraphy of the fan should, therefore, provide insight into the tectonic history of the Himalayas and thus the collision between the Indian and Asian plates.

From information gathered during two geological/geophysical expeditions to the Bengal Fan, Curray and Moore (1971) have correlated unconformities in the fan throughout the entire Bay of Bengal. These unconformities have been related to pronounced and persistent velocity contrasts as determined both by refraction and sonobuoy wide-angle seismic reflection measurements. The stratigraphic ages of these unconformities were not determined directly, but the authors speculated that they may correspond to periods of major uplift of the Himalayas, one in late Miocene and one in Plio-Pleistocene times.

Two drilling sites (217 and 218) were proposed on and adjacent to the Bengal Fan to accomplish the following specific objectives:

1) To determine stratigraphic ages of the two major unconformities;

2) To obtain sediments from the three main stratigraphic units defined by the unconformities, which were thought to represent pre-fan material, and two stage of fan deposits (Curray and Moore, 1971). Changes in provenance of the detrital sediments might give an indication of the development and history of erosion of the Himalayas.

3) To provide information on the late history of the Ninetyeast Ridge; and

4) To obtain samples for paleontologic and stratigraphic control at this latitude in the northeastern Indian Ocean.

EXPLANATORY NOTES

Format and Authorship

This Initial Report (volume) is divided into three parts. Part I (Chapters 1-9) is the introduction and scientific objectives of the cruise and the individual site reports which largely resulted from the work completed by the scientific party onboard ship. Part II (Chapters 10-38) consists of the work carried out after the cruise by shore-based laboratories on samples and data taken during the cruise and other special studies on various aspects of the scientific results. Part III (Chapters 39-41) is a synthesis of the cruise results prepared by various members of the Shipboard Scientific Party.

Authorship of the site reports is shared collectively by the Shipboard Scientific Party. The format of each one of these reports is the same. Sections on background, objectives, and operations were prepared by C. C. von der Borch and J. G. Sclater; sections on lithology were prepared by R. Hekinian, A. C. Pimm, R. W. Thompson, and J. J. Veevers; sections on biostratigraphy were prepared by S. Gartner, D. A. Johnson, and B. McGowran; sections on correlation reflection profile and stratigraphic column were prepared by J. J. Veevers; the summary and conclusions sections were prepared by the entire scientific party. In addition, each site report contains a section on the geochemistry program prepared by the shipboard geochemist, L. S. Waterman.

Authorship of Parts II and III is cited by chapter.

Data Presentation

The basis for numbering sites, holes, cores, sections, and samples and the procedure for handling the cores received onboard ship are described in detail in Volume XXI, Chapter 2, Explanatory Notes.

The time scale used in this volume is that of Berggren (1972) for the Cenozoic and follows the informal scheme for the Upper Cretaceous used in Volume XIV (Hayes and Pimm et al. 1972). The complete time scale used is given as Figure 4a Chapter 41 (this volume).

Lithologic Classification and Nomenclature

The classification used during Leg 22 was put together by the DSDP staff and is based on a series of premises, the most important ones being:

1) It has to be mainly descriptive.

2) The proper sediment name should be determinable with the aid of a petrographic microscope, though in some instances additional data from the shore-based laboratories are required.

3) It should be possible to indicate all major and minor constituents of the sediment in the sediment name.

4) Quantitative class limits should be used.

5) As much as possible, adopted terms should be in common use.

As can be seen from these premises, the emphasis is on practicality. It should be realized that the classification employed here is designed to give the user the maximum amount of information and in so doing, a certain amount of flexibility in the terms used is essential.

Classification of Biogenic Sediments

Sediment names are obtained from percentage estimates in smear slides. Admittedly, such estimates vary greatly between individuals, but they are a big improvement over vague terms like "abundant," "common," and "rare." Difficulties are encountered when dealing with sediments containing constituents of greatly different size classes. A good example is a sediment consisting of a mixture of foraminifera and nannofossils. Almost certainly, the nannofossil percentage will tend to be estimated too high.

Percentage limits used in determining the sediment name are 2, 10, and 25. Major constituents present in quantities over 25% provide the sediment name. In order of decreasing abundance, the names of these major constituents are listed progressively farther to the left. Minor constituents are those present in quantities under 25%. Their names are added to the sediment name with a suffix-**rich** for constituents present in percentages between 10% and 25%,

bearing for those with percentages between 2% and 10%. They again are listed from right to left in order of decreasing abundance. Constituents present in amounts smaller than 2% may be added with the suffix **trace.**

Terrigenous and authigenic constituents can be present in biogenic sediments. As long as they do not constitute major components, their names are added in the same way as the biogenic components. For unconsolidated biogenic sediments, the term **ooze** is added as a suffix to the name. For indurated biogenic sediments, the common terms **chalk** and **limestone** are used.

Example: Given an unconsolidated sediment consisting of 35% foraminifera, 30% nannofossils, 20% clay, 8% zeolites, and 7% volcanic glass shards. The name of this sediment would be "glass shard and zeolite-bearing clay-rich nannofossil foraminiferal ooze."

This example highlights a difficulty of which readers should be aware. The total percentage numbers have, of course, to add up to 100. In practice, minor and trace constituent estimates are rounded off to make the total for all constituents 100. Percentage figures like 8 and 7, do not, of course, indicate that estimates can be made within a 1% accuracy. An accuracy of 5% for minor constituents is already considered to be very good.

Abbreviations of names are occasionally employed, for convenience sake. The most common are "foram" for foraminifera, "nanno" for nannoplankton or nannofossil, and "rad" for radiolarians.

Classification of Clastic Sediments

A classification of clastic sediments presents more problems and is likely to provoke more discussion than one for biogenic sediments. But again, practicability has been the underlying principle.

When detrital grains are the only constituents, the sediment is given a simple grain-size name. Detrital in this scheme means clastic grains derived from the eorsion of pre-existing rocks, except for those of fossil or authigenic origin. Grain-size classes and percentages are again measured and estimated from smear slides. The Wentworth Scale is used for the size-class boundaries, and Shepard's (1954) sand-silt-clay triangle is used to derive textural terms. The major percentage limits in this triangle are 20, 50, and 75.

When the clastic components are redeposited fossils or fossil fragments, they are also given a grain-size name, like the detrital sediments. However, this name is preceded by the appropriate fossil constituent names, in a fashion similar to that used for the biogenic sediment classification.

In several instances on Leg 22, carbonate material of unknown origin was clearly deposited in a shallow water environment. Here the prefix **carbonate** is used in conjunction with the suitable grain-size term, e.g., **carbonate silty sand.**

A sediment can also consist of a mixture of detrital grains and nonreworked (nonclastic) fossil tests. When the detrital grains are a major component, the size term is determined from the textural triangle. The fossil component will not receive a size term, but will be named as in the biogenic sediment classification. A hyphen is placed between the nonclastic and clastic terms.

Example: Given a sediment consisting of 40% nonreworked foraminifera, 20% detrital silt, and 40% clay. The recalculated detrital percentages are 33 and 67. The sediment name will be **foraminifera-silty clay.**

Classification of Sediments with Volcanic or Authigenic Constituents

For volcanic constituents clearly of primary origin existing classifications have been adopted. Terms used in this volume include: **lapilli tuff, tuff, crystal tuff, lithic tuff, volcanic ash.** In some cases where clay-size material is clearly (and subsequently confirmed on shore by X-ray data) comprised of weathered volcanic constituents the informal term **volcanic clay** has been employed. Because of the importance of indicating to the user the origin of the material, this nomenclature is preferred to a simple clastic term. Where the clastic constituents in a sediment are clearly of volcanic origin and have been reworked, then the prefix **volcanic** is used with the appropriate grain-size term, e.g., **volcanic conglomerate.**

Authigenic constituents are treated in the same way as nonclastic biogenic constituents. An example (zeolite) is already given in the section on the biogenic sediment classification. However, when authigenic constituents are clearly reworked, they are treated in the same way as reworked fossil tests.

A special case is the diagenetic effects on calcareous oozes at depth in several of the Leg 22 sites. Many cores contain abundant fine particles of calcium carbonate of unknown origin. Although many of these have been shown to be of nannoplankton origin under the electron microscope, they are usually too small to be identified under an ordinary microscope. However, some of these grains are undoubtedly of authigenic origin. An estimate of relative abundances of fossil versus nonfossil material is impossible onboard, so the prefix **micarb** (microscopic calcium carbonate) has been used to describe this material, e.g., **micarb ooze, micarb chalk.** For indurated carbonate rocks existing **limestone** and **dolomite** terminologies have been used.

Symbols

The lithologic symbols used in the core and hole summaries of Leg 22 are reproduced in Figure 2.

Complex lithologies have been represented on the core summary forms using a vertical striping system. To do this, the constituents are divided into the following percentage percentage classes: 0-2, 2-10, 10-25, 25-50, 50-75, and 75-100. The lithologic column is subdivided into five subcolumns, their boundaries being the midpoints of the percentage classes (Figure 3). Percentages under 10% cannot be represented this way. For constituents between 2% and 10%, a letter or other symbol can be sparsely overprinted on the main symbols. Constituents under 2% are ignored in the lithology columns. They are, however, mentioned in the text, in the smear slide compositions.

Colors

The reader is advised that colors recorded in core barrel summaries were determined during shipboard examination immediately after splitting core sections. Experience with sediments shows that many of the colors will fade or

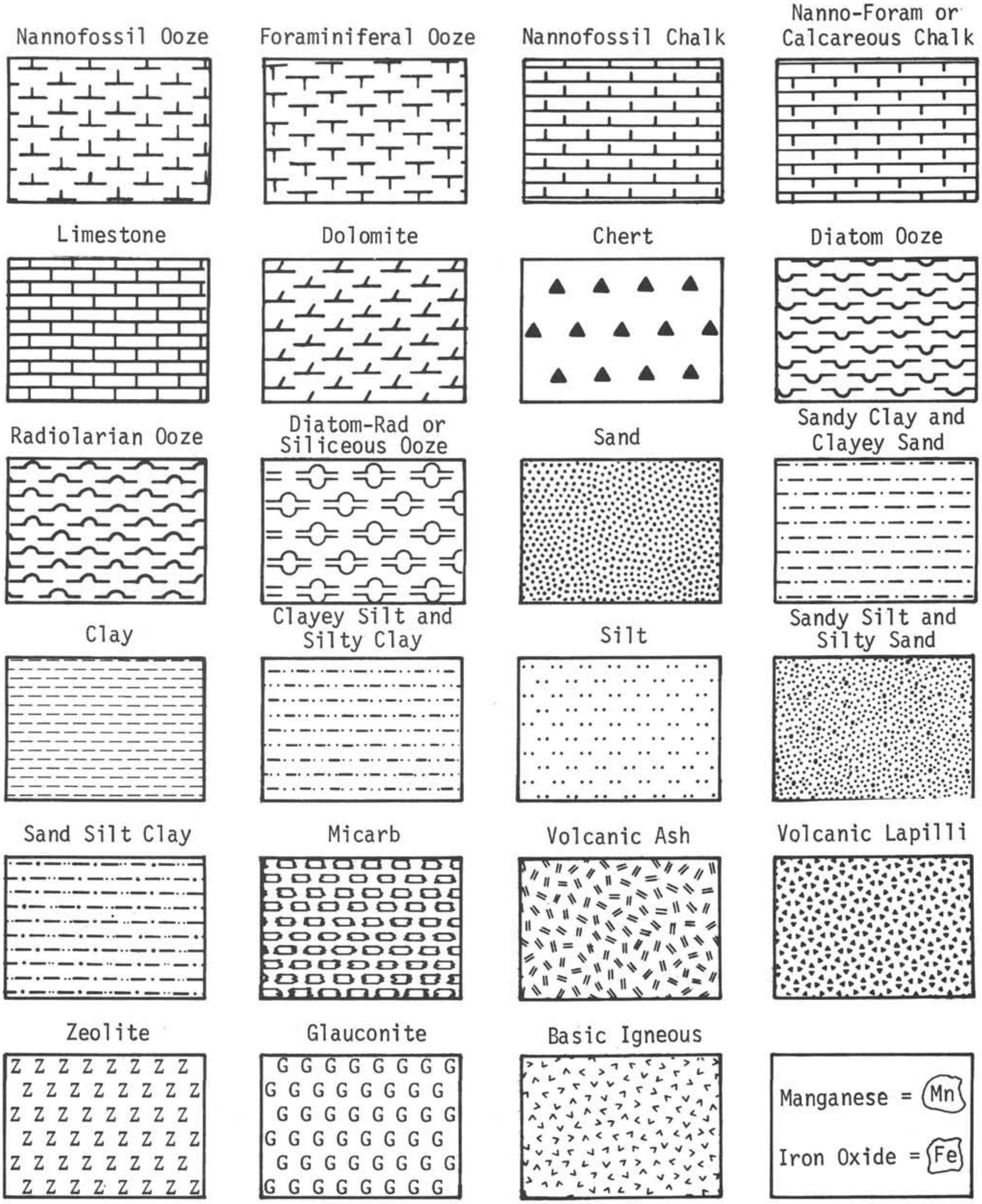

Figure 2. *Lithologic symbols and letters used on core and site summary forms.*

disappear with time after opening and storage. 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.

Survey Data

Specific site surveys for holes drilled on Leg 22 of the Deep Sea Drilling Project were carried out in the vicinity of three sites only (211, 214, 216). The other sites were chosen on the basis of existing seismic profiles.

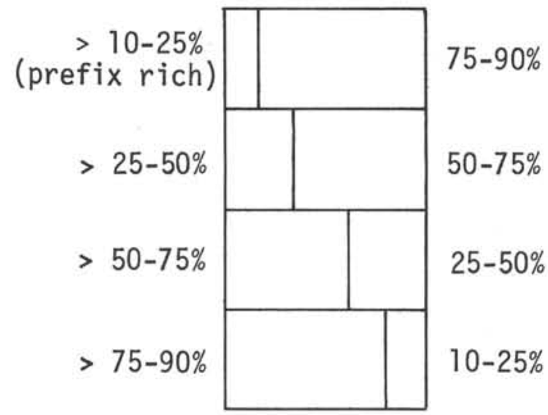

Figure 3. *Vertical bar width representation of class limits.*

Data for each site is as follows:
Site 211—CONRAD 14 site survey
Site 212—CONRAD 9 seismic line
Site 213—ANTIPODE 12 seismic line
Site 214—CONRAD 14 site survey
Site 215—CIRCE 5 seismic line
Site 216—CONRAD 14 site survey
Site 217—ANTIPODE 11 seismic line
Site 218—ANTIPODE 11 seismic line

We would like to acknowledge the assistance of Lamont-Doherty Geological Observatory of Columbia University in providing data from the CONRAD cruises and, in particular, G. Carpenter for making the survey of Site 211 and S. Eittreim for the surveys of Sites 214 and 216. Scripps Institution of Oceanography, University of California at San Diego, provided data from the CIRCE and ANTIPODE cruises. We would particularly like to thank J. Curray and D. Moore for their work in the vicinity of Sites 217 and 218 on cruise ANTIPODE 11 which they made available to us.

Criteria for Correlating Reflection Profile and Stratigraphic Column

1) Ignore laboratory determinations of sediment velocities. The wide variations in the Leg 22 values must indicate either (a) instrumental error, or (b) rearrangement of the packing (and hence porosity-density) of the sediment. In this view, only consolidated materials, including chert and basalt, have their physical properties unaffected by the drilling process.

2) Determine the interval velocity of the entire sediment column. This was precisely calculable for all but the last two holes on Leg 22, because the depth to volcanic rocks was unequivocally determined in both profile and hole.

3) This value imposes the chief constraint on interval velocities between reflectors. For example, the overall velocity of 1.7 km/s in Hole 211 rules out the possibility of any significant intervals having velocities greater than, say, 2.0 km/s.

4) Identifications of reflections with depth in the hole is made at "obvious" lithological boundaries and immediately tested by calculating the resulting interval velocity. For example, in Hole 214, the tentative identification of reflector 2 at a marked geological boundary at 333 meters leads to a calculated interval velocity of 1.1 km/s, which is rejected.

5) This process is continued until an optimum matrix of depths (if possible, related to recognizable lithological boundaries) and reflection time, with acceptable interval velocities, is derived.

6) Whichever method is used, one can be certain that, except for the sea floor and volcanic basement, the identification will be inherently uncertain.

Inorganic Geochemistry Program

A flow sheet showing the handling and experimental procedures for the Leg 22 geochemistry program is given as Figure 4.

For the first time since Leg 15, samples were collected by removing a 10-cm "mini-core" at the time the sediment-filled liner was subdivided into 150-cm sections. These mini-cores were taken to the chemistry laboratory and resistivity and punch-in *p*H measurements were made immediately on the undisturbed sediment. The resistivity measurements were made with a Schlumberger-type EMT-D mud tester. The punch-in *p*H measurements were made with a Model 801 Orion digital *p*H/mv meter using a Beckman Model 39301 *p*H electrode and an Orion Model 90-02 double junction reference electrode. Temperatures were measured with a Weston s.s. dial thermometer.

Mini-core sediment samples were extruded from the plastic liner, impaled on a s.s. spatula, and scraped to remove 1-5 mm of material which had been in contact with the liner. Mini-cores were split lengthwise primarily to examine them for evidence of drilling fluid intrusion.

The *p*H measurements on the freshly squeezed, unfiltered pore water were made with an Orion flow-through electrode of the same type as used for the Leg 15 geochemical program. Resistivity measurements were made on 2-ml portions of pore water using a "suck-up" cell provided with the Schlumberger instrument.

ACKNOWLEDGMENTS

The authors wish to thank Captain Lloyd Dill, Drilling Superintendent, C. Guess, and their crews; and Operations Manager, L. Hayes, whose excellent performance made the spectacular results of Leg 22 possible. Of special note was the large recovery of basaltic material from many sites including the deepest (Site 212) so far drilled by the project and also the successful penetration at two sites (211, 218) of thick sequences of sandy turbidite material which is notoriously difficult in such a drilling opearation as that employed by the *Challenger*. All this was accomplished without the loss of a single hole or item of drilling equipment. Undoubtedly this was a wonderful performance by the drilling crews.

Appreciation is also extended to the very competent staff of marine technicians under the direction of T. B. Gustafson. Of special mention was the performance of the electronics technicians P. Porter and A. Porter for their efforts towards the success of the heat flow program on this cruise.

Deep Sea Drilling shore laboratories at La Jolla provided grain size and carbon-carbonate analyses under the

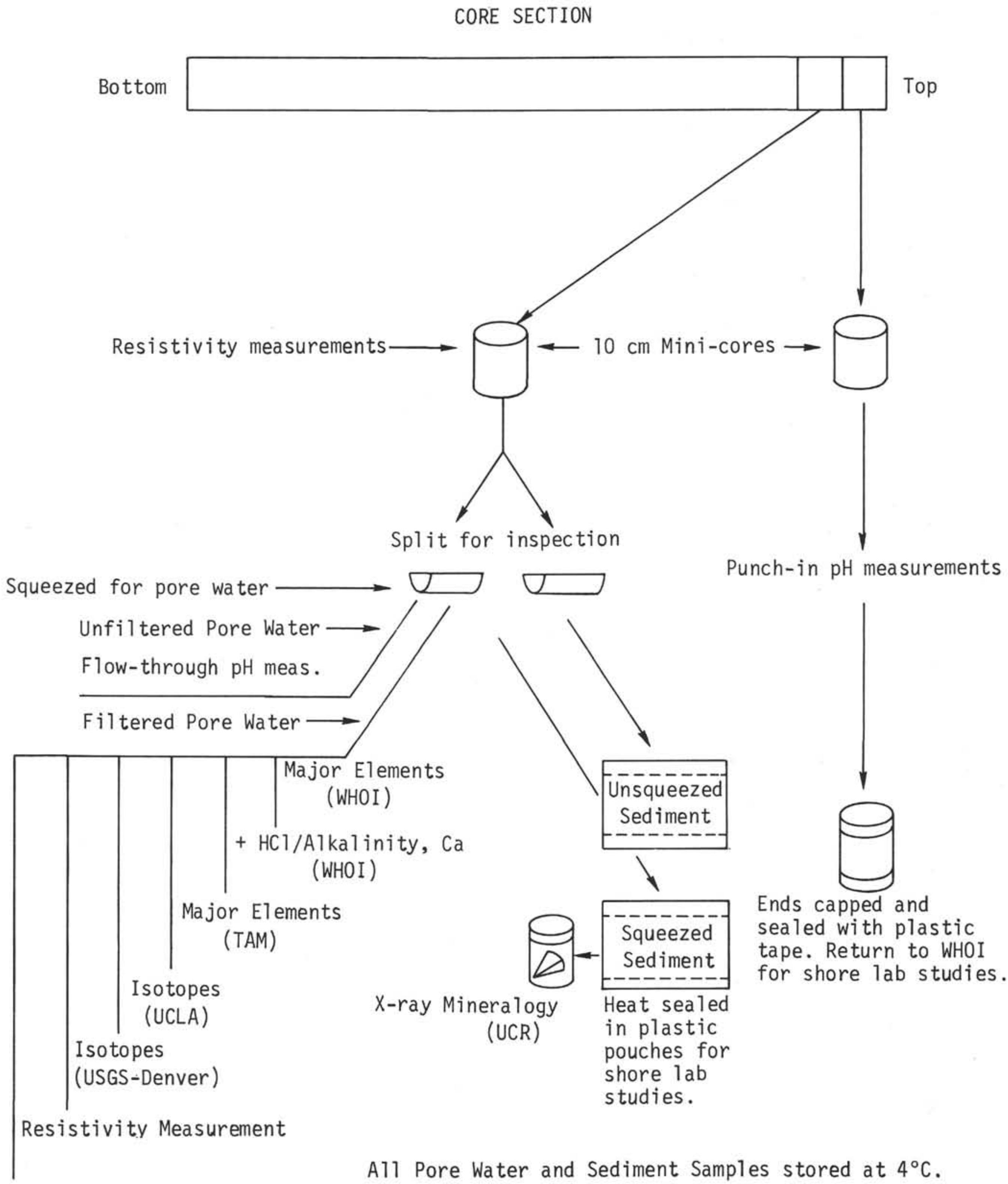

Figure 4. *Inorganic geochemistry program for Leg 22.*

direction of G. Bode. X-ray diffraction analyses were made at the University of California at Riverside under the supervision of H. E. Cook.

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