2. EXPLANATORY NOTES

RESPONSIBILITIES OF AUTHORSHIP

In the chapters which follow, Part I: The Shipboard Report, in general, the paleontological sections have been written by Tsunemasa Saito and Stephen Percival, Jr., the stratigraphy sections by K. J. Hsu and James Andrews, and the physical properties sections by R. E. Boyce.

Further, in the discussion which concludes this part of Volume III (Chapter 13), certain members of the shipboard scientific staff have made the primary contributions. In order that they may receive proper recognition for this effort, and also to facilitate the answering of questions which may arise in different parts of the report, the initials of the primary author(s) have been placed after the subtitle of the appropriate section.

SURVEY DATA AND SITE BACKGROUND

All depth measurements by sonic methods have utilized a Gifft precision graphic recorder, usually operating with a full-scale sweep of one second. Uncorrected depths (in fathoms) are measured from the recordings assuming a full scale of 400 fathoms. Corrected depths (in meters) have been adjusted for: (a) actual speed-of-sound in water from Matthews (1939) tables, and (b) actual depth of the echo-sounding transducer below water level, assumed constant at 5.8 meters (19.0 feet).

In addition, any depths or distances referred to the drilling table have been calculated under the assumption that this level is 10.0 meters (32.8 feet) above the water line. At each site water depths that are listed in the tables have been determined from the length of drill pipe suspended below the ship when the pipe encountered bottom.

BASIS FOR NUMBERING SITES, CORES AND SECTIONS

When a sediment sample was brought on board ship, it was usually contained in a 9-meter long plastic liner inside the core barrel. After the core was pulled out of the barrel, it was cut into sections of 150-centimeter length. These sections were labelled consecutively, with the first section at the top, and the sixth at the bottom. The sections were, however, measured from the bottom up. Consequently, when recovery was slightly less than 9.0 meters (30 feet) the first section of each core would be less than 150 centimeters long. When less than 7.5 meters (24.6 feet) of core were recovered, the core could only be divided into five, or fewer, 150-centimeter sections, yet the top section of a short core would still be labelled Section 1. On some occasions more than 9.0 meters (30 feet) were obtained, so that a small remainder, 10- or 20-centimeters long, would be left after six sections were cut off from a core. This remainder would be called Section 0 of that core, denoting its position above Section 1.

The samples were numbered before being processed. The numbering system adopted for this report, recommended in the Core Description Manual (May 1968), includes a designation for leg-site-hole-core-section-interval. Thus, Sample 3-13A-1-2, 75 centimeters was taken during Leg 3, at Site 13, where a second hole (13A) was drilled in addition to the original hole (13), and was cut from the first core, the second section, and at 75 centimeters from the top of that section.

A core-catcher about 20 centimeters long was attached to the lower end of the metal core barrel. Samples recovered from the core catcher were designated by the abbreviation CC (e.g., 3-13A-1, CC). A core catcher sample was commonly the first sample studied on board ship; and, in some cases, it may represent the only sample from a core when recovery was poor (e.g., 3-13A-6, CC).

On rare occasions, the only samples recovered were small chips caught between the teeth of a center bit used in drilling. Those samples would be designated CB (e.g., 3-13A-3A, CB). After the completion of drilling each hole, the drill string would be pulled on board and disassembled. Sediments caught between the teeth of the outer drill bit were often also sampled and studied. Those would be designated OB samples (e.g., 3-13A, OB). The authors found that the outer bit samples usually included the youngest sediments on a location, indicating that the drill bit was contaminated when it first entered a hole.

HANDLING OF CORES

After a core section had been cut, sealed and labelled, it would be brought into the core laboratory for processing. The routine procedure listed below was usually followed:

1. Weighing of the core section.
2. GRAPE analysis for bulk density.

3. Gamma ray counting for radioactivity.
4. X-ray photograph for sedimentary structures.
5. Sonic velocity determinations.
6. Thermal conductivity measurements.

Sonic velocity was not determined for sections containing much water. Thermal conductivity measurements were made on all sections of the cores of Site 13, but only on certain selected sections of cores from other sites.

After the physical measurements were made, the core liner was cut by an electric saw, and the end caps by a knife. The core could then be split into halves by a cheese cutter, if the sediment was a soft ooze. At times, when compacted or partially lithified sediments were included, the core had to be split by a machine saw.

One of the split halves was designated a working half. Penetrometer readings were taken to give a measure of the degree of consolidation of the sediments. Samples, including those for grain size, X-ray mineralogy, interstitial water chemistry and total carbonate content, were taken, labelled and sealed.

The working half was then sent to the Paleontology Laboratory. There, samples for shipboard and shore-based studies of nannoplanktons, foraminifera, and Radiolaria were taken, as well as, some oriented samples for paleomagnetic studies. During Leg 3, footage of the cores recovered was almost four times greater than the average of the previous cruises. Under the conditions of rapid core recovery during the latter part of the leg, shipboard paleontological determinations, as a rule, were made only on core-catcher samples. This entailed considerable further work by the paleontologists on shore.

The other half of a split section was designated an archive. The cut surface was smoothed with a spatula to bring out more clearly the sedimentary features. The color, texture, structure and composition of the various lithologic units within a section were described, and any unusual features noted. A smear slide was made, usually at 75 centimeters, if the core was uniform. Otherwise, two or more smear slides were made, each, for sediment of distinct lithology. The smear slides were examined microscopically. The archive half of the core section was then photographed. Both halves were sent to cold storage when they had been processed. All the samples are now deposited at the Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York.

Out of a total of some 600 sections only a small percentage of cores were not split into halves. There were two reasons for this: either the core was too soft, or the core duplicated the stratigraphy of a core from another hole at the same site.

The unusually soft cores, designated "soupy", were split during the first part of the leg, until it was realized that a great amount of samples was lost as these cores were split. A particularly difficult situation arose when soupy intervals were intercalated between partially lithified intervals, as in the case of some Eocene and Paleocene sections from Site 21. The cheese-cutter would not cut the hard intervals readily, so that they behaved like pistons which extruded the intervening soupy samples. Consequently, the authors decided during the latter half of the leg to split only those soupy sections from which information that was essential for the preparation of the Initial Core Description had to be obtained. Other soupy sections were opened at the lower end of the section after physical measurements were made. Samples were taken and labelled 150 centimeters, or 148 to 150 centimeters (e.g., 3-19-10-4, 150 centimeters). The color and texture were described, and smear-slides were made and examined microscopically for sediment-composition. Since most of the soupy cores had a uniform lithology over long intervals, the samples obtained from the end were considered representative of the whole section.

Some duplicate sections, such as, those from Site 17, were not split. They were sent to cold storage after physical measurements were made. Other duplicate sections, such as, those near the Cretaceous-Tertiary contact at Sites 20 and 21, were split and processed.

Not uncommonly, when hard rocks were being penetrated, the only recovered samples would be chips caught by or adhering to the core catcher. For example, Sample 3-17-5, CC consists only of three dust-like specks of basalt glasses, which were mounted on a smear slide and examined microscopically to confirm that the basement there was indeed a basalt. Except for that one smear slide, no archive sample is available. In cases where several chips of rock fragments were obtained (e.g., 3-13A-6, CC), those chips were washed and placed in small plastic vials to be utilized partly as working samples, and partly as archive. At several sites, considerable amounts of basement material (basalts or sedimentary rocks) were obtained. The hard rocks were washed and numbered consecutively from the top down (Rock Number 1, 2, ...) and oriented vertically by an arrow (pointing upward) where possible. The small chips were placed in several plastic bags, sealed and numbered (Bag Number 1, 2, ...). The order of the rock and bagged specimens from each section was noted on the visual core-description sheet. The core was then photographed and sent to storage. The basement samples were, thus, left in a tray sealed within a transparent plastic tube for shore-based research, except for a few fragments which were shipped to the Woods Hole Oceanographic

Institution as possible working samples. However, in accordance with the policy of the JOIDES Advisory Panel, those "working samples" were not processed and are now to be made available as a part of the materials for shore-based research.

DRILLING DISTURBANCES

Disturbance apparently could not be avoided while cores were being taken from very soft oozes near the ocean bottom. The first core from each site was taken from the near-surface sediments. Those cores were apparently not cut, but rather intruded into the core barrel. Consequently, the structure exhibited by such cores is reminiscent of that of a diapric salt dome. Vertical contacts between sediments of various lithologies, parallel to the liner axis, have been observed in some of these disturbed cores.

This type of disturbance became less evident 10 or 20 meters below the surface, although an upward bulge of contact surfaces is not uncommon in late Tertiary sediments; the more consolidated early Tertiary and Cretaceous sediments may be relatively undisturbed, as indicated by nearly horizontal contacts.

The presence of lithified or partially lithified layers, or intercalations within an unconsolidated sediment resulted in another kind of disturbance: thin hard layers were fragmented and broken during the coring processes. In these cases, hard fragments were mixed with soft sediments and intruded into the core barrel as breccias. Such breccias were first mistaken as pebbly mudstones or fluxoturbidites. It is now recognized that they are "drilling breccias," which are particularly common in the Cretaceous cores from Site 13.

Soupy cores may represent another manifestation of drilling disturbances. Some cores were uniformly soupy; however, also noted was an apparent interbedding of relatively firm and very soupy oozes, particularly in early Tertiary sediments. The authors first marvelled at this irregularity in the degree of compaction between adjacent sedimentary layers of identical lithology. Eventually, they realized that soupy cores were a common product when circulation during coring had to be undertaken periodically in order to preserve the drill hole. For instance, some extremely soupy materials were obtained from the holes at Rio Grande Rise, when circulation had to be maximized to prevent the foraminiferal sands (Quaternary)–which had slumped down from above–from plugging the hole. Drilling disturbances of this kind made the interpretation of the measured physical properties difficult; particularly penetrometer readings. Considerable attention must be paid to such difficulties in any subsequent re-interpretation by others.

A fourth type of drilling disturbance has been suspected because of the repetitions of certain stratigraphical sections. For example, the Burdigalian-Aquitanian boundary was observed at two different cored intervals from Hole 15 (e.g., at 3-15-7-8 and 3-15-9). This could be interpreted as the upper contact being preserved in a slump block. Another explanation is that the contact was actually cored twice as the drill pipe was raised and lowered when the ship pitched and rolled. Lengthening of the drill pipe to accommodate a slight drift by the ship probably did take place at times. The writers witnessed at least one occasion when a section of drill pipe had to be removed from the drill string because the ship was being brought to its original position by the automatic positioning system on board. These considerations led the authors to suspect that a certain amount of section duplication in pelagic ooze of relatively uniform lithology might also have taken place, although there is no way of detecting such occurrences.

Drilling disturbances, such, as those described above, convinced the authors that minor contamination of cores by an exotic element sometimes occurred. In one case, this was evidenced by the presence of a few specimens of Pleistocene planktonic foraminifera in an Oligocene core taken some 100 meters (328 feet) below. This was most likely a result of the caving problem associated with the drilling ano, perhaps, the contamination from sediments caught in the space between the teeth of the outer drill bit.

Similarly, occurrences of a few Pliocene nannoplanktons beneath a Lower Miocene core (e.g., Site 14), were taken as an indication of contamination, but not as evidence of submarine slumping.

The occurrence of drilling breccias bears testimony of another kind of contamination. A thin friable chalk layer (*Braarudosphaera* Chalk) in Hole 14, probably considerably less than a meter thick (judging on the basis of drilling-rate changes), was broken and chalk chips were found throughout the 9-meter core. Examination of X-ray photographs revealed that broken chips of hard layers tended to be scattered along the length of a core, particularly in the space between the soft-sediment core and a plastic liner. The recognition of an exotic element in a drilling breccia was, however, not made without difficulty.

For example, a few tiny chips of nannoplankton ooze, including Campanian species, were mixed with chert fragments, broken drill bits, tiny diamond crystals and other elements in a purple shale of Core 3-13A-7-1. Only after a careful study showed that the shale is barren of such nannofossils, and that the lumps are lithologically and paleontologically identical to a thick section of the Campanian ooze above, was it concluded that those chips were contaminants.

The possibility of contamination during the handling of cores cannot be excluded, although shipboard personnel did take precautions to avoid such occurrences. A likely source could be traced to the practice of having to split a core lengthwise with a cheese cutter, and to smooth the cut surface with a spatula for core description and for photography. This sort of contamination was usually not very serious because, commonly, the cored intervals were rather uniform and the faunal zones thicker than a section. In addition, special caution was exercised when important contacts were studied.

To summarize, the major sources of contamination are:

(1) Oozes caught between the teeth of drill bits.

(2) Cave-ins or other residues gathered at the bottom of a hole and somehow picked up by the core barrel (probably when the drill string rose and fell with the pitch and roll of the ship).

(3) Mixing during the intrusion of a "drilling breccia".

(4) Necessary practices in the handling of cores.

The authors want to emphasize, however, that this discussion of the kinds of drilling disturbances and possible sources of contamination should not prejudice the reader against the over-all good quality of the cores. On the whole, the shipboard scientists were quick to spot such factors so that their descriptions and interpretations were not hampered or confused thereby. It is estimated that less than 10 per cent of the cores were seriously disturbed so as to affect the measurements of their physical properties, and hardly any core was so seriously contaminated that the authors could be misled on their stratigraphy. On the other hand, it is hoped that the future investigators of the Leg 3 cores will consider such sources of possible errors, and that they will consult shipboard scientists before they draw any major conclusion on the basis of anomalous occurrences of fauna, flora or rock types.

BASIS FOR AGE DETERMINATIONS

The sediments from the ten sites drilled on Leg 3 are extremely rich in the planktonic foraminifera and calcareous nannoplankton with only rare occurrences of Radiolaria and diatoms. Thus, the calcareous microfossils were most frequently used for determining the age of the sediments. The definition of all the stages, epochs and their diagnostic microfossils is given in the Appendix II: Time Stratigraphic Framework.

Since the planktonic foraminifera are exclusively applied for the recognition of the time-stratigraphic scheme adopted by the manual, if any conflict in ages derived from planktonic foraminifera and calcareous nannoplankton arises, planktonic foraminiferal evidences are preferred. Whenever planktonic foraminifera are absent or nondiagnostic, the calcareous nannoplankton are used for age determination. The calcareous nannoplankton determinations were based upon Appendix II, as well as, other applicable literature, such as, that by Bramlette, Bukry, Gartner, Hay, Martini, Stradner, Sullivan and others.

In addition to assigning ages to the cores, zonation of the cored sediments has been attempted throughout most of the stratigraphic sequences using the zonal schemes of the calcareous nannoplankton and planktonic foraminifera which are currently available in the literature.

Two major Cenozoic planktonic foraminiferal zonations are widely accepted today. The first of these was originally established by Bolli (1957a, b, c) for the Caribbean region, and it has subsequently been modified by Bolli (1966) and Bolli and Bermudez (1965). Blow and Banner in Eames *et al.* (1962), Banner and Blow (1965) and Blow (1969) have proposed a second zonation based on different species. The correlation of these two zonations has been discussed by Blow (1969), and modification of parts of them has been suggested by Berggren (1965) and Parker (1967). The planktonic zonal scheme for the Cretaceous has been discussed by Bolli (1966) and Pessagno (1967). For the purpose of this initial core description, zones most suitable for the particular faunas found in this leg have been selectively applied from these available zonal schemes (Figure 1). For late Tertiary (Upper Miocene-Pliocene) and the Quaternary, no zonation presently available is adequate, especially since most of the stratigraphic interval cored contains a temperate fauna, and the existing zonations are based on tropical faunas. Thus, no zonations have been attempted in that part of the section.

The basic zonations used for the calcareous nannoplankton are those of Bramlette and Wilcoxon (1967) for the Oligo-Miocene and of Hay in Hay *et al.* (1967) for the Eocene, with modifications based on the work of Bramlette and Sullivan (1961), and of Mohler and Hay in Hay *et al.* (1967) for the Paleocene (Figure 2). Since no satisfactory zonation for the younger Tertiary (Upper Miocene-Pliocene) and the upper part of the Upper Cretaceous (Campanian/Maestrichtian) has yet been proposed, zonation of this part of the stratigraphic section has not been attempted. However, the work of Bukry and Bramlette (1968) has proven to be extremely useful for the late Cenozoic sequence and the works of Stradner (1963), Bramlette and Martini (1964), Gartner (1968) and Bukry (1969), for the Upper Cretaceous.

In the Core and Section Summaries, besides the zonations of the interval and its age, the most diagnostic species and, sometimes, most abundant species present are listed in an abbreviated form. The samples studied are

Figure 1. *Cenozoic and Late Cretaceons chronostratigraphy, planktonic foraminiferal zones, important foraminiferal datum levels, and relationship of the zones used in this report to those proposed by other workers.*

Arrow pointing down indicates the point at which foraminiferal genera or species next to it make their first evolutionary appearance and arrow pointing up delineates the point at which foraminifers become extinct.

ERA	PERIOD	EPOCH	AGE/STAGE		M.Y. (lower boundary)
CENOZOIC	QUATERNARY	RECENT			
CENOZOIC	QUATERNARY	PLEISTOCENE	E	Calabrian	1.8
CENOZOIC	NEOGENE TERTIARY PERIOD	MIOCENE	L	Astian / Piacenzian	2.8, 3.0, 3.34
CENOZOIC	NEOGENE TERTIARY PERIOD	MIOCENE	E	Zanclian	5.5
CENOZOIC	NEOGENE TERTIARY PERIOD		LATE	Messinian Tortonian	11
CENOZOIC	NEOGENE TERTIARY PERIOD		MIDDLE	Langhian	19
CENOZOIC	NEOGENE TERTIARY PERIOD		EARLY	Burdigalian	
CENOZOIC	NEOGENE TERTIARY PERIOD		EARLY	Aquitanian	26
CENOZOIC	PALEOGENE TERTIARY PERIOD	OLIGOCENE	L	Chattian	
CENOZOIC	PALEOGENE TERTIARY PERIOD	OLIGOCENE	E	Rupelian-Lattorfian	38
CENOZOIC	PALEOGENE TERTIARY PERIOD	EOCENE	LATE	Bartonian	45
CENOZOIC	PALEOGENE TERTIARY PERIOD	EOCENE	MIDDLE	Lutetian	49
CENOZOIC	PALEOGENE TERTIARY PERIOD	EOCENE	EARLY	Ypresian	54
CENOZOIC	PALEOGENE TERTIARY PERIOD	PALEOCENE	LATE	Thanetian	
CENOZOIC	PALEOGENE TERTIARY PERIOD	PALEOCENE		Montian	
CENOZOIC	PALEOGENE TERTIARY PERIOD	PALEOCENE	EARLY	Danian	65
MESOZOIC	CRETACEOUS	MAESTRICHTIAN			72
MESOZOIC	CRETACEOUS	CAMPANIAN			76

M.Y.	DATUM LEVELS
1.8	*Globigerinoides obliquus*
2.8	*Globoquadrina altispira*
3.0	*Sphaeroidinellopsis seminulina*
3.34	*Globorotalia margaritae*
	Globigerinoides ruber
	Orbulina
	Globigerinoides sicanus
	Globigerinita stainforthi
	Globigerinita dissimilis
	Globorotalia kugleri
26	*Globigerinoides* spp.
	Chiloguembelina cubensis
	Globigerina angulisuturalis
	Pseudohastigerina micra
38	*Globorotalia cerroazulensis*
45	*Acarinina* spp.
49	*Hantkenina aragonensis, Globigerina frontosa*
54	*Pseudohastigerina wilcoxensis*
	Globorotalia pseudomenardii
	Globorotalia pusilla pusilla
	Globorotalia uncinata
65	*Abathomphalus, Globotruncana, Rugoglobigerina*
72	*Globotruncana calcarata*

ZONES USED IN THIS REPORT*	BOLLI (1957a,b,c) BOLLI (1966)	BLOW (1969)
Not defined	Not correlated	N23
		N22
		N21
		N20
	G. acostaensis	N19
		N18
		N17
		N16
	G. menardii	N15 *G. continuosa*
	G. mayeri	N14 *G. nepenthes/G. siakensis*
	G. ruber	N13 *S. subdehiscens G. protonepenthes*
	G. fohsi robusta	N12 *G. fohsi*
	G. fohsi lobata	N11 *G. praefohsi*
	G. fohsi fohsi	N10 *G. peripheroacuta*
Globorotalia peripheroronda	*G. fohsi barisanensis*	N9 *O. suturalis/G. peripheroronda*
Globigerinatella insueta/ Globigerinoides sicanus	*P. glomerosa*	N8 *G. sicanus/G. insueta*
Globigerinatella insueta/ Globigerinoides trilobus	*G. insueta*	N7 *G. insueta/G. trilobus*
Globigerinita stainforthi	*Catapsydrax stainforthi*	N6 *G. insueta/G. dissimilis*
Globigerinita dissimilis	*Catapsydrax dissimilis*	N5 *G. dehiscens praedehiscens/ G. dehiscens*
Globorotalia kugleri	*G. kugleri*	N4 *G. quadrilobatus primordius G. kugleri*
Globigerina ciperoensis	*G. ciperoensis ciperoensis*	N3 *G. angulisuturalis*
Globorotalia opima opima	*G. opima opima*	N2 *G. angulisuturalis/ G. opima opima*
Globigerina ampliapertura	*G. ampliapertura*	N1 *G. ampliapertura*
Globigerina sellii/Pseudohastigerina barbadiensis	*Cassigerinella chipolensis/ Hastigerina micra*	P19 *G. sellii/P. barbadiensis*
Globigerina tapuriensis		P18 *G. tapuriensis*
Globorotalia cerroazulensis	*Globorotalia cerroazulensis*	P17 *G. gortanii gortanii/ G. centralis*
		P16 *C. inflata*
Globigerapsis mexicana	*Globigerapsis semiinvoluta*	P15 *G. mexicana*
Truncorotaloides rohri	*T. rohri*	P14 *T. rohri/G. howei*
Orbulinoides beckmanni	*Proticulasphaera maxicana*	P13 *O. beckmanni*
Globorotalia lehneri	*G. lehneri*	
Globigerapsis kugleri	*G. kugleri*	
Hantkenina aragonensi.	*H. aragonensis*	
Acarinina densa	*G. palmerae*	
Globorotalia aragonensis	*G. aragonensis*	
Globorotalia formosa formosa	*G, formosa formosa*	
Globorotalia subbotinae	*G. rex*	
Globorotalia velascoensis	*G. velascoensis*	
Globorotalia pseudomenardii	*G. pseudomenardii*	
Globorotalia pusilla pusilla	*G. pusilla pusilla*	
Globorotalia uncinata	*G. angulata G. uncinata*	
Globorotalia trinidadensis	*G. trinidadensis*	
Globorotalia pseudobulloides/ Globigerina daubjergensis	*G. pseudobulloides*	
Globigerina eugubina	*G. eugubina*	
Abathomphalus mayaroensis	*A. mayaroensis*	
Globotruncana gansseri	*G. gansseri*	
Rugotruncana subcircumnodifer	*G. lapparenti tricarinata*	
Globotruncana calcarata	*G. calcarata*	
Pseudotextularia elegans	*G. stuarti s. l.*	
Planoglobulina glabrata		
Not defined		

*Emended from Bolli, 1957a, b, c; Bolli, 1966; Lutærbacher and Silva, 1964; Blow, 1969; and Pessagno, 1967.

Figure 2. *Cenozoic and Late Cretaceons chronostratigraphy, calcareous nannoplankton zones, important calcareous nannoplankton datum levels, and correlation of the calcareous nannoplankton zones with those of planktonic foraminifers.*

Arrow pointing down indicates the point at which calcareous nannoplankton species next to it make their first evolutionary appearance and arrow pointing up delineates the point at which calcareous nannoplankton species become extinct.

PLANKTONIC FORAMINIFERA			CALCAREOUS NANNOPLANKTON	
AGE		THIS REPORT	Bramlette and Sullivan, 1961; Hay, 1964; Hay *et al.*, 1967; Bramlette and Wilcoxon, 1967.	DATUM LEVELS
MIOCENE		*Globorotalia acostaensis**		
		*Globorotalia menardii**		*Discoaster hamatus*
		*Globorotalia mayeri**		
		Globorotalia peripheroronda	*Sphenolithus heteromorphus*	*Sphenolithus heteromorphus* *Discoaster exilis*
		Globigerinatella insueta/Globigerinoides sicanus *Globigerinatella insueta/Globigerinoides trilobus*	*Helicopontosphaera ampliaperta*	
		Globigerinita stainforthi	*Sphenolithus belemnos*	*Sphenolithus belemnos*
		Globigerinita dissimilis	*Triquetorhabdulus carinatus*	*Discoaster challengeri*
		Globorotalia kugleri		*Coccolithus* aff. *bisectus*
OLIGOCENE		*Globigerina ciperoensis*	*Sphenolithus ciperoensis*	*Coccolithus bisectus*
		Globorotalia opima opima	*Sphenolithus distentus*	*Sphenolithus distentus, S. predistentus*
		Globigerina ampliapertura	*Sphenolithus predistentus*	*Discoaster tani* s.l.
		Globigerina sellii/Pseudohastigerina barbadiensis *Globigerina tapuriensis*	*Helicopontosphaera reticulata*	*Reticulofenestra umbilica*
EOCENE	LATE	*Globorotalia cerroazulensis*	*Isthmolithus recurvus*	*Discoaster barbadiensis* *Isthmolithus recurvus*
		Globigerapsis mexicana		
	MIDDLE	*Truncorotaloides rohri*	*Discoaster tani nodifera*	*Chiasmolithus grandis*
		Orbulinoides beckmanni		
		Globorotalia lehneri		*Chiphragmalithus quadratus*
		Globigerapsis kugleri	*Chiphragmalithus quadratus*	
		Hantkenina aragonensis	*Discoaster sublodoensis*	*Discoaster sublodoensis*
	EARLY	*Acarinina densa*	*Discoaster lodoensis*	*Discoaster lodoensis*
		Globorotalia aragonensis		
		Globorotalia formosa formosa	*Marthasterites tribrachiatus*	*Marthasterites tribrachiatus*
		Globorotalia subbotinae	*Discoaster diastypus*	*Discoaster diastypus*
PALEOCENE		*Globorotalia velascoensis*	*Discoaster Multiradiatus*	*Discoaster multiradiatus*
		Globorotalia pseudomenardii		
		Globorotalia pusila pusila	*Fasciculithus Tympaniformis*	*Fasciculithus tympaniformis*
		Globorotalia uncinata	*Cruciplacolithus tenuis*	
		Globorotalia trinidadensis		
		Globorotalia pseudobulloides/Globigerina daubjergensis		
		Globigerina eugubina		
LATE CRETACEOUS	MAESTRICHTIAN	*Abathomphalus mayoroensis*		*Arkhangelskiella, Microrhabdulus, Tetralithus, Lithraphadites.*
		Globotruncana gansseri		*Tetralithus nitidus nitidus*
		Rugotruncana subcircumnodifer		*Tetralithus nitidus trifidus*
	CAMPANIAN	*Globotruncana calcarata*		
		Pseudotextularia elegans		
		Planoglobulina glabrata		

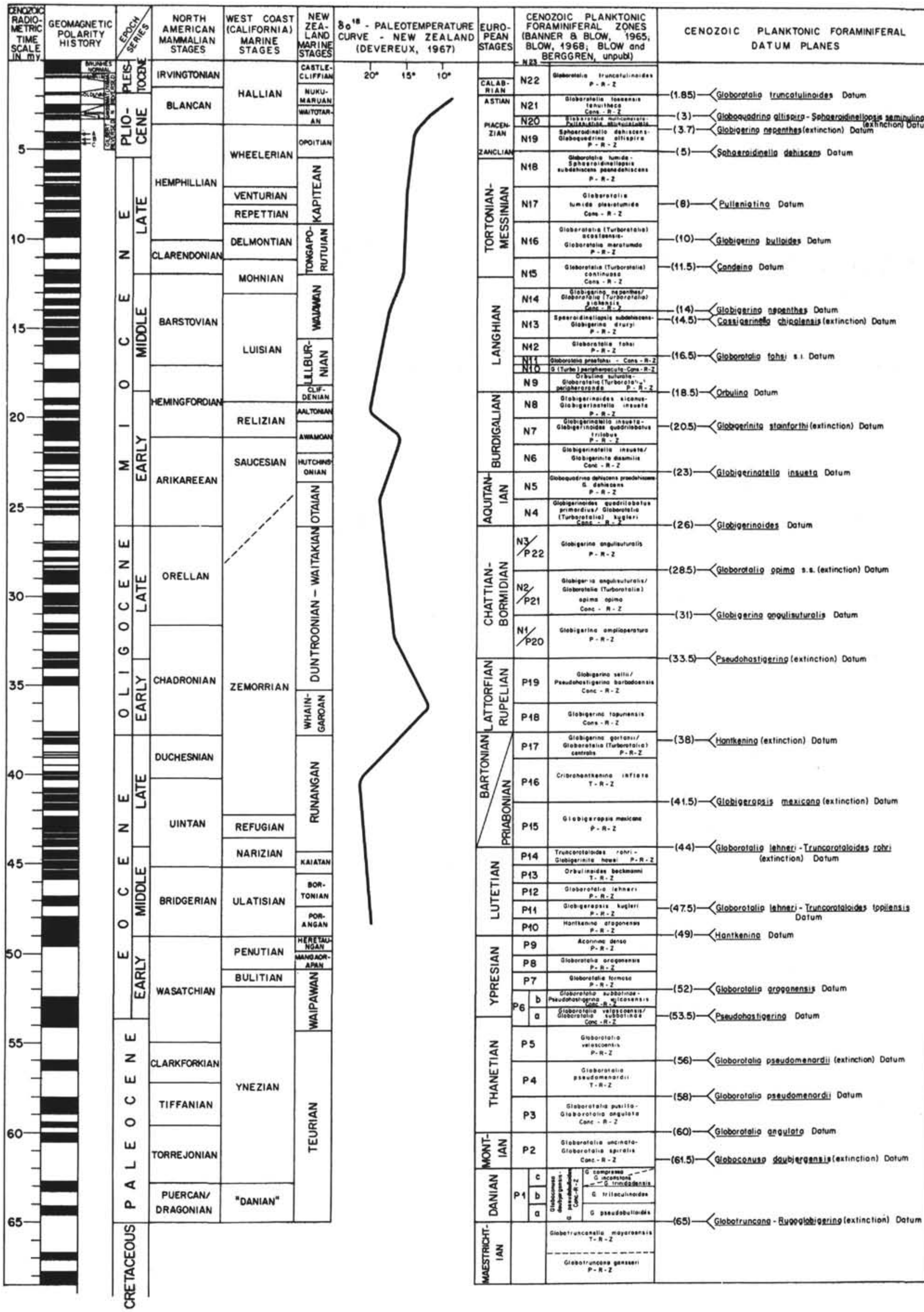

Figure 3. *Relationship between planktonic foraminiferal zones and radiometric ages. (from Berggren, 1969)*

shown alongside the columns containing the photographs and lithologic symbols. The abbreviations used to denote the various groups in a sample are N= calcareous nannoplankton, F= planktonic foraminifera and R= Radiolaria. In most of the cases, floras and faunas change only slightly from section to section in one core; therefore, unless a stratigraphic hiatus representing a considerable length of time is present, the citation, "Flora similar to above" or "Fauna similar to above" or "Flora and Fauna similar to above" is given in the sections below the one containing a full list of species. Sometimes there will appear the names of one or more species associated with this citation.

If the occurrence of species is felt to be the first appearance in the geologic history in the area around the drill site, the statement "First geologic appearance of...." will be given to distinguish it from a mere first downward occurrence of a species in drill holes, as discussed below. In many cases, the first geologic appearance of a species is coincident with the first evolutionary appearance of that particular species. The first appearance of a species as used in the Core and Section Summaries, as well as, the Site Reports refers to the first occurrence in the cored section from the top of the hole; and it is roughly coincident with extinction or last appearance of a given species in this area. If two or more samples were studied in one section, and they are of similar species composition, the list of species or previously mentioned citation is applicable to both samples. Only where floral or faunal changes occur are the samples separately described.

Beside the name of a species of planktonic foraminifera on a faunal list will appear (R) or (L) which indicates the dextral or sinistral coiling preference of the form. When a form is particularly rare, the designation "(Rare)" will be found beside it. Any occurrences of reworked forms or contamination or abnormal preservation are asterisked beside the floral or faunal description with explanations at the bottom of the Core or Section Summaries; and these occurrences are discussed in the Site Report. Asterisks are also used in the zonal columns occurring on the Core and Section Summaries where there is not sufficient space to name a zone. The name will be found at the bottom of the summary.

Absolute ages for the planktonic foraminiferal and calcareous nannoplankton zones were determined by using the stratigraphic correlation chart (Figure 3) supplied by W. A. Berggren of the Woods Hole Oceanographic Institution for the present project. This chart shows the relationship of the planktonic foraminiferal zones to applicable radiometric ages obtained from various parts of the world. Undoubtedly, this chart is subject to change as more dates become available in the future. The absolute ages are here used only to provide a means with which an approximation of the rate of sedimentation and the rate of sea-floor spreading can be made. No attempt was made to list all the species present in any given sample because of the large number of cores and the large number of samples in each that were examined. Undoubtedly, some significant species may have been overlooked. Many problems need to be solved and a great amount of detailed micropaleontologic study is possible on these materials. Thus, this report represents only a very preliminary study and should be used as a guide to determine the cores useful for detailed investigations by subsequent workers.

The planktonic foraminifera were studied by T. Saito, the calcareous nannoplankton by S. F. Percival, and the Radiolaria by E. D. Milow.

STRATIGRAPHIC PRACTICES AND NOMENCLATURE

Current stratigraphical practices in oceanography were used to assign chronostratigraphical designations to deep-sea samples. With the drilling of the Blake Plateau holes as a preliminary program by JOIDES (1965), subsurface stratigraphic units were defined and correlated as time-stratigraphic units. The experiences of stratigraphers on land have led the authors to be aware of the inherent danger of designating rock-stratigraphic units by time-stratigraphic nomenclature, particularly if such units should be proven homotaxial; namely, if such units have a similar order of arrangement in different locations, but are not exactly contemporaneous (ACSN, 1961, p. 649). Consequently it was suggested at the outset of the leg that the section penetrated by drill at each site should be divided into rock-stratigraphic units, each being assigned an age range on the basis of their paleontology and their relationship to other units. This caution was justified. In the process of drilling twelve holes at seven sites across the South Atlantic Ridge, the correlation of the rock-stratigraphic units proves their homotaxial nature. This practice not only alleviated the necessity of lengthy and repetitive core descriptions, but the rock-stratigraphic units also provided the basic elements for a synthesis of the sedimentary history of the South Atlantic.

The existing Code on Stratigraphic Nomenclature was formulated by and for stratigraphers working on continental geology. The code recommends a bionomial nomenclature: the formal name of a rock-stratigraphic unit of any rank should consist "of a geographic name combined with a descriptive lithologic term or with the appropriate rank term alone" (p. 651). The Code further suggests that "the geographic name should be the name of a natural or artificial feature at or near which the rock-stratigraphic unit is typically developed... A subsurface name may be given a farm name, if its type locality happens to be in some sparsely populated area with few geographic names." The Code makes no provisions for submarine subsurface units. The authors found it impossible to follow the Code when designating the Mid-Atlantic Ridge formations; there are few available geographic names there suitable for that purpose. In addition, those formations are not only submarine, but also subsurface units, and more than one type of section may be represented at a single site.

Our experiences during Leg 3 of the cruise led the authors to suggest the stratigraphic practices which follow; and, they are contacting the American Commission on Stratigraphic Nomenclature for formal approval. Tentatively the authors recognize two types of rock-stratigraphic units:

(1) *Subsurface Lithologic Unit.* A stratigraphic section penetrated by drill at each site should be divided into a number of subsurface lithologic units. The division may be made on shipboard on the basis of visual examination of cores and smear slides, to be confirmed or modified by further ship- and shore-based studies of the mineralogy and physical properties. Such a unit may consist of sediments of one particular type or it may be characterized by a heterogeneous assemblage of different sediment types. Some arbitrarily chosen criteria must be selected to draw boundaries between units if lithological changes are gradual or transitional, or if a boundary does not fall within the core interval. In the latter case, drill-rate data and logging data, if available, may provide additional criteria.

The authors recommend that subsurface lithologic units be named by the project, the site, the core and the section numbers of the core in which the unit first appeared (e.g., DSDP 3-13-1-1). In this report the prefix DSDP will be omitted.

(2) *Formations.* As stated in the Code, "the formation is the fundamental unit in rock stratigraphic classification... A formation ... is mappable at the earth surface or traceable in the subsurface. ... It may contain between its upper and lower limits (i) rock of one lithologic type, (ii) repetitions of two or more lithologic types, or (iii) extreme heterogeneity of constitution which in itself may constitute a form of unity compared to the adjacent rock units" (ACSN, 1961, p. 650). A submarine subsurface formation should have the same attributes. *Subsurface lithologic units which could be traced from one site to another constitute submarine formations.*

Oceanographers have designated subbottom acoustic reflectors by alphabets (e.g., Horizon A). To borrow this practice for submarine formations would lead not only to confusion, but also to some other inherent difficulties encountered by stratigraphers when sequential symbols are used as names. On the other hand, a certain mnemonic device is desirable. After much consideration and consultation, the authors have decided to use the names of historical exploratory vessels for submarine formations. Such a practice of employing already familiar names has an added advantage in that the formations at any region could be named in an alphabetical order, for example, from the youngest to the oldest, as a flexible mnemonic device.

The formations described for the southern Mid-Atlantic Ridge Province are as follows, with their type sections:

Formation Name	Type Section
Albatross Ooze	3-16-1-1
Blake Ooze	3-16-4-5
Challenger Ooze	3-16-9-1
Discovery Clay	3-19-1-2
Endeavor Ooze	3-15-6-4
Fram Ooze	3-17A-2-4
Gazelle Ooze	3-20C-3-1
Grampus Ooze	3-14-6-1
Hirondelle Ooze	3-20C-5-1

All ooze formations are chalk oozes, except the Endeavor, which is a marl ooze formation. However, following the recommendation of the Code, compound terms for lithologic description are avoided, and no adjectives are placed between the geographic and lithologic terms.

PHYSICAL PROPERTIES

Natural Gamma Radiation

Natural gamma-radiation measurements have the potential of detecting significant concentrations of radionuclides in sediments in order to distinguish different sediment types, which may concentrate differing amounts and types of isotopes. Natural gamma radiation generally distinguishes shaly from non-shaly formations (Lynch, 1962). In fine-grained sediments, clay and zeolite minerals have ion exchange capacities which may hold gamma-ray emitting isotopes, in addition to isotopes which may be contained in the original mineral structures. According to Lynch (1962), gamma radiation from sands tends to be low unless potassium feldspars are abundant. Silica and calcium carbonate from organisms usually have low radiation, although radionuclides can be concentrated by some organisms (Koczy, 1963); and dolomites are more likely to contain radioactive elements.

Gamma measurements, in general, do not distinguish between any particular isotopes. In sediments, the potassium isotope series typically contributes about half the total natural gamma radiation, with the remainder usually being emitted from the uranium and thorium isotopes (Evans, *et al.* 1968). The natural radiation from gamma-ray emitting isotopes, such as: U^{235}, Ra^{226}, Pb^{212}, P^{214}, K^{40}, Th^{208}, Bi^{214}, P^{36}, and other isotopes in marine sediments is discussed by Koczy and Rosholt (1962), Koczy (1963), Mauchline and Templeton (1964), Prospero and Koczy (1966), and Lal and Peters (1967) which contain comprehensive reviews and references.

Aboard the *Glomar Challenger,* natural radiation was recorded at intervals of 7.62 centimeters (3 inches) along the core during 2.5-minute periods at Sites 13 and 14, and 1.25-minute periods at Sites 15 to 22. The data will be reported at the 1.25 minute scanning period. The actual volume of the sample is greater than the 7.62 centimeter (3.00-inch) core segment. The exposure or scanning time must be considered when comparing these data to those of other legs. Radiation counts at the ends of the cores are low because the volume of sediment being scanned is reduced. Detailed equipment descriptions are in Evans *et al.* (1968), and in the Leg 2 volume.

The gamma radiation data may not precisely represent *in situ* conditions as the samples were disturbed.

Porosity-Wet Bulk Density-Water Content

Porosities and wet-bulk densities of sediments have been studied thoroughly because of their relation of other physical properties of sediments. Correlations of porosity and wet-bulk density to other properties such as, sound velocity, encouraged Hamilton *et al.* (1956), Laughton (1954; 1957), Sutton *et al.* (1957), Shumway (1960), Schreiber (1968), and Horn *et al.* (1968) to collect marine sediment samples and analyze their porosities, densities and other physical properties and their interrelationships. Porosity-density interrelationships have been reported with respect to "soil mechanics" of marine sediments (Hamilton, 1959; Moore and Shumway, 1959; Richards, 1962), heat conductivity in marine sediments (Bullard *et al.,* 1956; Bullard and Day, 1961; Ratcliffe, 1960), and electrical conductivity in marine sediments (Boyce, 1968). In general, these were "near surface" sediments.

Porosity and wet-bulk density relationships to consolidation have been studied by Hamilton (1959; 1960) in an investigation of the thickness, consolidation, ages, and the amounts of original sediments in the ocean basins. Actual measurements of porosity, wet-bulk density and related properties of sediment samples, which were buried to depths of 130 meters (426 feet), from the Guadalupe Mohole Site, were reported by Igelman and Hamilton (1963), Moore (1964) and Hamilton (1964; 1965).

Porosities were measured continuously with the Gamma Ray Attenuation Porosity Evaluator (GRAPE) and individual small samples removed from the cores. Porosity is defined in this report as:

$$\left[\frac{\text{(volume of pore space)}}{\text{(volume of wet sample)}}\right] \times 100.$$

Individual sample porosities were determined from the volume of the wet sample and weights of the wet and dry sediment sample. Water content is defined as the weight of water in the sediment divided by the total weight of the saturated sediment, expressed as a percentage without salt corrections.

Wet-bulk densities were measured by three methods: (1) by weighing the total core section, (2) from individual small samples (porosity sample), and (3) with the GRAPE unit. The GRAPE data are approximations based on electron/density ratios of minerals [(number of electrons per atom)/(atomic weight of the absorber)]. This ratio is assumed to be 0.5, which is applicable for most minerals (Lynch, 1963; Evans and Cotterell, 1968). (See Leg 2 volume.) Problems arise when grain matrices, like some opaline and clay minerals, have water included in their mineral structure which could be misconstrued as pore space.

GRAPE information is presented in the form of continuous analog graphs. These graphs are calibrated with an uncorrected sea water density of 1.03 g/cc (100 per cent porosity) and an aluminum bar (2 per cent porosity) using a corrected density of 2.6 g/cc (Schlumberger, 1966), which allows the best graphical approximation of bulk density data. Porosities are calculated from the GRAPE densities via approximated grain matrix densities of cores or sections. But, these sections may have layers of sediment with high (dolomite) or low (opaline silica) grain matrices, thus the GRAPE porosity values may be in error in excess of 5 per cent. The reader interested in specific individual porosities with a distinct matrix density may easily calculate them via the wet-bulk density, and grain matrix density. Specific porosity samples and GRAPE porosity values usually agreed within ±5 per cent.

GRAPE wet-bulk densities and the wet-bulk densities from the core section weights were in many cases low (10 per cent), which is probably related to excess water and air trapped in the core section. The selected porosity wet-bulk density samples appear to be the most reliable. The GRAPE wet-bulk densities appear to typically vary by about ±5 per cent. These discrepancies may be caused by disturbed and compacted sediment adjacent to the core liner, which the GRAPE unit includes in its measurements.

These porosity wet-bulk density values may not entirely represent *in situ* conditions as some cores were disturbed during the coring operations.

Sediment Sound Velocity

Knowledge of the sound velocity of marine sediments is important for interpretation of reflection profiles, refraction assumptions and well-log correlations and predictions. Velocities in marine sediments have been measured previously under laboratory conditions and, in some cases, have included *in situ* measurement, by Hamilton (1956; 1963), Hamilton *et al.* (1956), Laughton (1954; 1957), Sutton *et al.* (1957), Shumway (1960), Schreiber (1968), Horn *et al.* (1968) and others. These investigators, and Nafe and Drake (1957; 1963), related surface sediment sound velocities to other mass physical properties of surface sediments. Subsurface sediment sound velocities have been analyzed by Hamilton (1965) on the samples retrieved from the experimental Mohole (Guadalupe Site).

The sound velocities measured on Leg 3 of the Deep Sea Drilling Project were not corrected to *in situ* temperatures and pressures, but are reported at ambient laboratory conditions. The application of such corrections is discussed by Hamilton *et al.* (1956), Hamilton (1963; 1965), Sutton *et al.* (1957), Laughton (1954; 1957) and Shumway (1958; 1960).

The sound velocities of the sediments were measured while the core was still in its plastic liner using a pulse method, which is described in detail by Winokur and Chanesman (1966). The pulse technique has been used or described in slightly different equipment setups by Patterson (1956), Laughton (1957), Sutton *et al.* (1957) and Abernethy (1965).

The Winokur and Chanesman (1966) method essentially measures the differences in time for sound (400 kHz) to travel through a standard water sample and the unknown sediment sample at a known temperature and pressure. The sound velocity of the water is known, and the dimensions of the sediment and water samples are assumed to be the same; thus, velocity can be calculated.

The precision of this method is markedly decreased if the dimensions of the standard water core and the sediment core are not identical; and, in many cases, the dimensions of the core liner were physically distorted. This problem was compounded by the oil in the transducer heads having a lower sound velocity than that of the sediment or water. Thus, the short axis of an elliptical core would have a longer travel time than the long axis, which is the reverse of what should occur. This particular arrangement had a reproducibility of about ±5 per cent, but, on the average, the error was less than this percentage.

These sound velocities, even after temperature-pressure corrections, may not necessarily represent *in situ* velocities as many of the cores were disturbed during coring.

Penetrometer

The purpose of the penetration measurements was to indicate only relative differences of the sediment "strength" for purposes of lithologic description. Penetrometer values are in units of 1/10th of a millimeter that a standard needle will penetrate under a fixed load of 50 grams (±0.1 gram). The needle is about 5 centimeters in length and 1.00 to 1.02 millimeters in diameter. This apparatus is described in detail in the *American Society of Testing and Materials* (1965). These measurements were not designed to set a specific value on sediment strength, but rather to be a basis for relative degrees of comparison.

Thermal Conductivity

According to Langseth (1965):

> The measurement of heat flow through the surface of the Earth is fundamental to the study of the thermal state that exists at depth in the crust and the upper mantle. The heat flux at the surface can be determined by measuring the temperature gradient and multiplying by the conductivity of the material between the two points of measurement."[1]

The extent to which the temperature distribution at depth can be extrapolated via conductivity measurements depends on (1) whether the interval of temperature measurement is free from the flow of mass such as, circulating interstitial water, which would greatly disturb the conductive heat transfer; (2) whether the conductivities of the rocks at the site are homogeneous enough to allow meaningful extrapolations of the observed heat flux; and (3) whether the actual conductivity measurements are representative of *in situ* conditions. For detailed discussions of heat flow, heat conductivity, and references, see *Geophysical Monograph, No. 8,* of the American Geophysical Union entitled "Terrestrial Heat Flow."

At the present time heat flow measurements have not been successful, however, heat conductivity measurements have been continued. These measurements combined with continuous porosity measurements, hopefully, supply good approximate average heat conductivities that must be known in order to extrapolate temperatures with increasing depth. This would be useful for geochemists and students of mantle convection.

Aboard the *Glomar Challenger* the transient-needle method was used to measure the heat conductivity of

[1]Langseth, M. G., 1965. Techniques of measuring heat flow through the ocean floor. (Chapter 4) **In** "Terrestrial Heat Flow." *American Geophysical Union Monograph No. 8.* 58.

the sediments. This needle is 6.4 centimeters long and 1.0 millimeter in diameter, and it contains a heater and a thermister. The sediment is heated by the needle and the temperature is measured by the thermister. The rate at which the sediments dissipates this heat is a function of its thermal conductivity. This method is described in detail by Von Herzen and Maxwell (1959) and Langseth (1965). The method has a reproducibility of about 2.5 per cent.

Heat conductivity measurements were predominately performed on disturbed sediment samples. The reader may with to attempt recalculating the porosities and heat conductivities to what he believes to be *in situ* conditions. These conductivities measured from disturbed samples of true unconsolidated sediments may, in part, reflect approximations of gross *in situ* conditions and, in part, reflect the coring disturbance and grain size distribution. Some of the firmer sediments appear to be cored in a relatively undisturbed condition. These heat conductivities are reported at ambient laboratory temperatures and pressures.

CHEMICAL PROPERTIES

Interstitial Water

Interstitial waters were squeezed (Manheim, 1966) from selected sediment samples. The sediment residues and expelled waters were collected and saved, except for one drop of water which had its salinity measured with a Goldburg Hand Refractometer. Salinity is expressed here as parts per thousand (ppt) and defined as the gram weight of solids in one kilogram of sea water, with all carbonate converted to oxides, bromine and iodine replaced by chlorine, and all organic matter oxidized and dried. Previous analyses of interstitial waters of marine "surface" sediments have been reported by Brujewicz and Zaitzeva (1959) and Shishkina (1966), who examined the chemical features of the marine interstitial solutions of the Bering Sea sediments and Shiskina and Bykova (1961) who studied the interstitial waters of Atlantic sediments. Interstitial water salinities of these surface sediments were discovered to have only slight variations from the normal bottom water salinity.

Interstitial waters of deeper sediments were examined by Siever and others (1961; 1965) and Manheim (1967). Siever studied the chlorinities of pore waters of sediments from the Mohole (Guadalupe Site), the Gulf of California and the Atlantic Ocean, and found about ±1 ppt deviation from 19.3 ppt chlorinity. Manheim (1967), studying samples from the JOIDES drilling off the coast of Florida (JOIDES, 1965), reported distinct changes in interstitial water salinities. Apparently, fresh waters traveling from the continent through aquifers were diluting these sediments.

A possible source of contamination of the Leg 3 samples is the sea water, which was circulated down the drill pipe. Care was exercised to sample interstitial water from cores that appeared to be least disturbed.

DATA PRESENTATION

The data obtained during Leg 3 are presented in this report in the following manner. First, there is a section dealing with Shipboard Reports in which each site is described in terms of: (1) the survey data and site background material; (2) the operational data which include positioning, drilling and coring facts; (3) paleontology; (4) stratigraphy; (5) physical properties, including: gamma radiation, porosity, wet-bulk density, water content, sound velocity, penetrometer, thermal conductivity and interstitial water salinity. Further, for each site a Hole Summary is presented in graphical form. The Hole Summary, in turn, is further broken down into Core Summaries and, where conditions warrant, described as selected Section Summaries.

Leg 3 Shipboard Results are summarized and conclusions drawn on three separate geographical areas: Sierra Leone Rise, Rio Grande Rise and Mid-Atlantic Ridge. Since several holes can be correlated with respect to the Mid-Atlantic Ridge Sites, that summary has been further subdivided into paleontologic, stratigraphic and geophysical considerations. A history of the South Atlantic Basin concludes this section.

Following the Shipboard Reports there is a separate section pertaining to Shore Laboratory Reports. This is concerned with: (1) grain size analysis, (2) calcium-carbonate analysis, (3) X-ray mineralogy, (4) neutron activation analysis, (5) Coccolith dating, (6) calcareous nannoplankton dating, (7) foraminifera dating, (8) Interstitial water, and (9) paleomagnetism.

REFERENCES

See consolidated list at the end of Chapter 13.