1. INTRODUCTION

D. E. Hayes, Lamont-Doherty Geological Observatory of Columbia University, Palisades, New York
and
A. C. Pimm, Scripps Institution of Oceanography, La Jolla, California

GENERAL OBJECTIVES

The main objectives of Leg 14, as outlined by the JOIDES Atlantic Advisory Panel of the DSDP, were to study the processes of sedimentation, sediment disposition and structural evolution of continental margins off West Africa and northern South America. The results off West Africa were then to be compared to those obtained off the eastern margin of the U. S. A. on Legs 1 and 11 of the DSDP in order to study the evolution of the North Atlantic and in particular to investigate the early history of continental drift. Specific targets and objectives included: 1) drilling several holes on or adjacent to the West African Continental Rise; 2) drilling a deep sea diapiric structure north of the Cape Verde Islands, presumed by many to be a salt dome; 3) drilling two large anomalous morphologic features-the Ceara Rise and Demerara Rise-off northeast South America.

Locations of the Leg 14 sites and other sites drilled by the DSDP off West Africa are shown on a map folded into the pocket at the back of this volume. This map also shows the major tectonic units of the West African continent, the generalized bathymetry of the adjacent Atlantic Ocean, selected major structural and geophysical parameters of the sea floor, and the schematic stratigraphic succession as recorded at each drill site.

A summary of the site data is given in Table 1. The location of drill sites and summary lithostratigraphic logs are shown respectively in Figures 1 and 2. The allocation of time for the various cruise operations is given in Figure 3.

SUMMARY OF SIGNIFICANT RESULTS

Basalt, judged on all available evidence to be part of Layer 2 of the oceanic crust, was recovered at Sites 136 and 137 in the east Atlantic from depths that correlate with the anticipated depth of the basement reflector. Sediments overlying the basalt indicate the best estimate for the age of the basalt at Site 136 is 106 to 109 million years and at Site 137 is 100 to 102 million years. Reconciling these ages with one another and with the major features of the magnetic anomaly pattern, may require drastic revision of the published hypotheses of sea-floor spreading in the North Atlantic.

At Sites 138 and 141, basalt was also recovered but at depths that do not correlate well with the basement reflector from seismic profiles. At Site 138, the basalt is thought to be part of a sill covering about 100 meters of additional sediments and the true oceanic basement layer. At Site 141, highly altered basalt was encountered at a depth of 297 meters in the core of a piercement structure defined by a zone of no acoustic reflections. This feature has been interpreted in the literature as a salt diapir, but sediments cored above the basalt showed no sign of any salt concentrations.

Major hiatuses in the Tertiary and Upper Cretaceous sections were inferred from the lithostratigraphy at Sites 135, 136, and 140. Similar hiatuses are indicated for many other sites drilled in the North Atlantic and elsewhere. The interrelation of all these hiatuses is not yet known, but many of them are interpreted as representing periods of erosion or non-deposition in response to ocean-wide or global events.

Several sites in the east Atlantic (135, 136, 137) show an older (Lower to Upper Cretaceous) calcareous facies passing up into younger deep-sea clay facies in the Upper Cretaceous to Lower Tertiary. This facies change is interpreted as recording the subsidence associated with the lateral migration of sites away from the Mid-Atlantic Ridge axis, thereby passing from depths lying above the carbonate compensation depth to depths below it.

Several sites (135, 136, 139, 140, 141) show a Quaternary to Upper Tertiary calcareous facies resting on a non-calcareous clay-silt-sand facies of early Neogene and older age. This facies change could be caused by: a deepening of the carbonate compensation depth in late Tertiary times; uplift of some sites; and a buildup of the continental rise or any combination of these processes. These results show that terrigenous material is a minor constituent of rise sediments off West Africa in the late Tertiary in strong contrast to the continental rise of eastern U.S.

A prominent reflecting horizon that underlies most of the Ceara Abyssal-Plain at subbottom depths ranging from 300 to 1000 meters is the result of a series of thin alternating chalk/marl ooze and turbidite layers deposited in the Late Miocene or Early Pliocene. A major portion of the Ceara Abyssal Plain sediments lie above the reflecting horizon and have probably been deposited since the Early Pliocene. The generally undisturbed character of the reflector abutting the flank of the Ceara Rise indicates any major vertical motion of the Ruse was pre-Early Pliocene.

Marine sidements were deposited on the Demerara Rise prior to the inferred separation of South America and Africa. The sedimentary record also shows an almost continuous history of subsidence of at least 2000 meters of the Demerara Rise since early Cretaceous times. Three hiatuses, each of about 8 million years duration, indicate interruptions in the sedimentation of this area.

An excellent succession of Cenomanian nannoplankton was recovered at Site 137 and should be valuable in establishing a world-wide biostratigraphic subdivision of the Late Mesozoic. At Site 141, a rich well-preserved

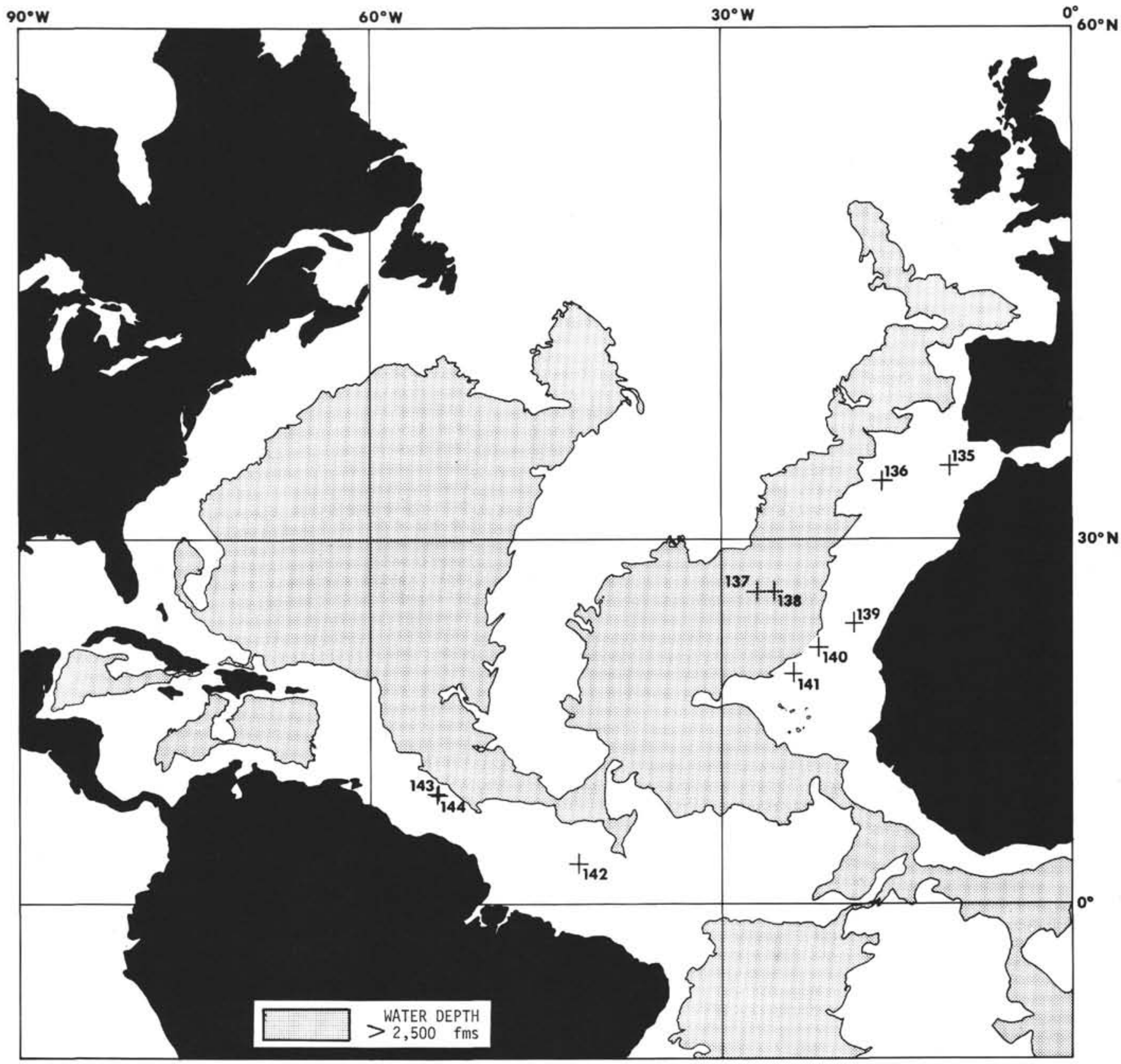


Figure 1. *Location of sites drilled on Leg 14.*

assemblage of Pliocene and Quaternary calcareous microfossils will prove to be valuable in biostratigraphic correlation of tropical and temperature zonations.

SITE 135

Site 135 lies about 40 km southeast of the southern edge of the Horseshoe Abyssal Plain on a topographic high 750 meters above the abyssal plain. The site is south of the seismically active Azores-Gibraltar fracture zone.

The top 325 meters of the section is comprised of nannoplankton chalk ooze of Pleistocene, Pliocene, and Miocene age. Below this, 364 meters of mostly terrigenous sediments, with some silicified intervals and marl or limestone at the base, range in age from Early Eocene to Early Aptian. It is not possible to reasonably estimate the thickness of individual lithologic units within this lower interval.

A prominent reflecting horizon at ∿0.4 second can be traced from beneath the adjacent abyssal plain onto the topographic high. This reflector corresponds to a major unconformity which marks the abrupt change from terrigenous to pelagic sedimentation that occurred following post early Eocene and pre-late Oligocene uplift and faulting.

An estimated 350 meters of sediment are present between the lowest sample obtained and oceanic basement (layer 2).

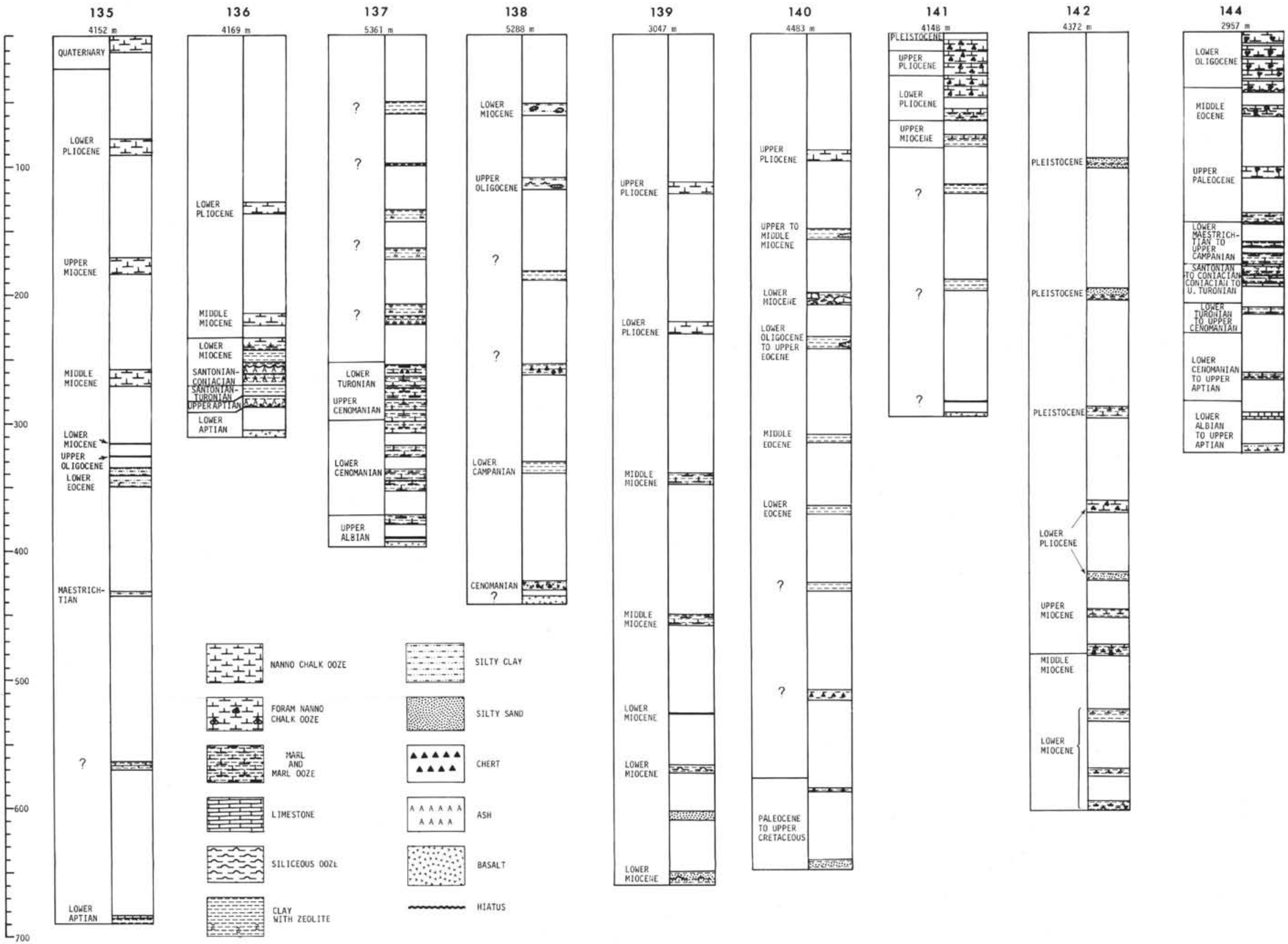


Figure 2. *Summary of lithostratigraphy of Leg 14 sites.*

TABLE 1
Leg 14 Site Summary Data

Site	Hole	Latitude	Longitude	Water Depth (m)	Cores w/Recovery	Meters Cored	Meters Recovered	Meters Drilled	Total Meters Penetrated
135	0	35° 20.80′N	10° 25.46′W	4152	9	57.0	24.60	632.0	689.0
136	0	34° 10.13′N	16° 18.19′W	4169	9	77.0	34.50	236.0	313.0
137	0	25° 55.53′N	27° 03.64′W	5361	17	136.0	67.81	265.0	401.0
138	0	25° 55.37′N	25° 33.79′W	5288	7	54.0	23.41	388.0	442.0
139	0	23° 31.14′N	18° 42.26′W	3047	7	61.0	17.31	604.0	665.0
140	0	21° 44.97′N	21° 47.52′W	4483	8	53.0	29.81	598.0	651.0
140	A	21° 44.97′N	21° 47.52′W	4483	2	18.0	9.06	235.0	253.0
141	0	19° 25.16′N	23° 59.91′W	4148	10	81.0	72.42	217.0	298.0
142	0	03° 22.15′N	42° 23.49′W	4372	9	72.0	40.87	537.0	609.0
143	0	09° 28.45′N	54° 18.71′W	3493	0	0	0	32.0	32.0
143	A	09° 28.45′N	54° 18.71′W	3493	1	9.0	3.00	14.0	23.0
143	B	09° 28.45′N	54° 18.71′W	3493	0	0	0	36.0	36.0
143	C	09° 28.45′N	54° 18.71′W	3501	0	9.0	0	40.0	49.0
143	D	09° 28.45′N	54° 18.71′W	3501	0	0	0	18.0	18.0
144	0	09° 27.23′N	54° 20.52′W	2957	8	39.0	27.80	288.0	327.0
144	A	09° 27.23′N	54° 20.52′W	2957	6	54.0	28.83	146.0	200.0
144	B	09° 27.23′N	54° 20.52′W	2957	3	27.0	26.98	9.0	36.0
					Total Meters:	747.0	406.40	4,295.0	5,042.0
					Total Feet:	2,450.0	1,333.00	14,091.0	16,542.0

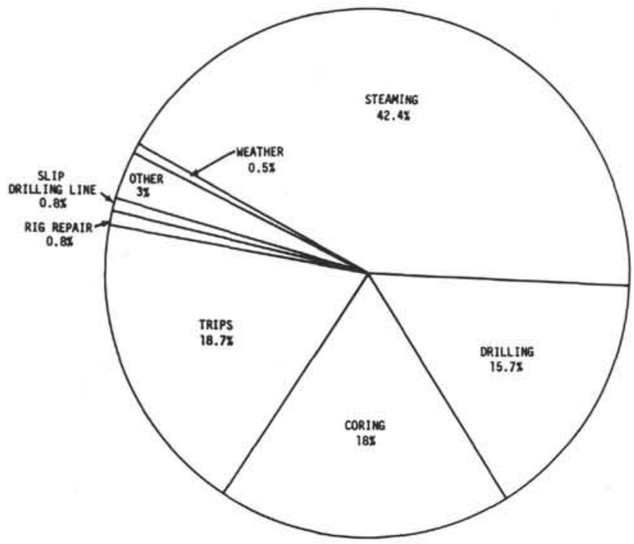


Figure 3. *Cruise operations.*

SITE 136

Site 136 lies about 160 km north of Madeira and 900 km southwest of Gibraltar in an area of abyssal hills.

Pliocene to Miocene nannoplankton chalk ooze overlies early Miocene clay. From 259 to 268 meters, the Miocene clay passes into a 9 meter interval of barren clay and then into Senonian ash and calcareous red clay. The time period represented by this 9 meter interval is about 60 million years. The oldest sediments cored were multicolored clays and, at 290 meters, nannoplankton marls of Albian age. Aptian shales, however, were recovered from bit cuttings. Oceanic basalt (tholeiitic diabase) was recovered at a depth of 308 meters which correlates well with the anticipated depth of the acoustic basement. The widespread occurrence of this basement reflector, its acoustic character, and the petrology of the basalt suggest that true oceanic basement was sampled. The oldest sediments at this site (~105 to 110 million years) are therefore surprisingly young in view of its proximity to the continental margin and when compared to the crustal age inferred from magnetic anomalies and drilling results in the western North Atlantic.

SITES 137 AND 138

Site 137 was drilled in an area of abyssal hills close to the foot of the continental rise about 1000 km west of Cap Blanc, West Africa. Site 138 was located 130 km to the east and on the continental rise.

The objectives here were to compare the sedimentary history of Site 137 with Site 138 in order to understand the apparent differences in thickness and character of the sediments as shown by seismic reflection profiles. A secondary objective was to determine if the thick palygorskite sequence sampled at Site 12, Leg 2 extends into this area.

At Site 137, about 245 meters of brown clay of Tertiary to Senonian age passes down through a 32 meter transitional zone of Turonian to Cenomanian black clay, calcareous clay, and chert into about 120 meters of nannoplankton marl/chalk ooze of early Turonian to late Albian age.

Basalt was reached at 397 meters subbottom, and correlates well with the basement reflector at 0.40 second. Late Albian marl ooze was recovered in a sidewall sample three meters above the top of the basalt. The basalt is a strongly altered porphyritic flow rock cut by numerous fractures filled mainly with chlorite and less commonly calcite and zeolite; it has alkalic affinities.

At Site 138, about 200 to 250 meters of Tertiary clay, silt, and sand rest on 190 to 240 meters of Upper Cretaceous sediment. The latter is mainly mudstone and shale with thin chert at 255 meters; clay at 332 meters; and dolomite silt and dolomite clay cyclically interbedded with carbonaceous mud at 425 meters. A 50-cm layer of fine-grained altered basalt lies within one dolomite-clay sequence. At a subbottom depth of 437 meters, the hole is bottomed in coarse-grained, slightly altered, basalt with alkalic affinities. If this unit represents the basement reflector at about 0.50 second on the *Challenger* seismic profile, then compressional wave velocities averaged for the complete sedimentary succession (~1.76 km/sec) are lower than would be expected. Compared with Site 137 the age (Cenomanian) of sediment above the basalt appears too young (Cenomanian versus late Albian), suggesting that the latter is an intrusive sill and not oceanic crust. One of the intermediate reflectors on the *Challenger* profile may be represented by the indurated shale and chert in Core 4 (~255 meters).

Palygorskite-rich clay sequences were penetrated at both sites, and at Site 137 the minimum thickness is at least 120 meters, compared with 85 meters for Site 12; the thickness at Site 138 is not known.

SITE 139

Site 139 lies on the middle continental rise 250 km west of Cap Blanc.

The objective was to recover sufficient sediment to compare the geological history of this continental rise with that of the eastern United States.

About 520 meters of Pliocene to Miocene nannoplankton chalk and marl ooze, with a small terrigenous component, overlie Early Miocene diatom ooze with quartz sand which is at least 140 meters thick.

The strongest intermediate reflector, seen on the seismic profiles at 0.60 second, probably corresponds with the pronounced change in lithology from carbonate to siliceous sediments inferred at a depth of 523 meters.

The sediments show a marked salinity gradient from 38 ppt in Core 1 to 75 ppt in Core 7.

SITE 140

Site 140 is located at the foot of the continental rise 450 km west of Cap Blanc at the magnetic quiet zone boundary.

The objective was to compare the sedimentary history here with that at Sites 136-139.

About 150 meters of nannoplankton chalk ooze of Pliocene age and about 75 meters of silty clay and diatom ooze of Miocene age, overlie, with a 20 to 30 million year hiatus, at least 400 meters of Middle Eocene to Upper Cretaceous siliceous clay, shale, and chert with thin silt and sand beds. Dolomite is common to abundant in some silt beds.

The Miocene and older sediments contain an abundance of detrital quartz. Nearly all sediments from this site show evidence of redeposition and have high sedimentation rates.

The first major zone of reflections on the *Challenger* record can be correlated with the major lithologic changes from calcareous ooze above to silty clay below.

SITE 141

Site 141 is located about 200 km north of the Cape Verde Islands on a "diapiric structure" in an area of gently rolling bottom topography.

About 80 meters of chalk ooze of Pleistocene to Pliocene age rests on about 200 meters of brown, red, and green barren clays. These sediments rest on a highly altered, serpentinized basalt at a subbottom depth of 295 meters.

The transition from non-carbonate to carbonate sediments occurs at a total depth of 4243 meters, about 400 meters shallower than other sites in the area, and indicates a significant local uplift of this site of deposition since early Pliocene.

The structure drilled has an appearance on seismic reflection records similar to that of known salt diapirs. There is no indication of anomalously high salt concentrations at this site. The "diapiric structure" is represented by a steep sided zone of no acoustic reflection. Neither the 300 meters of ooze and clay nor the underlying basalt are represented by identifiable reflecting horizons. Hole 141 was drilled in the crest of a structure that has a topographic expression of about 400 meters and diameter of 2-4 km. Numerous, apparently, similar structures are present nearby.

SITE 142

Site 142 lies in the Ceara Abyssal Plain about 10 km south of the steep southern flank of the Ceara Rise and about 650 km northeast of the Amazon River.

The seismic profile at Site 142 shows three main reflecting units in the abyssal plain sediments abutting against the flank of the Ceara Rise. An upper reflective zone represents a unit about 305 meters thick and consists of Pleistocene subarkosic silty sand and calcareous mud to nannoplankton marl ooze. A transparent zone represents a unit about 120 meters thick and consists of Pliocene foraminifera nannoplankton chalk ooze passing down into calcareous clay, foram sand, and sandy silt. A lower reflective zone represents a unit about 100 meters thick and consists of interbedded marl muds, nannoplankton marl/chalk ooze, foram sands, and clay. The age of this unit ranges from topmost Miocene to the Middle Early Miocene. The top of the lower reflective zone is defined by a prominent seismic reflector which extends over thousands of square kilometers. The reflecting horizon boundary may serve as an important Pliocene/Miocene marker horizon.

The flank of the Ceara Rise was penetrated near 537 meters subbottom. Only one core, indurated nannoplankton marl mud of Early Miocene age, was recovered beneath this level. At about 607 meters subbottom, a center bit sample of nannoplankton marl yielded an Early Miocene flora.

Subsidence of the drilling site since Early Miocene is indicated on lithologic grounds.

SITES 143 AND 144

Site 143 lies about halfway down the lower flank of the Demerara Rise, and Site 144 lies near the top just below the edge of the flat upper plateau, about 3 km southwest of Site 143 and about 270 km north of the Guianas.

The objectives at these sites were to sample old sediments in a likely area of the proto-Atlantic Ocean and to date an angular unconformity shown by seismic reflection records.

Only one core of Cretaceous material was recovered at the sea floor at Site 143 before technical problems necessitated abandoning the site.

A sequence of Oligocene at the sea floor to Early Albian to Late Aptian sediments at a depth of 325 meters, was recovered at Site 144. Three small hiatuses were detected: (1) in the Late Eocene at 46 meters, (2) at the Tertiary Cretaceous boundary at 147 meters, and (3) between Late Campanian and Early Santonian at 180 meters.

The succession here consists of Oligocene to Paleocene foraminifera-nannoplankton chalk ooze with Radiolaria in the Eocene. Paleocene and Maestrichtian sediments are mainly zeolitic marl. At 181 meters there is a pronounced lithology change to zeolitic calcareous carbonaceous shale with a strong H_2S odor which is mainly of Senonian to Turonian age. Below this, marls, quartzose marlstone, shelly limestone, and carbonaceous clay were deposited from Cenomanian to Aptian times.

Sediments formed at the site of deposition, and those from neighboring marginal shelves and the continent, indicate regional subsidence over a long period of time.

EXPLANATORY NOTES – UNDERWAY PROCEDURES

The *Glomar Challenger* underway geophysical date were collected using: a Varian proton-precession magnetometer, a 12 kHz (30° half-angle) transducer transceiver system recorder on Gifft GDR-IC-19 recorders for precision depth determination, and a seismic reflection profiler system consisting of a Bolt PAR 600A air gun, a 20 phone EVP-23 element towed array, a Bolt PA-7 band pass filter and Edo Western Model PBR 333 recorders. The normal frequency recording band was 30-150 Hz.

All navigation was accomplished with the aid of the Navy satellite navigation system and precision fixes obtained about every 2 hours using a ITT Model Satellite receiver-computer system. The adjusted navigation was reexamined at the laboratory using the dead reckoning information of gyrocompass and distance through the water (Chesapeake E-M log) to interpolate in detail between satellite fixes using computer techniques in the manner of Talwani *et al.* (1965).

The normal operations in approaching a site consisted of steaming across the proposed site at a reduced speed of 4-6 knots and dropping a marker buoy. After steaming beyond the site 2-3 miles, the towed geophysical gear was retrieved, the ship course was reversed, and the ship was returned to the vicinity of the marker buoy. In most instances, sufficient relief of the bottom topography allowed us to use the depth recorder to relocate our designated site to within a fractional part of a mile. Special surveying operations were conducted at Site 141 before selecting the drill site (see Chapter 8). At least 12 fixes were obtained at each site and were used in determining the mean position of the sites.

OPERATIONS

Drilling statistics are included in the site summary given as Table 1. A time analysis of Leg 14 is given as Figure 3. Leg 14 involved an unusually high percentage of steaming time because of the location of sites on both sides of the Atlantic Ocean (Figure 1). Pertinent comments on the operations at each site are given in the site reports but some general comments are given here under the following headings:

(1) Steaming
(2) Site surveys
(3) Drilling and coring operations
(4) Sidewall sampling
(5) Heat flow tests
(6) Other tests

Steaming

The *Glomar Challenger* steamed a distance of 5352 nautical miles during Leg 14 and at an average speed of 9.6 knots. A speed of 10 knots or greater was attempted between sites. When approaching each site, ship speed was reduced to 8 knots or less in order to reduce ship noise and obtain better seismic reflection profiles. After passing over the site, speed was reduced to 4 knots to effect retrieval of the towed geophysical gear.

A few hours were used to detour *Glomar Challenger* to near Santo Antao, Cape Verde Islands to rendezvous with a Portuguese vessel to board additional equipment and scientific party members.

Site Surveys

Because there was so much time required for steaming on this leg, only a small amount of time was spent by the *Challenger* in surveying selected site locations.

In most instances the prospective sites were approached along a previous geophysical line and could be selected by comparing the *Challenger* seismic profiles with this existing data.

Most survey time was spent at Site 141 where it was essential for scientific and safety considerations to locate the exact crest of the piercement structure and to position the site on it.

Drilling Operations

Drilling operations were satisfactory and only minor amounts of time were lost at two sites. At Site 136, six hours were lost when bad weather conditions caused a delay in initial spudding. Remainder of the lost drilling time occurred while on Site 143. Damage to three bottom hole assemblies was sustained while attempting to spud in on the sediments of the steep and firm northern slope of the Demerara Rise. Further time was also lost at this site when a commercial longline for tuna fishing drifted into the drill string.

At all Leg 14 sites except Site 139, Smith 4-cone button bits were used. This type of bit performed well in chalk oozes; moderately well in most calcareous clays; and drilled hard rocks such as limestone, silicified mudstone, and basalt slowly but efficiently. The button bits, however, were quite inadequate for drilling some noncalcareous clays and mudstones. The bit tended to ball up in these materials and penetration was very slow. The great advantages of the button bits were that they could drill most softer formations quickly and could penetrate thick sequences of hard rock, without wearing out.

A 4-cone mill tooth bit was run at Site 139 in an attempt to increase the penetration rate in the thick sequence of anticipated terrigenous sediments. The penetration rate did increase, but in the firmer sediments core recovery dropped significantly and in sand beds was less than 5 per cent. The conclusion drawn from this low core recovery is that in firmer materials this mill tooth bit tends to "walk" (that is, does not rotate about the axis of the bit) and thus destroy the core before it can get in the barrel. This is probably due to the absence of stabilization pads, which are present on the button bit.

More detailed analyses of the drilling rates on different formations are given under the respective site reports.

Some problems were encountered with malfunctioning acoustic beacons. At Site 137, an additional beacon had to be dropped as the signal from the first beacon became unacceptable to the shipboard computer. At Site 142, the hole had to be abandoned because although the two beacons dropped at different times and using different frequencies both gave inadequate signals, they could not be replaced because they were still transmitting signals. Of the 12 beacons used, one 16 kHz and two 13.5 kHz malfunctioned.

Sidewall Sampling

A sidewall sampling device was used during Leg 14. The time required to run the device is only a little longer than the normal round trip time with the core barrel (the sampler is actually attached to the bottom of this), and the location of the required sample can be judged very accurately by the length of drill string. Several samples can be obtained from one hole by repeated lowerings of the sampling device and progressively raising the drill string to the depth of each sample required.

The sidewall sampler therefore can be an extremely useful addition to the sampling capacity of the operation. It does have certain limitations–mainly that of not being able to penetrate hard formations without damage. Furthermore, if it is bent, it cannot be retrieved through the drill string.

Heat Flow Tests

Under the direction of Dr. Al Erickson, a prototype downhole temperature probe was tested at Sites 142 and 144. Two tests were made in soft ooze and one in harder ooze.

The tests indicated the feasibility of the use of the probe in soft formations but established the need for minor mechanical modifications and the necessity for additional work on the electronic data system. It was demonstrated that difficulties may be experienced when the probe is used in harder formations.

Other Tests

In addition to the tests described above, two tests were made of beacon release systems for the re-entry system to be used on the following leg. The tests were made in water depths of 3350 and 4600 meters. Both tests were only partially successful.

An additional use for such a release system would be in a situation such as that which occurred at Site 142, where both beacons with different frequencies were giving an inadequate signal for positioning and yet were still strong enough to interfere with any other beacons that might be dropped here. A release mechanism would enable a malfunctioning beacon to be removed from the sea floor thus eliminating its interference effect and providing insurance against loss of the hole being drilled.

A hydraulic position indicator was installed as an experiment and tested at Site 136. This system enables the crew to determine the vessel's position in relation to the drill hole by attaching four load cells from the drill pipe to pressure gauges on the derrick. The system was used at the end of Site 142 when the dynamic position system became almost inoperative because of the two malfunctioning beacons. Using a combination of the erratic positioning system and the hydraulic positioning indicator, the *Challenger* was held in position long enough to pull the drilling string out of the hole without damage.

DATA PRESENTATION

In Chapters 2 to 10 the data for each site report is presented in a standard format under the following subheading:

Abstract

Site Data – position as determined by satellite navigation, water depth determined from drill string measurement, total penetration, time site was occupied from dropping of sonar beacon to recovery of drill string, number of cores recovered, and a bathymetric map showing site location, ships track and a key to the continuous reflection seismic profiles illustrating the nature of the site.

Background, Survey, and Operations – describes the source of background data upon which site selection was made, major scientific objectives for drilling the site, morphological and geophysical characteristics of the site, and surveys made by the *Glomar Challenger* to finally select the site, and a table and graphical summary of the drilling and coring operations conducted on site.

Biostratigraphy – a general account of the biostratigraphy is followed by brief notes on the foraminifera, calcareous nannoplankton, and in a few sites (from samples sent to workers on shore) the diatoms and organic microfossils. The diatom determinations of Hans-Joachim Schrader of the Geologisch-Palaontologisches Institut und Museum der Universitat Kiel were made using the lithology smear slides–consequently exact determination of the smaller species was impossible.

Following this is a table giving diagnostic fossils by cores. Included in this table are the codes outlined below which are used to indicate preservation of the calcareous fossils.

Etching due to calcite solution and secondary calcite overgrowth are treated separately, and the following categories of preservation are used on the diagnostic fossils form.

G: Perfect state of preservation, no etching, no overgrowth.

Etching:

E-1: Slight etching, delicate features destroyed.

E-2: More delicate species completely dissolved, traces of etching on many specimens.

E-3: Many isolated shields, only resistant species preserved.

Overgrowth:

O-1: Slight thickening of the arms of discoasters, elements of coccoliths start to grow.

O-2: Arms of discoasters strongly thickened, delicate central structure obscured.

O-3: Discoasters show very much calcite overgrowth, ("Calcification species"), delicate coccoliths covered to such a degree that they can no longer be identified with certainty.

No information is given on Radiolaria in the site report chapters as no expert in this field was present on Leg 14; however, slides and selected samples were prepared by Lillian Musich on board. A shore laboratory report, based on the prepared radiolarian material, is given elsewhere in this volume. Wherever the Radiolaria provided age data not available from other fossils, this information was used in the Site Report.

Absolute Age Determinations – at several places in this volume the age of various horizons is given in millions of years. The absolute age numbers assigned to the geological time scale units are given in Table 2 and are used throughout this volume for the sake of uniformity. The Tertiary units closely follow widely accepted ages. The Cretaceous units differ somewhat from all published data, and the ages given here should be considered informal as they have been obtained from the latest information available from several of the Deep Sea Drilling cruises and were arrived at by consultation with numerous cruise participants.

Lithostratigraphy – this section gives a purely descriptive account of the lithologic units recognized.

Physical and Chemical Properties – measurements were made as follows: consolidation using the Penetrometer, bulk density and porosity using the GRAPE (Gamma Ray Attenuation Porosity Evaluator), water content by weight and from this a volumetric determination of porosity and bulk density, and natural gamma radiation. pH and Eh values were routinely measured on all cores that were not too badly disturbed by coring. Owing to malfunctioning equipment, sonic velocity measurements could only be made in a few places–mainly on consolidated material using the microtran.

A brief account of the results correlated with lithology is given, and tables summarize the density, porosity, water

TABLE 2
Time Scale Used in this Volume

Millions of Years	Stage	Subdivision	System
0			
1.8	Pleistocene		
	Pliocene		
5			
	Lt. Miocene	Upper	Tertiary
10.5			
	M. Miocene	Upper	Tertiary
16			
	E. Miocene	Upper	Tertiary
22.5			
	Lt. Oligocene	Lower	Tertiary
30			
	E. Oligocene	Lower	Tertiary
37.5			
	Lt. Eocene	Lower	Tertiary
43			
	M. Eocene	Lower	Tertiary
49			
	E. Eocene	Lower	Tertiary
53.5			
	Lt. Paleocene	Lower	Tertiary
60			
	E. Paleocene (Danian)	Lower	Tertiary
65			
	Maestrichtian	Upper	Cretaceous
72			
	Campanian	Upper	Cretaceous
80			
	Santonian	Upper	Cretaceous
84			
	Coniacian	Upper	Cretaceous
87			
	Turonian	Upper	Cretaceous
91			
	Cenomanian	Upper	Cretaceous
100			
	Albian	Lower	Cretaceous
104			
	Aptian	Lower	Cretaceous
109			
	Barremian	Lower	Cretaceous

content and chemical data for each section (150 cm) or part section. It should be noted in these tables that GRAPE values are averages of 800 determinations for each full section, but the sediment sample is only one determination at the location of the water content sample.

The natural gamma radiation (corrected to a mean porosity of 60%) is shown graphically on each core form. All gamma measurements throughout this volume refer to counts/7.6cm/1.25mm. No other physical or chemical property data are shown on the core forms because of the disturbed nature and poor recovery of many cores. Where particularly good and significant data were obtained, more detailed information is given in Chapters 18 and 26.

Site and Core Forms – an explanation of the information given on these forms is provided in the Sediment Classification section below. In places where the detail is too great to show on the core forms, individual 150 cm sections are also shown.

Discussion and Conclusions – this section discusses the results of the drilling given earlier in the descriptive part of the site report and draws conclusions that can be made based on an interpretation of the data for that particular site.

SEDIMENT CLASSIFICATION

The shipboard sediment classification used in Leg 14 is essentially that devised by Olausson (1960) for description of the cores collected on the Swedish Deep Sea Expedition. The basic framework of this classification is as follows:

I. *Pelagic deposits.*
- A. *Oozes.*
  - 1. $CaCO_3 > 30\%$.
    - a. Skeletal remains of pelagic forams or pteropods lower than 30%.
      - aa. $CaCO_3$ = 30-60% – *marl ooze.*
      - bb. $CaCO_3 > 60\%$ – *chalk ooze.*
    - b. Skeletal remains of pelagic forams or pteropods higher than 30%.
      - aa. $CaCO_3$ = *30-60% – foraminiferal (pteropod) marl ooze.*
      - bb. $CaCO_3 > 60\%$ – *foraminiferal (pteropod) chalk ooze.*
  - 2. $CaCO_3 < 30\%$ Skeletal remains of siliceous organisms >30%.
    - a. *diatom ooze.*
    - b. *radiolarian ooze.*
- B. *Red clay.* $CaCO_3 < 30\%$, and the amount of siliceous skeletal remains < 30%. The sediments are dominated by pelite. The red clay is considered as calcareous if $CaCO_3$ = 10-30%.

II. *Terrigenous deposits.*
- A. *Organic muds.* $CaCO_3$ or skeletal remains of siliceous organisms > 30%.
  - 1. $CaCO_3 > 30\%$.
    - a. Skeletal remains of pelagic forams or pteropods < 30%.
      - aa. $CaCO_3$ = 30-60% – *marl mud or sand.*
      - bb. $CaCO_3 > 60\%$ – *chalk mud or sand.*
    - b. Skeletal remains of pelagic forams or pteropods > 30%.

aa. $CaCO_3$ = 30-60% – *foraminiferal (pteropod) marl mud.*

bb. *$CaCO_3$* > 60% – *foraminiferal (pteropod) chalk mud.*

2. $CaCO_3$ < 30%. The amount of siliceous skeletal remains > 30%

   a. *diatom mud.*

   b. *radiolarian mud.*

B. *Inorganic muds.* Skeletal remains of siliceous organisms < 30%. $CaCO_3$ < 30%. Clayey muds. The average diameters < 5 micron.

   Black (*blue, green, gray* etc.) *silty mud.*

2. Silty or sandy muds or sands. The average diameters > 5 micron.

   Black (*blue, green, red, gray,* etc.) *silty mud.*

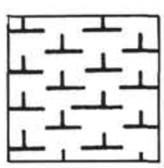
   Black (*blue, green, red, gray,* etc.) *sandy mud.*

   Black (*blue, green, red, gray,* etc.) *silty mud.*

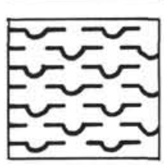
To use this classification, it is first necessary to decide whether the sediment is more basically pelagic or terrigenous in order to assign the term "ooze" or "mud." For sediments containing a mix of biogenic pelagic carbonate (or silica) and undifferentiated clay, this can be a problem, for the origin of the clay may be in doubt (that is, authigenic, a hemipelagic component, deposited from a nepheloid layer, etc.). The reader is asked to take this into account when considering the lithologic terms applied to a sediment. In most cases, however, the authors feel confident in the sediment names chosen, largely by relying on mineral assemblages or inferred paleoprovenance. Various adjectival terms for color, texture, and nature of materials have been used and are rather self-explanatory, being in common geologic usage. When several adjectival terms appear in a sediment name, the terms increase in relative importance to the right (that is, closer to the basic sediment name).

The basic sediment symbols used in the site chapters are as follows:

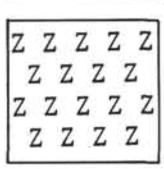
Nanno chalk ooze



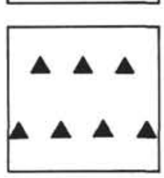
Radiolarian ooze



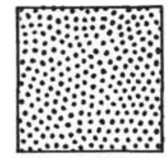
Zeolite



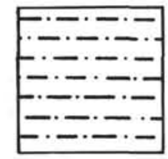
Chert



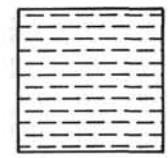
Sand



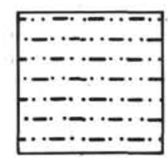
Sandy clay or clayey sand



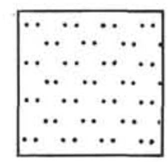
Clay



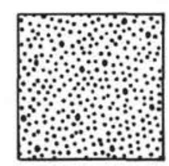
Clayey silt or silty clay



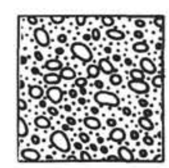
Silt



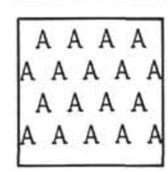
Sandy silt or silty sand



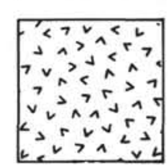
Conglomerate



Ash



Basic igneous



The above represent a few of a number of new lithologic symbols devised to pertain to a sediment classification newly adopted by DSDP. It was impractical to reconvert Leg 14 sediment names to the new classification; rather, only symbols were adopted as appropriate.

In the case of marl muds and marl oozes, the symbols for calcareous ooze and clay were either overlain, when in roughly equal proportion, or where one end member clearly dominated, its symbol was used and overlain by hand drafting the opposite symbol as needed. Similarly, A is overlain to indicate ash horizon, Z to indicate zeolite-rich sediments, etc. Foraminifers were notably rare in the Leg 14 calcareous oozes. Since their presence is important to discussions of paleotectonics and the carbonate compensation level, their presence in amounts >15 per cent is indicated by hand drafted symbols depicting forams. No provision is made with symbols to indicate degree of induration; the reader is asked to rely upon the sediment or rock name (that is, "mud" vs "mudstone"). Specifically, the term "chalk" in the Olausson classification refers not to friability but rather to $CaCO_3 > 60$ per cent.

SMEAR SLIDES

Smear slides were the basic means of mineral identification on shipboard. The shipboard party tried to be as specific as possible with regard to mineral identificatons. It was thought that it is better to err than to hesitate to guess and thus have the potential sample requestor never realize that material of interest to him might be present. Nonetheless, the shipboard party is quite confident of mineral identifications, and this has been largely substantiated by X-ray analysis. Some problem was experienced with carbonate, where standardization was not achieved until late in the cruise. Particularly with regard to "carbonate rhombs," the reader can feel relatively secure in its being dolomite.

Percentages are visual estimates by area of smear slide covered. Coarse fraction data represent material retained on a 62μ screen after washing.

CORE FORMS

The basic lithologic data is contained on core forms which are opposed by core photographs at the section level. The basic lithologic data is generally presented, for consistency, in the following order:

Sediment Name
Color Name and Munsell or GSA Rock color number
Composition
Structure
X-ray

Composition is usually expressed as percentages of minerals based on averaging of smear slide observations in the case of homogeneous sediments, or callouts of specific smear slide estimates where appropriate. Where X-ray data are presented, they are semi-quantitative and referred to as:

A – Abundant (> 25%)
C – Common (10-25%)
R – Rare (1-10%)
Tr – Trace

X-ray data given on the core forms were supplied by Ulrich von Rad at Hanover.

Where sedimentology is complex, the information is given at the section (150 cm) level. The reader is cautioned that when section-level forms are presented for a core, the corresponding core summary forms may be generalized.

SITE SUMMARY

Site summary forms are all at a scale of 1:200. The depth scale on the left indicates intervals actually cored. Actual recovery is shown as a black bar at the left of the boxes containing the sediment symbols. All of the boxes are the same size. The only other information given is the major sediment name and respective ages. This presents a relatively quick and easy-to-use synopsis; the reader is referred to core forms and chapter texts for more detail.

ACKNOWLEDGMENTS

Unpublished geological and geophysical information was provided by many sources and was employed both in the selection of sites and in the interpretation of the results. The research vessels *Vema* and *Robert D. Conrad*, of Lamont-Doherty Geological Observatory, collected seismic data and piston cores near Sites 136, 137, 138, 139, 140, 142, 143, 144. These unpublished data were made available to us respectively by J. I. Ewing and J. D. Hays. The seismic profiler data of LDGO constituted the primary source of information by which most of the sites drilled on this Leg were initially selected and have provided an extremely valuable basis for the regional synthesis of our results. A special survey of Site 142 was conducted by R. Embley and R. Markl on board *Robert D. Conrad* and is reported in Chapter 12. Unpublished seismic and bathymetric data were generously made available to us by CNEXO for Site 135, by Koninklijke/Shell and J. Curray (SIO) for Sites 143 and 144; A. S. Laughton, National Institute of Oceanography, England, provided topographic maps of parts of the eastern North Atlantic, and these were used as base maps for Site Reports 135 and 136.

Data on the bottom morphology near Sites 137-138 were made available, in advance of publication, by P. Rona at the Miami NOAA Lab. W. Pitman and M. Talwani generously provided the unpublished results of their analysis of the spreading history of the North Atlantic to us, and offered useful criticism and discussion on the topic of basement ages.

Diatom determinations were made by Hans-Joachim Schrader of the Geologisch-Palaontologisches Institut und Museum der Universitat Kiel. Sporomorph and microplankton determinations were made by D.O.J. Diederix, R. de Haan and W. O. Tichler of Shell International Petroleum, Maatschappy, The Hague.

We wish to thank the Global Marine shipboard staff, in particular, Capt. R. Dill, Drilling Superintendent C. Guess, and Operations Manager D. Redding (SIO).

The shipboard technicians under the direction of M. Lehman conscientiously provided essential support services to the scientific program, and their important contribution is gratefully acknowledged.