1. INTRODUCTION

The Shipboard Scientific Party[1]

The drilling vessel *Glomar Challenger* departed Fremantle, Australia on 20 December 1972 for Antarctic waters south of Australia and New Zealand (Figure 1). Leg 28 was designed to explore the long-term glacial, climatic, biostratigraphic, and geologic history of the South Pole continent and its environs. The leg was in a sense a test case for the operational feasibility of drilling at high latitudes, under severe weather and iceberg conditions. In addition, several holes were planned for the Ross Sea continental shelf in water depths of about 500 meters, much shallower than any previous successful attempts by DSDP. Additionally, several holes were planned to investigate the problems of sea-floor spreading and continental drift between Australia and Antarctica and the history of circumpolar circulation and associated deep-sea sedimentation processes.

During the voyage a total of 16 holes was drilled at 11 sites and 1404 meters of sediment recovered (Table 1). A total of 7400 nautical miles was steamed during the port-to-port transit.

SUMMARY OF SIGNIFICANT RESULTS

1. Extensive glaciation began on the Antarctic continent at least by the early Miocene (20-25 m.y. ago), much earlier than previously assumed.

2. A dramatic change in Antarctic glacial history occurred about 4-5 m.y. ago. We tentatively identify the change as marking first, a climax in glacial advance, followed by abrupt melting and ice retreat to a position similar to that of today. Subsequent fluctuations in the extent of the Antarctic continental ice sheet have probably been comparatively minor.

3. Nannofossils and diatoms found in the abyssal sediments in a series of four holes (265-268) from the Wilkes Land continental rise to near the crest of the Southeast Indian Ridge indicate that water was cool temperate in the late Oligocene and early Miocene and that it gradually became much cooler with the cold "front" slowly progressing northward.

4. Assemblages of diatoms and silicoflagellates representing the Oligocene through the Recent and intermixed with some nannofossils, radiolarians, and foraminifers should greatly improve on the existing high-latitude biostratigraphic zonations.

5. Basaltic basement (layer 2) was sampled at four sites (265, 266, 267, 274), and at each of these sites the age of the basal sediments is in reasonable agreement with crustal ages predicted from sea-floor spreading studies.

6. Cherts and chertified terrigenous sediments of early Miocene to Oligocene age were found in three holes (268, 269, 274) at widely separated localities on the Wilkes Land/Ross Sea continental rise.

7. Throughout the Ross Sea continental shelf area, thick, pebbly, silty clays were deposited under glacial marine conditions without major interruption at least from early Miocene to earliest Pliocene. An angular unconformity near Sites 270, 271, and 272, identified from seismic records by Houtz and Davey (1973), appears to mark a glacial erosion surface. The gently dipping sediments were planed off during the early Pliocene by grounded shelf ice extending well north of the present Ross ice shelf.

8. Basement rocks penetrated at Site 270 consist of undated, gray, foliated marble and calc-silicate gneiss and are similar to the Koettlitz marble found 400 km to the west in the Royal Society Range. The Koettlitz marble has been considered equivalent to the Cambrian limestones in the Central Transantarctic Mountains, and it is possible that the basement rocks at Site 270 are also of early Paleozoic age.

9. Evidence from paleosols, glauconitic sands, and benthonic foraminifers indicates that the southeastern Ross continental shelf near Sites 270 and 272 subsided gradually from a point near sea level in the Oligocene to its present depth by the middle Miocene. There is no evidence of further large vertical motions. Although continental ice loading may account for the subsidence, the alternative mechanism of local tectonism cannot be discounted.

10. In three of the four holes drilled in the Ross continental shelf area, traces of gaseous hydrocarbons were found in parts of the dominantly Miocene terrigenous sediments. In all instances where gas was encountered, the holes were cemented prior to abandonment. These results will no doubt generate much interest and speculation in light of the energy crisis. Furthermore, producing oil and gas fields are found beneath the

[1]Dennis E. Hayes, Lamont-Doherty Geological Observatory, Palisades, New York (Co-chief scientist); Lawrence A. Frakes, Florida State University, Tallahassee, Florida (Present address: Monash University, Clayton, Victoria, Australia) (Co-chief scientist); Peter J. Barrett, Victoria University of Wellington, Wellington, New Zealand; Derek A. Burns, New Zealand Oceanographic Institute, Wellington, New Zealand; Pei-Hsin Chen, Lamont-Doherty Geological Observatory, Palisades, New York; Arthur B. Ford, U.S. Geological Survey, Menlo Park, California; Ansis G. Kaneps, Scripps Institution of Oceanography, La Jolla, California; Elizabeth M. Kemp, Florida State University, Tallahassee, Florida (Present address: Bureau of Mineral Resources, Canberra City, Australia); David W. McCollum, Florida State University, Tallahassee, Florida (University of South Carolina, Beufort, South Carolina); David J.W. Piper, Dalhousie University, Halifax, Nova Scotia; Robert E. Wall, National Science Foundation, Washington, D.C.; Peter N. Webb, New Zealand Geological Survey, Lower Hutt, New Zealand (Present address: Northern Illinois University, de Kalb, Illinois).

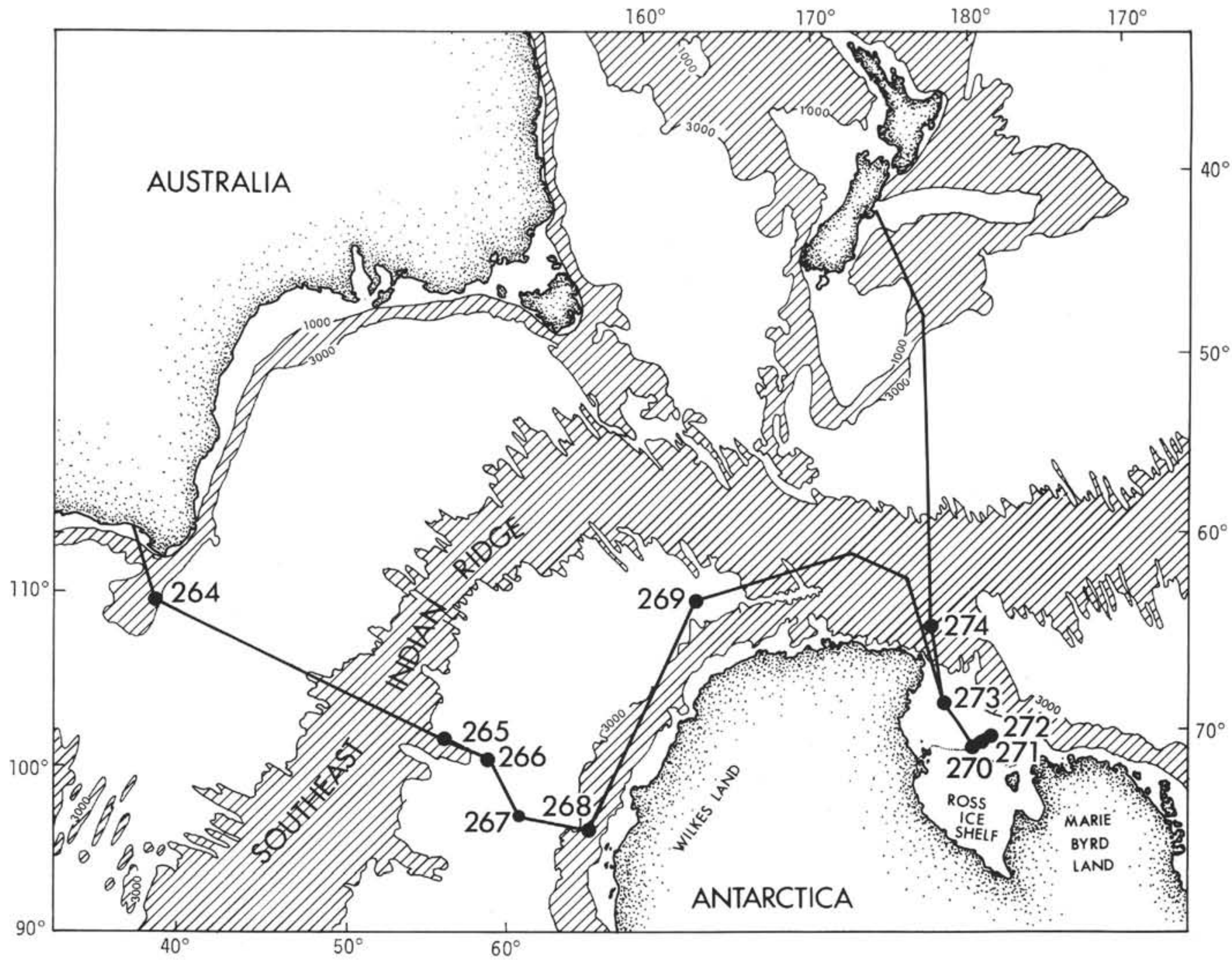

Figure 1. *Location of sites drilled during Leg 28 in Antarctic waters south of Australia and New Zealand and in the Ross Sea.*

TABLE 1
Leg 28 Coring Summary

Hole	Dates (1972-1973)	Latitude	Longitude	Water Depth (m)	Penetration	No. of Cores	Cored (m)	Recovered (m)	Recovery (%)
264	22-23 Dec.	34°58.13'S	112°02.68'E	2873	215.5	15	142.5	65.2	46
264A	23 Dec	34°58.13'S	112°02.68'E	2873	158.5	4	38.0	33.2	87
265	30-31 Dec	53°32.45'S	109°56.74'E	3582	462.0	18	169.0	108.0	64
266	2-4 Jan	56°24.13'S	110°06.70'E	4173	384.0	24	219.5	145.2	66
267	6 Jan	59°15.74'S	104°29.30'E	4564	219.5	7	58.0	25.9	45
267A	7 Jan	59°15.74'S	104°29.30'E	4564	70.5	3	28.5	11.6	41
267B	7-8 Jan	59°14.55'S	104°29.94'E	4539	323.0	10	95.0	53.5	56
268	10-12 Jan	63°56.99'S	105°09.34'E	3544	474.5	20	189.5	65.6	35
269	18 Jan	61°40.57'S	140°04.21'E	4285	397.5	11	103.0	38.8	38
269A	19-21 Jan	61°40.57'S	140°04.21'E	4285	958.0	13	123.5	55.4	45
270	30 Jan-2 Feb	77°26.48'S	178°30.19'W	634	422.5	49	422.5	263.7	62
271	3-5 Feb	76°43.27'S	175°02.86'W	554	265.0	24	233.0	15.3	7
272	6-8 Feb	77°07.62'S	176°45.61'W	629	443.0	48	439.0	162.0	37
273	10 Feb	74°32.29'S	174°37.57'E	495	76.0	9	76.0	27.9	37
273A	11-13 Feb	74°32.29'S	174°37.57'E	495	346.5	29	256.5	55.5	22
274	16-19 Feb	68°59.81'S	173°25.64'E	3326	421.0	45	421.0	279.1	66
Total						321	3013.5	1404.9	47

shelves of southeast Australia and western New Zealand, areas which were contiguous with the Ross shelf prior to continental separation, and the sediments there are much different from those found beneath the Ross continental shelf. It is premature to attach any economic significance to the Ross Sea hydrocarbons.

SITE SUMMARIES

Site 264

At Site 264, located near the southern edge of the Naturaliste Plateau in 2873 meters of water, thin Neogene and a well-developed Paleogene sequence of carbonate oozes and chalks, with some chert, was cored. The oldest material, beneath Cenomanian/Santonian chalks is undated volcaniclastic conglomerate. The inferred sonic velocity of the carbonate sediments is consistent with the interpretation that the top of the conglomerate corresponds to the strong acoustic basement reflector. Clasts in the conglomerate include pyroxene basalt and andesitic and dacitic glassy rocks. Unconformities recorded here span the following intervals: (1) Pliocene-upper Eocene, (2) lower Eocene-mid Paleocene, and (3) mid Paleocene-Cenomanian. A cool subtropical deep-water environment has prevailed (with some fluctuations) at this site from at least the Late Cretaceous.

Site 265

Site 265 is located 500 km south of the Southeast Indian Ridge crest in 3582 meters of water. An anomalously thick sequence of acoustically transparent sediment here overlies oceanic basement, inferred from magnetic lineations to be 12-14 m.y. old.

About 370 meters of predominantly diatom oozes of early Pliocene to Recent age overlie about 75 meters of nannofossil ooze and chalk of middle to late Miocene age. The significance of the marked lithologic change remains uncertain; however, it may relate to a rapid northward movement of cold water in response to a major pulse of Antarctic glaciation. Sedimentation rates were extremely high during the Quaternary, exceeding 130 m/m.y., thus accounting for most of the thick sedimentary sequence.

Relatively fresh, coarse-grained tholeiitic basalt underlies the nanno ooze, whose middle Miocene age is in good agreement with the age of basement as predicted from magnetic lineations.

Site 266

Site 266 lies about 800 km south of the Southeast Indian Ridge crest in 4173 meters of water. A major objective was to compare the history of sedimentation here, where sediment thickness is normal, with that at Site 265.

About 150 meters of diatom ooze of Quaternary to late Miocene age grade down into 105 meters of mixed nanno and diatom oozes, with some clay, of late to middle Miocene age. The latter unit overlies 117 meters of nanno chalk and claystone of early Miocene age. These sediments rest on basaltic glass, and the age of the basal sediments (20-22 m.y.) is in good agreement with that predicted on the basis of magnetic anomaly lineations (23-24 m.y.). The sedimentary sequence suggests a gradual cooling at the site from early Miocene to the present. Ice-rafted detritus is found in the late Miocene to Quaternary unit.

Site 267

Site 267 is located in the deep basin south of the Southeast Indian Ridge and about 600 km north of the Wilkes Land continental shelf in 4574 meters of water. One objective was to compare the patterns of sedimentation here with those of Sites 265 and 266 to the north. Three holes were drilled at this site.

The section penetrated at the adjacent Holes 267 and 267A consists of about 100 meters of Pliocene and Quaternary silty clays which overlie middle Oligocene to lower Miocene nanno oozes and chalks. A major climatic event in the middle to late Miocene is suggested by the change from carbonate to siliceous biogenic deposition, followed shortly by the appearance of ice-rafted detritus. Glassy basaltic rock was encountered at 205 meters, and about 16 meters were cored. The age of the basal sediment (27-30 m.y.) does not conform with the late Eocene age (41 m.y.) indicated by magnetic anomalies, and it is probable that a basal unconformity exists.

Hole 267B was offset about 2 km from Holes 267 and 267A. About 300 meters of middle Miocene and younger diatomaceous silty clays overlie a thin layer of lowermost Oligocene chalk. Thus, the Oligocene and lower Miocene are extremely condensed, or may be present near the base of the clay sequence. The age of the lower Oligocene chalk (35-38 m.y.) is slightly younger than the basement age as indicated by magnetic anomalies.

Although Holes 267 and 267A are only 2 km from Hole 267B, their respective sections, including total thickness, are remarkably different.

Site 268

Site 268 is located on the lower continental rise just north of the Knox Coast of Antarctica in 3544 meters of water. There were no previous geophysical surveys for this site, but by extrapolation of observations from the east and north, the total sediment cover was expected to exceed 2 km and to overlie oceanic crust older than magnetic anomaly 20 ($\sim$50 m.y. B.P.). The objectives were to extend the reconnaissance profile of holes toward the coast in order to recover terrigenous material that might relate to the poorly known geologic history of this sector of the continent.

As far as penetrated, the section consists of clayey sediments totaling 474 meters and ranging in age from middle Oligocene to Quaternary. Ice-rafted pebbles and granules are common well down into the lower Miocene part of the section, and isolated granules occur in the Oligocene. Sediments in which chert has formed were deposited in the Oligocene and earliest Miocene, prior to the interval of abundant ice rafting. The upper silty clays at Site 268 include turbidites, whereas the lower ones show structures suggesting transportation by deep ocean currents.

Site 269

Site 269 lies near the southeastern edge of the South Indian abyssal plain in about 4170 meters of water. The total sediment thickness at this site is estimated from seismic sonobuoy data to be about 1300 meters.

A 958-meter-thick sequence of largely Neogene silty turbidites was penetrated in two holes at Site 269. The deeper hole bottomed in sediments which are at least as old as middle Oligocene. Ice-rafted materials are much less obvious here than at Site 268, and granules were observed only in the upper 50 meters of the section. Chert occurrences were noted within a 250- to 300-meter-thick detrital sequence which is poorly dated as lower to middle Miocene. The youngest chert units coincide roughly with the oldest diatom-rich claystones. Basement was not sampled here because of bit failure following a combined 1400 meters of drilling at the two holes. An additional 200-300 meters of hard sediments are judged to lie between our point of deepest penetration and basement.

Sites 270, 271, and 272

Sites 270, 271, and 272, located in the southeastern portion of the Ross Sea, are in water depths ranging from about 550 to 650 meters. A series of holes was planned to sample the thick sequence (>1.5 km) of gently dipping strata that are truncated near the sea floor. A basement high, defined on the basis of observed compressional wave velocities, of 4-5 km/sec, lies beneath about 400 meters of sediment at Site 270. The objectives at these sites were (a) to investigate the initiation and fluctuations of the Ross ice shelf and continental glaciation in general, (b) to date the observed angular unconformity, and (c) to sample the basement high.

At Site 270 glacial deposits, containing molluscs, foraminifera, and diatoms, occur to a subbottom depth of about 385 meters and range in age from Oligocene to Recent. The angular unconformity apparent on the seismic profile is at a depth of about 30 meters below the sea floor and coincides with a marked increase in sediment induration. About 2 meters of glauconitic sand and carbonaceous sandstone occur below the glacial sediments, and these are in turn underlain by a coarse sedimentary breccia 25 meters thick, all of Oligocene age. The breccia is underlain by marble and calc-silicate gneiss which may be of lower Paleozoic age. These rocks exhibit the high compressional wave velocities corresponding to acoustic basement.

At Site 271 a marine environment with icebergs was in existence for much of the time back to the early Pliocene (3.0-3.7 m.y.). Very poor recovery allows little else to be concluded about depositional conditions. Large clasts are very abundant here, and their presence was probably one cause of the low recovery. The rate of deposition at this site is unusually high (70-80 m/m.y.), and it is probable that the angular unconformity was not reached by the drill bit. Methane and traces of ethane and ethylene were encountered at 265 meters below the sea floor, and drilling was immediately terminated.

The sedimentary sequence at Site 272 consists of poorly stratified silty clay grading to claystone with granules and pebbles. As at Sites 270 and 271, deposition of these sediments was in an open marine environment with contributions from floating ice. Clast types suggest that Marie Byrd Land is the most likely major source area, as in the older glacial deposits encountered at Sites 270 and 271. The angular unconformity, which at this site is at a depth of about 30 meters below the sea floor, separates middle Miocene sediments from questionable early Pliocene above. Methane and trace quantities of ethane were encountered from about 45 meters downward, but showed no significant downhole increase. Poor recovery within the lower 60 meters of the cored section is interpreted as an indication of dominantly sand layers there. The hole was terminated prematurely as a safety precaution.

Site 273

Site 273 is located in the west-central portion of the Ross Sea on the flank of an erosional valley which bounds the western edge of Pennell Bank. The water depth is 495 meters. The objectives were to contrast the history of sedimentation, glaciation, volcanism, and biostratigraphy with that of the eastern Ross Sea.

The stratigraphic sequence penetrated is similar to those at Sites 270-272. The post-Miocene portion of the section here is extremely condensed and includes extensive reworked material. The dominant lithology is mostly fossiliferous unstratified silty claystone with granules and pebbles. The clasts differ from those in the eastern Ross Sea in that diabase and basement rock types characteristic of the rocks exposed in the Transantarctic Mountains are present. The sequence dates back to at least the middle Miocene, indicating active ice erosion of the Transantarctic Mountains since that time. A pronounced reflecting horizon at 0.3 sec below bottom appears to mark an earlier erosional or scoured surface that can be traced over many tens of kilometers. A sharp increase in the hardness and sonic velocity of the sediment was encountered at 276 meters below bottom; this probably accounts for the seismic horizon. Traces of methane and ethane were first detected at about 150 meters, but there was no systematic or significant increase downhole.

Site 274

Site 274 lies on the continental rise northeast of Cape Adare in 3305 meters of water. The objectives at the site were to sample the anomalously thin sediments and the basement in an area close to the continent, yet removed from the present-day Ross ice shelf.

A largely terrigenous upper Eocene to Quaternary sequence about 415 meters thick overlies holocrystalline basalt. The age of the basal sediments (36-38 m.y.) is in agreement with the basement age indicated by magnetic anomalies (38-39 m.y.). Abundant ice-rafted clasts occur in the upper Miocene and perhaps also in the middle Miocene. During the Miocene, average sedimentation rates were about 5 m/m.y. in marked contrast to rates of about 20 m/m.y. both during the Oligocene and the Pliocene/Quaternary. Radiolaria and foraminifera are common only in the upper Miocene and younger sediments, while diatoms occur in great numbers throughout the section from the Oligocene upward. Cherts occur near the base of the section.

EXPLANATORY NOTES[2]

Underway Procedures

The *Glomar Challenger* underway geophysical data were collected using a Varian proton-precession magnetometer, a 12-kHz (30° half-angle) transducer/transceiver system recorded on Gifft GDR-1C-19 recorders for precision depth determination, a seismic reflection profiler system consisting of a Bolt PAR 600A airgun, a 20-phone EVP 23-element towed array, a Bolt PA-7 band pass filter, and two EDO Western Model PBR 333 recorders. The normal frequency recording bands were in the range of 30 to 150 Hz.

All navigation was accomplished with the aid of the Navy satellite navigation system and precision fixes obtained about every 2 hr using an ITT model 4007AB satellite receiver and a Digital Electronics Corporation PDP-8/S computer system. The adjusted navigation was reexamined on shore using 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. (1966). A total of 883 fixes was obtained during 42 days of steaming.

The normal operations in approaching a site consisted of steaming across the proposed site at a reduced speed of 4-6 knots; if a precise relocation was desirable, a marker buoy was dropped. After steaming beyond the site 2-3 miles, the towed geophysical gear was retrieved, the ship's 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 seismic survey lines were run near Site 268 to insure the absence of structural hydrocarbon traps. In general, the tentative sites had been well surveyed during previous *Eltanin* cruises, and no major additional surveys were conducted by *Glomar Challenger.*

Operations

Drilling and coring statistics are included in the site summary data of Table 1. A time analysis of the operations is shown in Figure 2. Pertinent comments on the detailed operations at each site are given in the site chapters, but general comments are categorized below.

Steaming and Survey

Glomar Challenger steamed a distance of 7400 n.mi. at an average speed of 8.9 knots. A speed of 10 knots or greater was attempted between sites. Ship speed was reduced to about 5 knots when approaching or departing from sites in order to effect higher resolution seismic reflection records. Speeds were further reduced to retrieve or deploy the towed geophysical gear. In a few instances, under conditions of poor visibility, slower than normal cruising speeds were employed to minimize the hazards of numerous nearby icebergs. Additional time was spent in rendezvousing with the icebreaker *Northwind* and during a cautious escorted transit through a narrow floe of brash ice of 1 to 3 oktas.

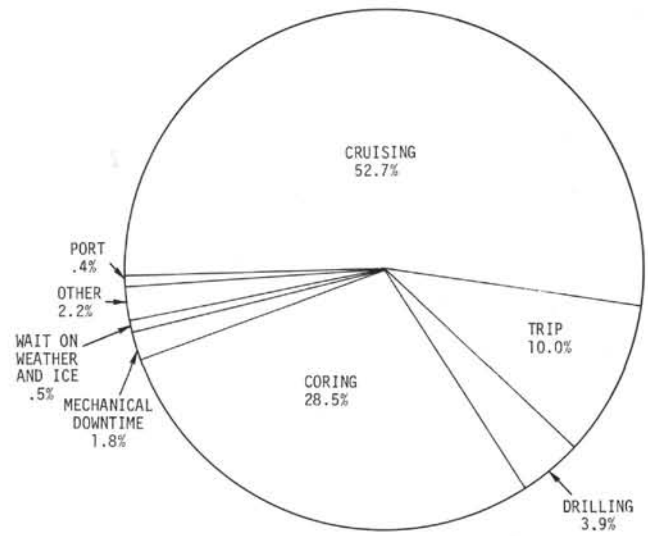

Figure 2. *Time distribution of operations during Leg 28.*

Site Positions

A minimum of 12 good satellite fixes was obtained at each site, and the assigned site position was determined from the arithmetic mean of the positions. The total scatter of all fixes was typically within 0.2 n.mi. of the accepted position.

On several sites, the proximity of numerous drifting icebergs required constant visual and radar surveillance. In at least two instances evasive maneuvering of *Glomar Challenger* was necessary to insure the safety of the vessel. This maneuvering necessarily modified the intended operational drilling plans and circumvented the realization of all of the intended scientific objectives. The total incidence of this situation was relatively minor in terms of actual time lost; the associated loss of scientific results is difficult to evaluate, even qualitatively.

Drilling and Coring Procedures

Summary of Coring Procedure

Cores are retrieved aboard *Glomar Challenger* by the punch core-rotary drilling method. The core is brought to the surface in a 6.6-cm I.D. plastic liner within a 9.5-meter core barrel by a wireline in the center of the drill pipe. In semiconsolidated sediments, the drilling assembly is rotated, and drilling fluid (most commonly seawater) is forced down the drill pipe around the outside of the coring assembly and out of openings in the bit face. The sedimentary material cut away by the bit becomes mixed with the drilling fluid and is lifted to the sea floor along the annulus between the drill string and outside of the hole. Commonly, the core barrel rotates

[2]When applicable, certain notes have been extracted from the shipboard handbook or previously published DSDP Initial Reports.

with the drilling assembly until friction between the cored material entering the barrel is sufficient to hold the barrel stationary.

It can be seen at once that a perfect balance must be maintained between the rate of descent of the drill string, pumping pressure, and speed of rotation to avoid the extremes of washing out a hole by fluid jetting ahead of the bit (where no core is retrieved) and using so little water and rotating at so slow a speed that core cutting is inhibited, the risk of sticking in the hole is increased, or the sediments retrieved are excessively compacted.

The desirable balance differs with the nature of the rocks being penetrated. If a core is desired in soft sediments, it is common to allow the drilling assembly to sink into the sediments under its own weight with little or no fluid pressure and little or no rotation at the drilling assembly. In some cases, this technique permits the recovery of good, relatively undisturbed cores; in other cases, most of the volume of the sediments displaced by the drilling assembly (more than 10 times the capacity of the core barrel) is extruded into the core barrel. Distortion produced by this phenomenon is usually quite obvious. Color varies in the sediment due to mottling or bedding planes.

In more indurated rocks, it is necessary to use higher fluid pressures and to rotate the drilling assembly more rapidly to cut the cores. The driller commonly releases the brake, increasing the weight of the drilling assembly on the bit face, then rests while circulating and rotating until a drop in fluid pressure indicates that some drilling progress has been made. The brake is released again, another segment is cut, and so forth.

Core recovery is usually poor where there are rapid variations in sediment hardness, such as where chert alternates with mudstone, or in pebbly mudstone. The softer material is often washed out while cutting the harder lithology.

At sites in the Ross Sea with abundant large pebbles, the core catcher was sometimes blocked by a single pebble, preventing further recovery.

Relationship Between Rocks in Place and Recovered Materials

It is obvious that some cores retrieved are representative of the rocks in situ with respect to some properties. In other cases, it is obvious that they are not. Most cores retrieved are between these two extremes.

Three fundamental problems result from the coring and handling techniques described above. First, the materials retrieved undergo a shift in properties simply by being removed from their in situ environment to the laboratory environment. Second, the process of recovering the core improperly samples the rock in place, and tends to mix, displace, disturb, or contaminate the retrieved materials. Third, the process of splitting the core sections and sampling them in the laboratory introduces more disturbances.

Completeness and Stratigraphic Reliability of Materials Recovered in a Core

The ratio between the amount of material recovered and the footage penetrated is highly variable. There may be no recovery; a few fragments may be caught in the core catcher; or, part or all of the section may be recovered.

A full core barrel is no guarantee of representativeness. As described above, in the soft upper layers, in particular, sediments may fill the core barrel to a height greater than the interval penetrated. Also, the fact that the length recovered is equal to or less than the length penetrated is no guarantee that the recovered material is complete or in proper sequence. The drilling techniques used are such that in alternating sequences of hard and soft beds, the hard beds tend to be recovered, whereas the intervening soft ones sometimes are not. Further, it is not uncommon for a paste consisting of pulverized rock or even a naturally plastic sediment from another stratigraphic interval to be intruded in partings between more indurated layers, although, more commonly, these pastes are injected along the walls of the core liner. This artificial bedding is often difficult to distinguish from natural bedding.

Disturbance of Materials Within a Core Barrel

Materials may be fragmented or homogenized by the coring process. Chert layers, thin beds of silicified siltstone, and limestone interbedded with softer materials are often fragmented forming a breccia and paste mixture. Materials may become sorted or compacted by the coring process. In semiconsolidated sediments, some sorting takes place by vibration during the coring and recovery process, the more dense components settling into the lower part of the core barrel. There is also a tendency for the sediments to compact as the core is forced into the core barrel. Friction between the core and the liner increases as the core enters the barrel, and the last few centimeters of core to enter the core barrel are most compacted. Both of these disturbances tend to make the lowest section in a core bed more dense than the uppermost section.

Materials may be reoriented within the core barrel. There is evidence to indicate that sometimes the core barrel rotates with the drilling assembly and some cohesive plastic sediments twist up the core barrel in corkscrew fashion. Occasionally, an animal burrow boring is seen to be so twisted. Thus, even though bedding may appear to be intact, the horizontal orientation has been disturbed. Occasionally, discrete pieces of sediments are rotated about a nonvertical axis. Such rotation is usually obvious, but may be obscured in homogenous sediments.

Contamination

Materials may become contaminated with drilling fluid (seawater on this cruise), with previously drilled material, or with scale and grease from the drill string. Ice-rafted pebbles, beds of chert, limestone, or well-indurated mudstone might be fractured when penetrated, and not all the fragments would be circulated out. Before the next core, fragments may sink to the bottom of the hole and subsequently be cored.

Numbering and Downhole Depth of Cores

Cores were cut into sections 1.5 meters long measured from the base of the recovered material. A sample designated as 28-269A-11-3, 24-25 cm (or abbreviated to 269A-11-3, 24-25 cm) came from between 24 and 25 cm below the top of Section 3 of Core 11 from the second hole (A) drilled at Site 269. A core-catcher sample is denoted by CC; e.g., 269A-11-3, CC. Cores of hard rock, such as basalt, are frequently recovered as cylindrical pieces of variable length. These are numbered consecutively from top to bottom, and thus a hard rock sample would normally be identified by both a centimeter interval in a core section and a piece number.

Since sections are measured off from the base of the recovered section, the upper part of the top section may be void.

By convention, and for convenience in data handling, when the core barrel is only partly full, the top of the uppermost section containing core material (not the top of the cored sediment itself) is assumed to represent the top of the cored interval, and the core-catcher sample is assumed to have been continuous with the base of the bottom section when in situ. That is, the recovered core material is "hung" from the top of the cored interval rather than placed at the bottom.

Since the plastic liner of the inner core barrel is 9.28 meters long, more than 9 meters of sediment may at times be recovered. In these cases the short extra core above Section 1 is designated Section 0.

Handling of Cores

In the core laboratory the following routine procedures were usually carried out.

1) Weighing of full sections to obtain a mean section density,

2) Continuous density/porosity determination along cores by the GRAPE (Gamma Ray Attenuation Porosity Evaluator),

3) Geochemical sampling.

The liners were then cut lengthwise and the cores split. Basalt cores were, however, left unsplit. Some of the basement cores from Site 270 were also left in the round.

The archive half of each core was cleaned, described by the sedimentologists, and photographed. The working half was sampled in the manner described in DSDP Volume 2, Appendix II. Sonic-velocity measurements were made at this stage. The working half of each section was then passed to the paleontologists for further sampling. Finally, both archive and working halves were stored in core vans onboard *Glomar Challenger* at a temperature of 4°C until the end of June 1973 when they were shipped from Guam to the United States. The cores are now stored at the DSDP East Coast Core Repository at Lamont-Doherty Geological Observatory. Requests for samples should be sent to the Curator, Deep Sea Drilling Project, Scripps Institution of Oceanography, La Jolla, California. Details of sample distribution policy can be found on page xvii of this volume.

Data Presentation

In Chapters 2 to 12 the data for each site report are presented in a standard format under the following subheadings:

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, bathymetric map showing site location, ship's track, and a key to the continuous reflection seismic profiles illustrating the nature of the site and abstract of principal results including a summary figure of sedimentation rates, age, lithology, compressional wave velocity, and seismic reflection data.

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, surveys made by *Glomar Challenger* for final site selection, and a table and graphical summary of the drilling and coring operations conducted on site.

Lithology—gives a purely descriptive account of the lithologic units recognized. A detailed account of the descriptive procedures is presented in a later section of this chapter.

Biostratigraphy—general account of the biostratigraphy, followed by brief notes on foraminifera, nannofossils, Radiolaria, diatoms, and silicoflagellates. The final biostratigraphy of several sites (266, 267, 269, and 274) and the zone correlation charts drew heavily on the shore-lab analysis of silicoflagellates by Ciesielski (this volume). An account is given of the biostratigraphic procedures employed including zonal range charts and a discussion of the assignment of absolute ages to the recognized geologic zones or boundaries.

Physical and Chemical Properties—measurements were made as follows: bulk density and porosity using the GRAPE, water content by weight, and from this, a volumetric determination of porosity and bulk density. *p*H and Eh values were routinely measured on all cores that were not too badly disturbed by coring.

Sonic-velocity measurements were made routinely using the Hamilton frame technique (Boyce, 1973). The results appear in graphic form on the site summary figure in each site chapter. Table or graphs summarize the density, porosity, water content run in, *p*H, Eh, and salinity.

The details of the physical and chemical property laboratory procedures and a brief description of special shipboard gas analysis at selected sites follow in a later section.

Discussion and Conclusions—discusses the results of the drilling given earlier in the descriptive part of the site report and draws conclusions based mainly on an interpretation for each particular site.

Site and Core Forms—the data presented on these forms are explained in detail under the sediment description section and include paleontology, lithology, physical properties, routine shore-lab study results, and core photographs.

Routine Shore-Lab Studies

Grain-Size Analyses

Grain-size distribution was determined by standard sieving and pipette analysis. The sediment sample was dried, then dispersed in a Calgon solution. If the sediment failed to disaggregate in Calgon, it was dispersed in hydrogen peroxide. The sand-sized fraction was separated by a 62.5μ sieve with the fines being processed by standard pipette analysis following the Stokes settling velocity equation (Krumbein and Pettijohn, 1938, p. 95-96) which is discussed in detail in Volume 9 of the Initial Reports of DSDP. In general the sand-, silt-, and clay-sized fractions are reproducible within ±2.5% (absolute) with multiple operators over a long period of time. A discussion of the precision of this method is in Volume 9.

Carbon and Carbonate Analysis

The carbon-carbonate data were determined by a Leco induction furnace combined with a Leco acid-base carbon determinator. The sample was burned at 1600°C liberating gas of carbon dioxide and methyl red. This gas was then passed through potassium hydroxide solution, which preferentially absorbs carbon dioxide, and the volume of the gas was measured a second time. The volume of carbon dioxide gas is the difference of the two volumetric measurements. Corrections are made to standard temperature and pressure. Step-by-step procedures are in Volume 4 of the Initial Reports of DSDP and a discussion of the method, calibration, and precision are found in Volume 9.

Total carbon and organic carbon (carbon remaining after treatment with hydrochloric acid) are determined in terms of percent of weight, and the theoretical percentage of calcium carbonate is calculated from the following relationship:

$$\text{Percent calcium carbonate } (CaCO_3) = (\%\text{ total C-\%C after acidification}) \times 8.33$$

However, carbonate sediments may also include magnesium, iron, or other carbonates; this may result in "calcium" carbonate values greater than the actual content of calcium carbonate. In our determinations, all carbonate is assumed to be calcium carbonate.

Precision of the determination is as follows:

Total carbon (within 1.2% to 12%)	= ±0.3% absolute
(within 0% to 1.2%)	= ±0.06% absolute
Organic carbon	= ±0.06% absolute
Calcium carbonate	
(within 10% to 100%)	= ±3.0% absolute
(within 0% to 10%)	= ±1.0% absolute

X-Ray Mineralogy

Semiquantitative determinations of the mineral composition of bulk samples, 2-20μm, and <2μm fractions were performed according to the methods described in the Initial Reports of DSDP, Volumes 1 and 2 and in Appendix III of Volume 4. The mineral analyses of the 2-20μm and <2μm fractions were performed on $CaCO_3$-free residues. The X-ray mineralogy results of this study are summarized in an appendix to this volume.

The high component of terrigenous detritus which has suffered little chemical weathering in many Leg 28 cores makes the calculation of the percentage of amorphous scattering unreliable. The amorphous scattering is calculated by subtracting from the observed diffuse scattering the predicted diffuse scattering of individual minerals. Most of the "mica" in normal deep-sea sediments is poorly crystallized illite; in many Leg 28 cores, much of it is more crystalline muscovite and biotite. The amorphous scattering is thus underestimated. The cristobalite diffuse scattering is based on Monterey Shale cristobalite; substantial variations in cristobalite diffuse scattering are seen in our chert samples.

Anomalously high chlorite and amphibole contents in some bulk samples are probably due to small pebbles of metamorphic rock. Anomalously high augite may be due to problems of quantifying augite in the presence of plagioclase. Halite is due to seawater contamination.

Sediment Description

In describing cores, the following features were noted. Some are discussed in greater detail below.

1) Core disturbance and lithification.

2) Color. This was estimated by comparing wet sediment with the GSA rock color chart.

3) Sediment type, on the basis of smear slides and sediment classification.

4) Bedding features. These logged graphically, and features judged "interesting" were photographed (in addition to the routine core photographs).

5) Pebbles and granules were systematically logged in most cores.

Core Disturbance and Lithification

The following terms for lithification were used on Leg 28:

Soupy: cores cut with wire. Sample holes fill up completely by plastic flow.

Soft: cores cut easily with wire. Sample holes fill in only slightly, or not at all, by plastic flow. Finger can be poked into sediment.

Stiff: cores difficult to cut with wire. Sample holes remain unfilled. Finger cannot be poked into sediment, but spatula can.

Semilithified: core needs to be cut on band saw.

Lithified: core requires cutting on diamond saw.

A problem occurs in cutting pebbly, or partly chertified lithologies. Pebbles require diamond saw cutting, yet the matrix induration may range all the way from soupy to lithified. The choice of the diamond saw for cutting may not be a true indication of the induration of the greater part of the sediment.

Visual comparison charts (prepared on Leg 23) for estimating the degree of plastic deformation of soupy, soft and stiff cores are provided in the core lab of *Glomar Challenger*. They are based on the degree of deformation of bedding planes and mottles. The charts show:

Slight: bedding bowed through 1 cm.

Moderate: bedding bowed through 4 cm.

Intense: bedding bowed through 10 cm.

Our impression is that the terms defined on the charts are rather on the low side for adequately describing the range of deformation that occurs, and our usage of the terms on Visual Core Descriptions probably reflects this feeling.

No classes of deformation for semilithified and lithified cores are suggested by DSDP. The following types of brittle deformation are recognized:

1) Solid core, breaking up into cylinders. Clearly no opportunity for rotation, except about a vertical axis.

2) Solid core, in subspherical blocks, which may have been rotated either by the bit, or within the barrel.

3) Fractured core, in which the core is severely fractured, presumably by the bit. Some individual blocks may have been rotated, but in general, this has not occurred, and the gross stratigraphy has been preserved. Individual beds 1 cm thick can be recognized, where they are of a distinctive lithology or color.

4) Microfractured core, in which intense brecciation has occurred to give blocks mostly in the 0.5 to 30 mm range. It is impossible to get a clean, smoothly split core surface, and there is some disturbance. The gross stratigraphy is preserved, and 1-cm-thick beds can be recognized.

5) Sediment slurry or drilling breccia, which consists of brecciated sediment, often with a range of lithologies, and a high fluid content. It is usually restricted to the tops of barrels, but sometimes appears to have been injected lower down, or to enclose lithified and semilithified sediment that is not in contact with liner.

On Leg 28, the term drilling breccia has *not* been used to describe the brecciated and fractured brittle sediments discussed in (3) and (4) above.

Where soft to stiff sediments contain large quantities of gas, the expansion of the gas under surface temperature and pressure conditions leads to the formation of distinct voids. There is also a general expansion of soft to stiff silty sediments, resulting in a very high pore content. This makes it very difficult to get a smooth split core face, so that sedimentary structures are generally unrecognizable.

Smear-Slide Examination

In order to gain some idea of the accuracy of preliminary sediment classifications, the results of shipboard examination of smear slides have been partially checked against shore-lab determinations of grain size and carbonate content. In general, shipboard determination of the relative frequency of components appears to be most reliable in the case of biogenic pelagic sediments; on Leg 28, estimates of the abundance of nannoplankton were within a few percent of carbonate percentages determined by shore-lab X-ray and chemical analyses. An exception to this general accuracy is in diatomaceous sediments which contain a large proportion of finely divided diatom fragments; visually, this last element is separated from fine clay fractions only with difficulty.

The most significant source of error in smear-slide determinations appears to be in the estimation of the sand component in sediments with a large detrital fraction. Sand appears to have been consistently underestimated in detrital sediments in near-shore Leg 28 sites; the underestimation is frequently by as much as a factor of four. This tendency is attributed to the mechanical difficulty of making a reasonably thin, readily examined smear in coarse sediments.

Sediment Classification and Nomenclature Rules

The naming and classification of sediments follows the system of Weser (1973). Certain minor modifications to the basically descriptive approach embodied in this system have since been made and are incorporated in the abbreviated summary below.

I. Rules for class limits and sequential listing of constituents in a sediment name.
   A. Major Constituents
      1. Sediment assumes the name of those constituents present in major amounts (major defined as >25%). See example in rule IA3.
      2. Where more than one major constituent is present, the one in greatest abundance is listed farthest to the right. In order of decreasing abundance, the remaining major constituents are listed progressively farther to the left.
      3. Class limits, when two or more major constituents are present in a sediment are based on 25% intervals, thus: 0-25, 25-50, 50-75, 75-100.
   B. Minor Constituents
      1. Constituents present in amounts 10%-25% prefixed to the sediment name by using the term *rich*.[3]
         Example: 50% nannofossils, 30% radiolarians, 20% zeolites is called a zeolite-rich rad nanno ooze.
      2. Constituents present in amounts 2%-10% prefixed to the sediment name by using the term *bearing*.[3]
         Example: 50% nannofossils, 40% radiolarians, 10% zeolites is called a zeolite-bearing rad nanno ooze.
   C. Trace Constituents
      Constituents present in amounts <2% may follow the sediment name but will be accompanied by the word *trace*. This procedure is optional.[3]

II. Specific Rules for Biogenous Constituents
   A. Nannofossil is applied only to the calcareous tests of coccolithophorids, discoasters, etc.
   B. Abbreviations and contractions as nanno for nannofossil, foram for foraminifera, rad for radiolarian, and spicule for sponge spicule may be used in the sediment name.
   C. The term ooze follows a microfossil taxonomic group whenever one of these groups is the dominant sediment constituent.
   D. Chalk is used to describe a semilithified carbonate ooze and limestone a lithified carbonate ooze.
   E. Semilithified diatom and rad oozes are termed diatomite or radiolarite, respectively. Lithified siliceous oozes are termed chert.

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[3]Normally, the trace constituents never appear in the sediment name. As regards minor constituents, the *bearing* and somet-mes even the *rich* constituents may be omitted from the sediment name when deposits are of a complex makeup.

III. Specific Rules for Clastic Sediments
  A. Clastic constituents, whether detrital, volcanic, biogenous, or authigenic, are given a textural designation. When detrital[4] grains are the sole clastic constituent of a sediment, a simple textural term suffices for its name. The appropriate term is derived from Shepard's (1954) triangle diagram.
  B. When the tests of a fossil biocoenosis or authigenic minerals and detrital grains occur together, the fossil or authigenic material is not given a textural designation. Note, however, that the detrital material is classified texturally by recalculating its size components to 100%. With the presence of other constituents in the sediment, the detrital fraction now requires a compositional term. For this purpose, the term detrital is employed, which enters the sediment name as per rules IA and IB.

IV. Color
  A. Color is not formally part of the sediment name. However, its employment for sediment description is important, particularly as it provides one of the criteria used to distinguish pelagic and terrigenous sediment. The color designation always precedes the sediment name. Color determinations were made using the GSA rock color chart with wet sediments.

V. General Comments
  A. Some fine-grained carbonate particles of unknown origin cannot be classified as either biogenous, clastic, or authigenic. Such particles are prefixed by the term *micarb*.
  B. The suffix stone is added to the textural term of consolidated clastic sediments.
  C. For cemented sediments the adjectives calcareous and siliceous are used as appropriate.

Logging of Pebbles and Granules

In soft and stiff lithologies, pebbles and granules (>2 mm) "outcropping" on the split core surface were detected by gently scraping with a spatula. Their estimated mean diameter was logged.

In semilithified and lithified sediment split by sawing, we attempted to measure the size and mark the position of each clast 2 mm or more in length. A larger minimum clast size was used when time was limited or core preservation was poor. The apparent long axis is used as an estimate of pebble size largely because the clast distribution can most easily be seen in the flat surface of the split core. In addition, Friedman (1958) has shown empirically that the mean of apparent long axes of quartz grains in a thin section is an only slightly biased estimate of the mean size determined by sieving. Chief sources of error in determining the number of pebbles per meter for the standard core width are in measurement (measurements were made quickly and to the nearest mm), in not recognizing and registering a clast, and in poor preservation of the core, which reduces the area over which pebbles can be seen and measured. The latter is probably the greatest source of error and may in places decrease the calculated values by as much as 20%. An accidental duplication in describing one core section showed that operator error is small (Table 2). Therefore, differences of more than 20% in the number of pebbles per meter are believed to reflect real differences in most cores.

TABLE 2
Comparison of Numbers of Pebbles Measured by Different Operators for Site 270, Core 12, Section 1

	Larger than 2 mm	Larger than 4 mm	Larger than 8 mm
Barrett	19	5	–
Ford	18	4	–

Biostratigraphy

The oceanic region around Antarctica is one of the classical areas of high productivity and diversity of silica-secreting plankton. Conversely, assemblages of carbonate-secreting organisms are limited to a few species and low population levels. Moreover, the calcareous nannoplankton are presently excluded from the area south of the Antarctic Convergence, and the planktonic foraminifer population includes only one or two species. As a consequence, the siliceous microfossils served as the primary means of age determination during Leg 28. For the younger part of the Cenozoic (<5 m.y.), the stratigraphic distribution of the siliceous groups is fairly well established with reference to paleomagnetic stratigraphy and thus to the absolute time scale. For older sediments, the absolute ages of zonal boundaries are more conjectural, but as a working scheme, the one shown in Figure 3 was adopted by the Leg 28 paleontologists (including P. Ciesielski, whose shore-based investigations of the silicoflagellates materially aided in the biostratigraphic interpretation of Leg 28 materials).

Comparison of the biostratigraphic charts of the different drill sites revealed a number of inconsistencies in the zone-to-zone correlation between different microfossil groups. As a result, the chart shown in Figure 3 should be regarded as a best compromise arrived at through long and often heated discussion. The hole-to-hole inconsistencies are yet to be resolved, but probably result from factors such as imperfect knowledge of the stratigraphic ranges of certain species, redeposition, and ecologically influenced irregularities in areal distribution.

Because of the general scarcity and limited diversity of the calcareous assemblages, no zonal schemes could be employed for these groups. The distribution of calcareous fossils with reference to the siliceous microfossil zonations is indicated in Figure 3, but the

[4]Detrital = all clastic grains derived from the erosion of preexisting rocks except for those of biogenous, authigenic, or volcanic origin.

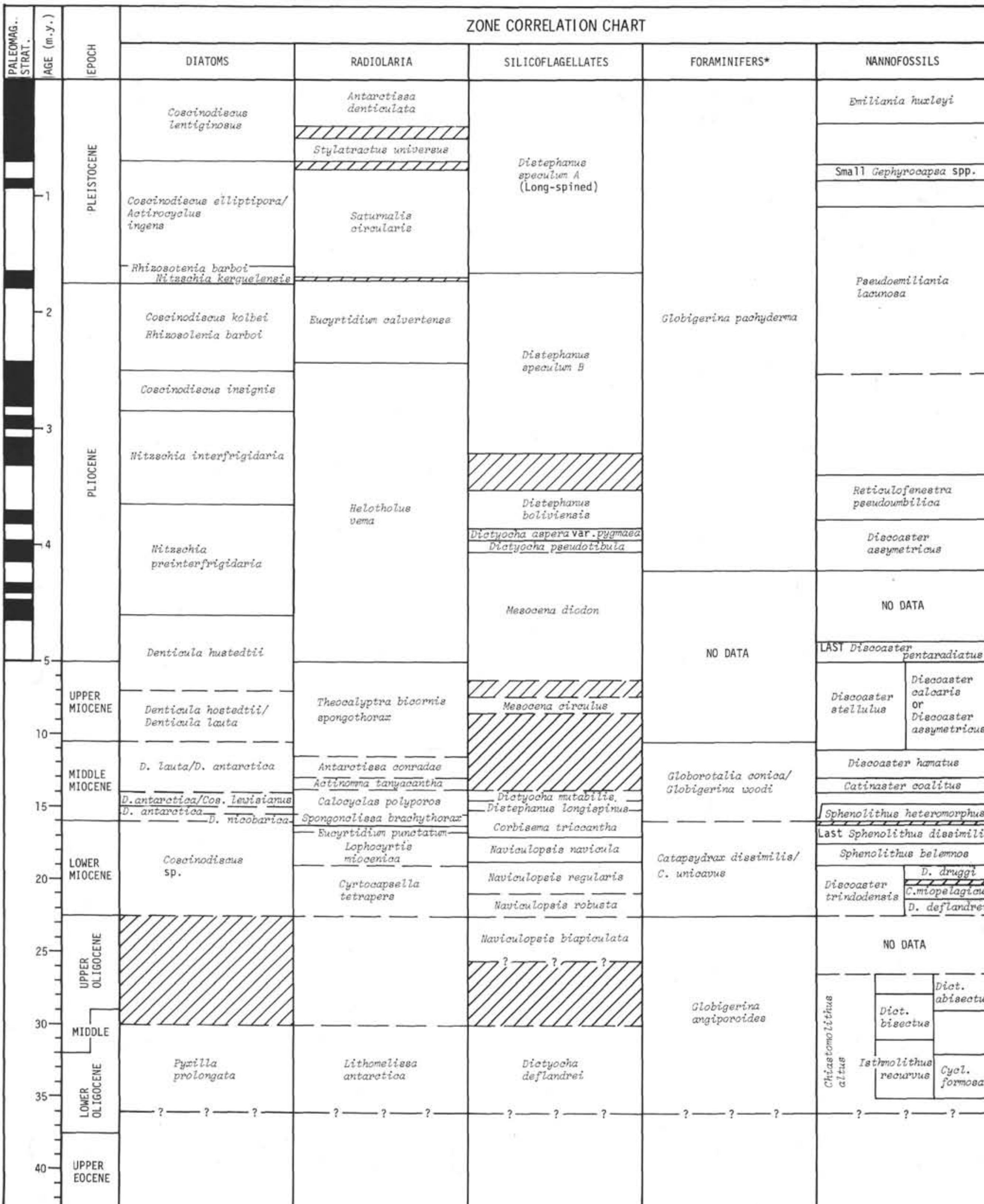

Figure 3. *Interrelations and ages of biostratigraphic zones for siliceous microfossils and distribution of calcareous microfossils, Leg 28.*

presence of certain "marker" species should not be construed as indicating equivalence to the commonly used lower latitude zonations. The biostratigraphic potential of calcareous microfossils at extremely high latitudes appears at present to be rather limited for the Oligocene to Recent, because of both original lack of diversity and, as found during Leg 28, the effects of calcite dissolution. Future sites in shallower water should add markedly to our knowledge of the biostratigraphy and paleoecology of the calcareous groups.

Physical Properties

Shipboard Measurements

The physical properties are presented in graphical form and discussed in each site chapter. Some explanation of the measuring techniques and data processing follows.

1) Sediment water content (*W*): The water content is defined as the weight of water in the sediment divided by the weight of the saturated wet sediment. The former is obtained by heating a 0.5-ml cylindrical sample (taken with a syringe) to about 110°C for 24 hr and weighing the sample before and after heating. The water content (%) is thus:

$$W = \frac{100\ (\text{weight of wet sediment - weight of dry sediment plus salts})}{\text{weight of wet sediment}}$$

No corrections were made for the salts, but the values are thought to be accurate to within ±3%.

2) Sediment porosity (ϕ): The porosity is defined as the volume of pore space divided by the volume of the wet-saturated sample and is expressed as a percentage. This can be obtained from GRAPE densities (see below) if a grain density is assumed. Variable amounts of diatoms in our sediments make estimation of grain density very difficult (cf. von Huene et al., 1973).

3) Wet-bulk density (ρ): The wet-bulk density is defined as the weight in grams per cubic centimeter of the wet-saturated sediment, i.e.,

$$\rho = \frac{\text{weight of wet sediment (g)}}{\text{volume of wet sediment (cm}^3\text{)}}$$

The densities of the seawater-saturated cores were measured in three ways: (1) by weighing each 1.5-meter core section giving a mean density for the whole section; (2) from the water content (*W*) (syringe samples); and (3) by continuous measurement along the length of the core section with the GRAPE using water (1.024 g/cm^3) and aluminum (2.6 g/cm^3) as standards. The GRAPE technique is described by Evans and Cotterell (1970), von Huene et al. (1973), and Boyce (1973). The plots of wet-bulk density determined with the GRAPE must be treated with great caution. Unusually low densities may indicate highly disturbed sediment, or drilled lithified sediment cores of lesser diameter than the core liner. Unusually high densities are often due to ice-rafted pebbles.

4) Compressional wave velocity (*Vp*): The sonic velocity (*V*) is obtained by timing a 400-kHz sonic pulse across two transducers and measuring the distance across the sample with a dial gage (Hamilton frame method; see Boyce, 1973). Measurements were made at laboratory temperature and pressure, a time delay of about 4 hr being allowed for the cores to reach equilibrium. The accuracy is about ±2%. The values (m/sec) are plotted on the site summaries.

Shipboard Geochemistry

Shipboard analyses for *p*H, alkalinity, and salinity are conducted routinely.

A 6 to 10 cm length of core liner (approximately 200-340 cc) is taken at approximately 50-meter intervals. As soon as this sample reaches room temperature, all of the sample is squeezed to yield 20-30 ml, if possible, of interstitial water through utilization of a stainless steel squeezer mounted in a Carver press. Except for a 2-3 ml volume used in shipboard analyses, this water is packaged in two aliquots (one in a fused glass ampule and one in a fused polyvinyl tube) and stored at 4°C. In addition, a 1-ml sample in a glass ampule is sent to Dr. Irving Friedman, USGS, Denver, Colorado. A 20-cc volume of unsqueezed sediment is taken in a plastic vial, the squeezed sediment is heat-sealed in a plastic bag, and both are stored at 4°C. These samples (the two water samples, unsqueezed and squeezed sediment) are shipped to Scripps for archive storage.

*p*H is determined by two different methods. One is a flow-through electrode method, the other is a punch-in electrode method. *p*H is determined on all samples via the flow-through method, which utilizes a glass capillary electrode in which a small portion of unfiltered pore water is passed. In the softer sediments a "punch-in" *p*H is also determined by inserting *p*H electrodes directly into the sediment at ambient temperature prior to squeezing. The *p*H electrodes for both methods are plugged into an Orion digital millivolt meter. These readings are converted to *p*H using the following formula:

$$p\text{H} = 7.41^5 + \frac{\text{EMF 7.41 buffer - EMF sample}}{\dfrac{\Delta\text{EMF}}{\Delta p\text{H}}}$$

$$\frac{\Delta\text{EMF}}{\Delta p\text{H}}\ (\text{or slope}) = \frac{\text{EMF 4.01 buffer - EMF 7.41 buffer}}{p\text{H}^5\ 7.41\ \text{buffer} - p\text{H}^5\ 4.01\ \text{buffer}}$$

Alkalinity is measured by a colorimetric titration of a 1-ml aliquot of interstitial water with 0.01 *N* HCl using a methyl red/blue indicator.

$$\text{Alkalinity (meq/kg)} = (\text{ml HCl titrated})\ \frac{(10\ \text{meq/l})}{1.025\ \text{kg/l}}$$

[5]Temperature adjusted volumes.

Salinity is calculated from the fluid's refractive index as measured with a Goldberg optical refractometer, using the ratio:

$$\text{Salinity } (^{\circ}/_{\circ\circ}) = (0.55)\ \Delta N,$$
$$\text{where } \Delta N = \text{refractive index difference} \times 10^4$$

Local surface seawtaer is regularly examined by each of the above methods for reference.

Gases

Since *Glomar Challenger* cannot set well casing, nor activate blowout preventers or other oilfield safeguards normally used while working in areas having potential high-pressure hydrocarbon accumulations, the JOIDES Advisory Panel on Pollution Prevention and Safety requires that such accumulations be avoided. However, hydrocarbon gases are not restricted to accumulations of matured petroleum hydrocarbons. Methane, as well as traces of ethane and higher hydrocarbons are produced by fermentative bacterial processes in virtually all anaerobic sedimentary strata that contain more than about 0.5% organic matter. This includes vast areas beneath the sea floor. Where sulfate is totally absent from the sediment and its pore fluid, large quantities of methane are frequently synthesized from H and CO_2, produced by fermentation of organic matter (Wolfe, 1971). Avoiding or aborting sites where such gas is found would severely limit the scope of DSDP. In order to distinguish between dispersed gas of fermentative origin and gas associated with matured petroleum hydrocarbons that form through thermal cracking and other transformations in sediments at depth and at higher temperatures (which may migrate upward into traps), gas chromatographic equipment has been mandated onboard *Glomar Challenger*. The equipment is intended to detect and distinguish methane from ethane and higher hydrocarbons. The presence of the latter in significant amounts is regarded as an indication of the possible presence of petroleum-type accumulations, and hence is grounds for terminating drilling at a site.

The shipboard instrument is a Carle "Basic" gas chromatograph (Model 6500) of the thermal conductivity type, with a detection limit on the order of 20 ppm. It employs helium carrier gas at the rate of about 20 ml/min.

The gas samples are withdrawn from gas pockets in cores by drilling and punching a sharp penetrating device through the core liner. In general, two samples were taken at each point where the core was punctured, and the core was normally sampled at two or three different points. The hollow point is connected through a petcock to a syringe. After penetration the syringe needle is inserted into the rubber membrane of an evacuated glass tube (Vacutainer) and the petcock opened. From this tube, standard volumes (e.g., 200 μl) of gas may be injected into the entry membrane of the gas chromatograph. This gas will be contaminated to a greater or lesser extent by air from the rig floor or laboratory, but an approximate correction for this air may be made from the area (height) of the air peak, assuming that the true pore gas does not contain appreciable nitrogen.

The gas chromatograph measurements analyze only the distribution of gases remaining in the pockets or separations found in the cores. During raising of the core from ocean floor depths to the surface, much of the original gas has an opportunity to dissipate. Since the solubility of gases increases with pressure, many of the separated gas phases may be lost.

Two gas standards were available for calibration of methane and ethane components. Components of high carbon number (heavier) hydrocarbons in low concentration cannot be detected with the instrument used. Also, sulfur dioxide and hydrogen sulfide were undetected, although they may be present in small concentrations. The high standard for CH_4 = 10,850 ppm; the low standard for CH_4 = 101 ppm; the high standard for C_2H_6 = 1014 ppm; the low standard for C_2H_6 = 103 ppm. The 100 μl samples were injected into the chromatograph for all standard and unknown samples. The low standards are of such low concentrations that they can scarcely be recognized at the highest gain (lowest attenuation) available on the chromatograph and are therefore not useful for calibration purposes. The high standard ethane and methane were readily measurable at the lowest attenuation and were used for crude calibration values from 1 to 1000. However, shipboard tests indicate the attenuation factor is significantly nonlinear when extended over a range of more than two orders of magnitude. For this reason, the standards can be used to quantitatively measure gas concentrations only when the unknown concentrations lie within about one order of magnitude of the concentrations in the standard. If concentrations much larger than the reference standards are encountered, so that large attenuation factors must be employed to keep the chromatograph peaks on scale, a nonlinearity is introduced which, if unrecognized, could lead to inferred concentrations in error by more than a factor of two. Computation of clearly an impossible situation greater than 10^6 ppm for methane in some unknowns led to the discovery of this source of error. When a particular unknown component comprises a significant proportion of the total sample, its concentration can be estimated by a "proportional area under the curve" technique and is probably accurate to about 10%. A combination of these "calibration techniques" was used in quantitatively estimating the concentrations of methane, ethane, ethylene, carbon dioxide, and nitrogen encountered in the gas samples from the sediments recovered at Sites 271, 272, and 273. These combined techniques can erroneously lead to values of slightly more than 10^6 ppm for the sum of all components. The greatest absolute errors lie in estimates of the high concentration components.

Authorship

The site chapters are the result of the collective efforts of the entire shipboard scientific party, and they are comprised of sections written by individual members. However, each section has been reviewed by several shipboard colleagues so that interpretations have been strongly influenced by party consensus.

The sedimentologists as a group are responsible for the lithology sections, with individuals assuming the major responsibility for the written text as follows: P.J.B. (Sites 264, 270, and 272); E.M.K. (Sites 265, 271, and 273); A.B.F. (Sites 265 and 274); and D.J.W.P. (Sites 267, 268, and 269). Ford was principally responsible for the petrographic descriptions of the crystalline basement rocks encountered.

Similarly, the paleontologists are collectively responsible for the biostratigraphy sections, each individual contributing primarily in his specialty faunal group as noted: foraminifera (Neogene), A.G.K. (Paleogene), P.N.W.; Radiolaria, P.C.; nannofossils, D.A.B.; diatoms, D.W.M. Additional palynological analyses were conducted by E.M.K. at selected sites.

Physical and chemical properties sections were written, respectively, by R.E.W. and D.J.W.P.

Introductory material, geophysical correlation, sedimentation rates, and discussions and conclusions were written by the co-chief scientists, D.E.H. and L.A.F., with special assistance from R.E.W.

Following the site chapters are the more interpretative chapters reporting on a specialist study of one site or drawing together the results of two or more sites. These chapters have been written by members of the Shipboard Scientific Party and by shore-based workers. The authorship is indicated in the text.

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