1. INTRODUCTION, PRINCIPAL RESULTS—LEG 35 DEEP SEA DRILLING PROJECT[1]

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Leg 35 was the third DSDP cruise to undertake drilling in Antarctic waters and the first in the Southeast Pacific Basin; the others were Legs 28 and 29 in the Southwest Pacific which took place during the austral summer of 1972/1973.

Glomar Challenger departed Callao, Peru, on 13 February 1974 and sailed to Valparaiso, Chile, to take on additional personnel, equipment, and supplies prior to departing for Antarctic waters. The cruise ended on 30 March 1974 at Ushuaia, Argentina, after steaming approximately 5239 n. mi. at an average speed of 7.7 knots.

During this unusually short leg a variety of mechanical and weather problems severely limited our drilling program and only 8 days were spent with pipe in the sea floor. Drilling operations were carried out at four sites in water depths between 3745 and 5026 meters. Two sites (322 and 323) lie on the Bellingshausen Abyssal Plain, and two (324 and 325) lie on the continental rise of Antarctica (Figures 1 and 2). Figure 3 shows location of the sites with relation to the acoustic provinces recognized in the region. A single hole was drilled at each site. A total of 193 meters of sediment was recovered which represents only 37% of the stratigraphic sections penetrated. Basalt was reached at two sites and 13.43 meters were recovered. A summary of coring operations is given in Table 1 and results are summarized graphically on Figure 4.

BACKGROUND AND OBJECTIVES

Regional Geology

Present knowledge of the sediments beneath the basin and the history of physical and biological events which they record are summarized by Goodell et al. (1973). The geology of Antarctica has been compiled in a geologic map (Craddock, 1972) and that of the Antarctic Peninsula is shown on two larger scale maps by Adie (1970).

The Andes Mountains of South America and the coastal zone of West Antarctica mark segments of the Pacific continental margin of Gondwanaland (Craddock, 1975), and recurrent orogenic cycles from the early Paleozoic through the latest Mesozoic have been recognized. The modern Andean chain, at 9000 km the longest on earth, serves as an ideal model for a "cordilleran-type" range (Gansser, 1973b); it is commonly explained as the result of oceanic plate subduction beneath an active continental margin. However, Gansser (1973a) argues that block-faulting rather than compression has predominated in the Andes during the Cenozoic.

The intersection of the Chile Ridge separates the active central Andes from the relatively quiescent southern Andes. The central Andes are marked by many active volcanoes and earthquakes, but the southern Andes contain only two active volcanoes and the infrequent earthquakes are widely spaced (Gonzalez-Ferran, 1972).

The rocks of coastal West Antarctica record a complex history of Phanerozoic sedimentation, volcanism, plutonism, metamorphism, and orogenic deformation. However, no rocks of certain Precambrian age are presently known. Several orogenic cycles have been identified; the youngest is the Andean of Cretaceous to early Tertiary age. Cenozoic volcanic rocks are widespread in coastal West Antarctica; for example, Peter I Island (see Craddock, this volume), within the southern part of our area (Figure 2), is a basaltic volcano of probable Miocene age, and other seamounts are known to occur here. Thurston Island, south of our Site 324, consists of Paleozoic and Mesozoic igneous and metamorphic rocks. Upper Tertiary basaltic extrusives rest upon a glaciated unconformity in the Jones Mountains, just inland from Thurston Island.

The geologic history of the Antarctic Peninsula and its relation to the evolution of the Scotia Arc have been treated by Dalziel and Elliot (1973). They suggest that the Scotia Arc probably formed by Cenozoic disruption of an earlier, nearly linear, belt which connected South America and the Antarctic Peninsula during the Mesozoic. Paleozoic and Mesozoic orogenic cycles have formed widespread igneous plutons and deformed metasedimentary and metavolcanic rocks in the Antarctic Peninsula and westward along the Antarctic coast (Adie, 1970; Craddock, 1972). Although there has been extensive Cenozoic volcanic activity in this part of Antarctica, there is very little evidence for Cenozoic compression and folding. Except for a few earthquakes in the western Drake Passage, the Antarctic plate appears to be aseismic at present.

Objectives of Leg 35 Drilling

The sites drilled on Leg 35 were selected to study a number of particular regional problems as well as to add to general knowledge of the area. Some specific objectives of the cruise and reasons for selecting the sites follow:

1) To study the nature and age of oceanic basement in an attempt to learn more about the pre-breakup configurations of Gondwanaland

The tectonic relationships and interactions between the Antarctic plate and the Antarctic Peninsula, the

[1]With Operations Summary by Lamar Hayes, Western Oceanics, Inc., Houston, Texas.

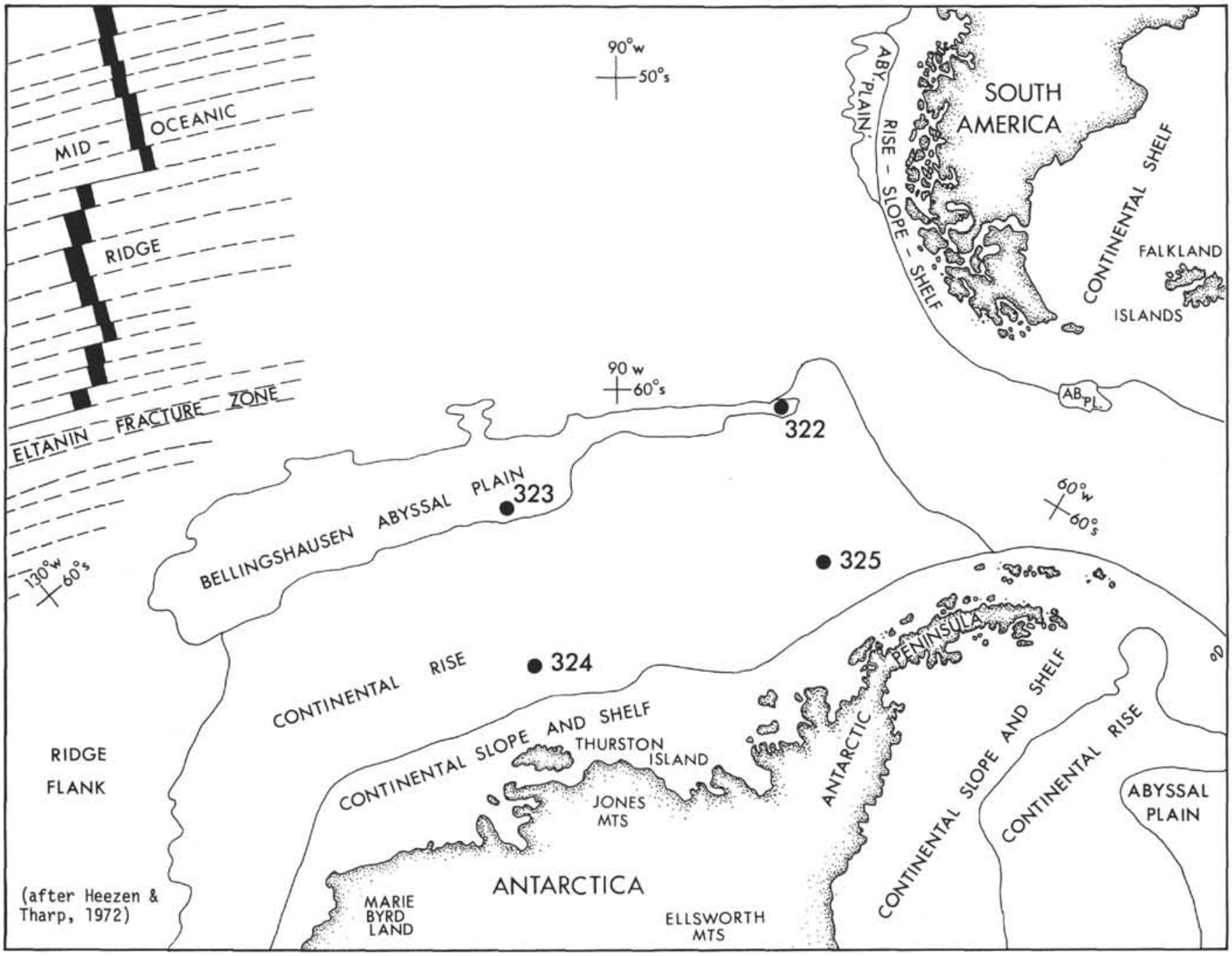

Figure 1. *Generalized physiography of the Southeast Pacific Basin and location of Leg 35 Sites (after Heezen and Tharp, 1972).*

Scotia Arc, the southern Andes, and the Chile Ridge are poorly understood. Prior to this cruise, no direct evidence was available on the age of the sea floor in the Southeast Pacific Basin.

For the vicinity of Sites 322 and 325 three models were considered, based on the limited magnetic data available: (1) Pitman et al. (1968) show the known magnetic anomalies which parallel the East Pacific Ridge, and projection of their data suggests a Mesozoic basement, probably Early Cretaceous in age, for the eastern margin of the basin; (2) Herron (1971) interprets the Chile Ridge as a spreading axis and if the crust at Sites 322 and 325 is formed by southwestward spreading away from the axis, an early Tertiary age is probable; and (3) Griffiths and Barker (1972) describe a northeast-trending spreading axis in the Drake Passage and if Site 322 and 325 crust came from this source, a late Cenozoic age is possible.

2) To determine deep and surface patterns of paleocirculation which cause changes of productivity patterns and sedimentation events that in turn determine regional acoustic stratigraphy

Global patterns of abyssal circulation appear to be closely connected to spreading patterns of Antarctic deep waters. Changes in the production of Antarctic bottom waters together with changes in sea-floor bathymetry, due to sea-floor-spreading processes, have played a major role in determining patterns of deep-sea sedimentation and in producing variations in sediment characteristics that are responsible for the acoustic reflectors. Seismic profiles in the basin reveal many different acoustic provinces (Figure 3) and reflecting horizons; we hoped to establish the basic acoustic stratigraphy of the area in an attempt to infer patterns of paleocirculation and variations in processes of accumulation.

The Antarctic Circumpolar Current flows eastward at more than 200 million m^3/sec (Gordon, 1967, 1972; Reid and Nowlin, 1971). Site 321 lies near the western entrance to the Scotia Sea and close to the present axis of this current; Site 323 lies about 250 miles south of the axis. Both sites are situated to provide data on the early history of this massive current system. The earliest time that the circumpolar current, as we know it now, could have existed was about 55 m.y.B.P. determined from magnetic interpretation of ocean crust production between Antarctica and Australia (Weissel and Hayes, 1972).

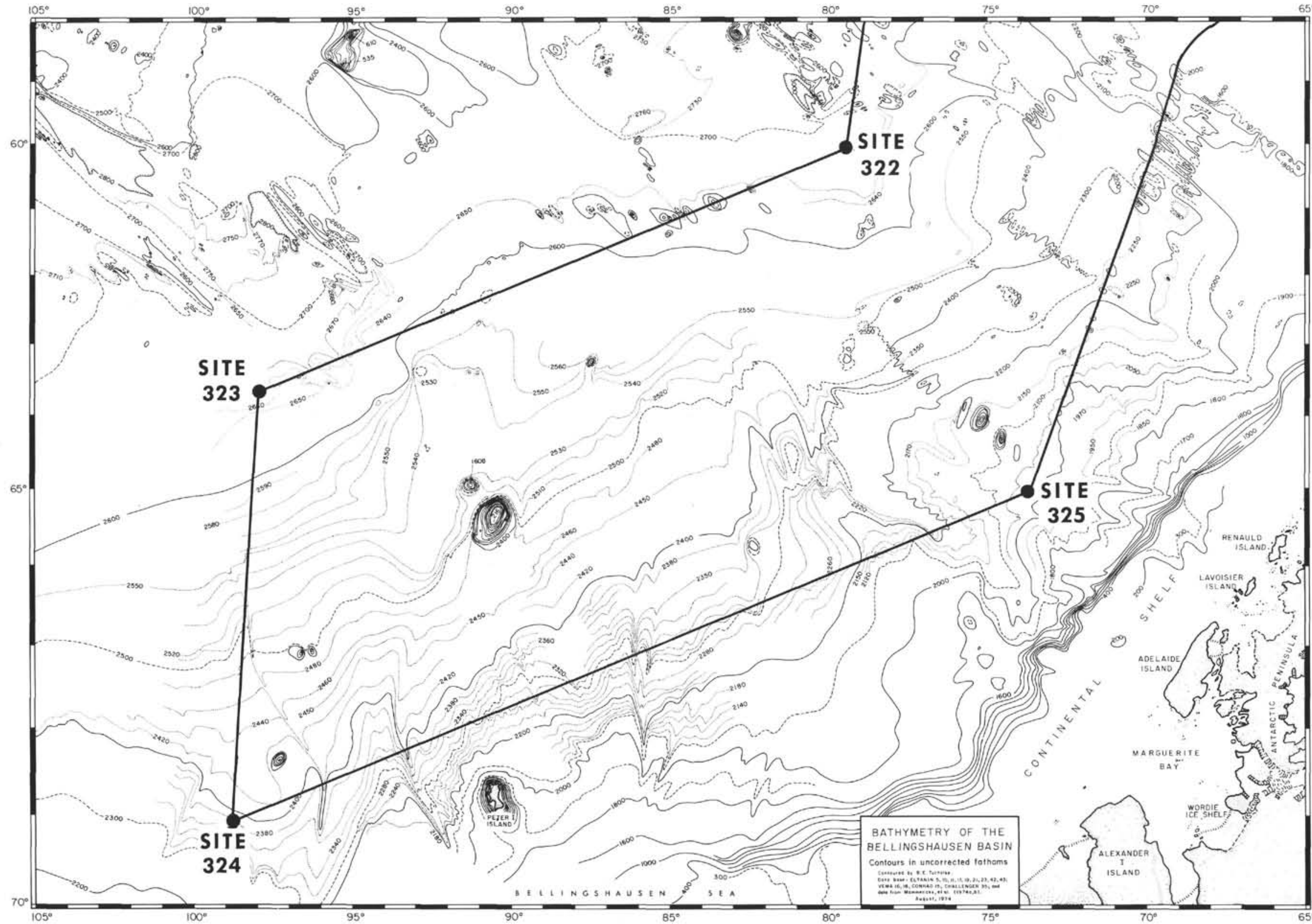

Figure 2. *Detailed bathymetric map of the Bellingshausen basin by B.E. Tucholke. Contours in uncorrected fathoms (1 fm = 1/400 sec).*

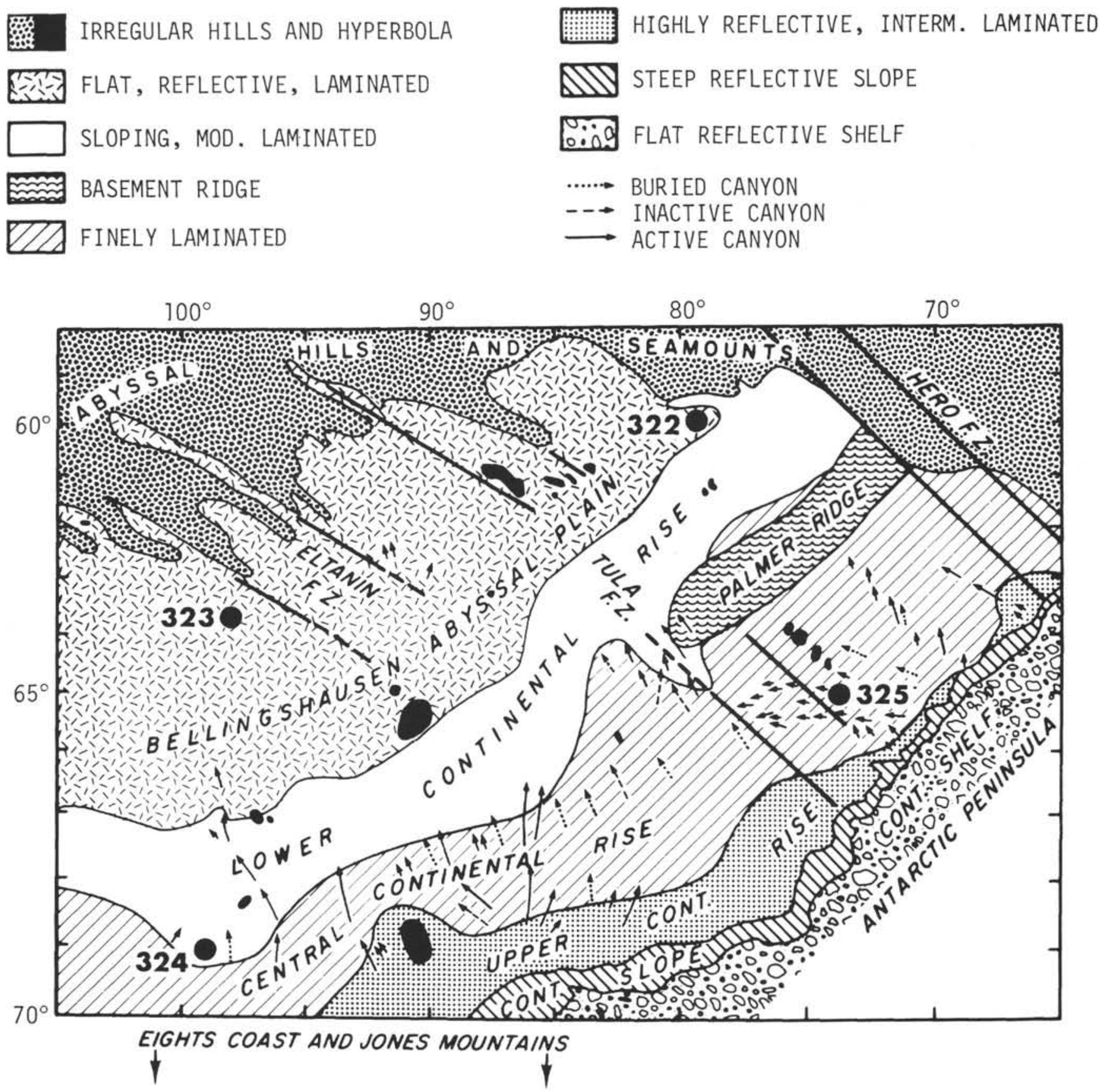

Figure 3. *Acoustic provinces of the Bellingshausen basin from Tucholke and Houtz, this volume.*

Kennett et al. (1972) report a regional Oligocene unconformity in the southwestern Pacific Ocean Basin. They attribute it to flow of a proto-circumpolar current initiated during the separation of Australia from East Antarctica. Sites 324 and 325 lie near the westward-flowing near-bottom, contour current on the continental rise (Hollister and Heezen, 1967). This current with a source in the Weddell Sea probably started soon after the Drake Passage opened or about 25 m.y.B.P.

3) To understand the history of continental glaciation of Antarctica

Evidence of Tertiary glaciation in the Jones Mountains (74°S, 94°W) was first reported by Craddock et al. (1964) and later summarized by Rutford et al. (1972). LeMasurier (1972) described the volcanic history of Marie Byrd Land and postulated the existence of a West Antarctic ice sheet since the Eocene. Margolis and Kennett (1970) studied the quartz grains and foraminifers in 18 piston cores from the South Pacific and inferred that Antarctic glaciation occurred during much of the time since the Eocene, but that there was a warm episode in the Miocene. During the DSDP Leg 28 glaciomarine sediments were found in holes in the Ross Sea, including beds as old as Oligocene at Site 270.

The Jones Mountains have yielded important evidence for Miocene glaciation of ice sheet dimensions in this part of West Antarctica. K-Ar radiometric ages on basaltic rocks overlying a fresh glacial pavement give

TABLE 1
Coring Summary, DSDP Leg 35

Site	Dates Occupied	Hours on Site	Latitude Longitude	Water Depth (m)	Penetration (m)	No. of Cores	Cored (m)	Recovered (m)	Recovered (%)	Age of Oldest Sediment	Deepest Unit
322	Feb. 27-Mar. 3	84	60°01.45'S 79°25.49'W	5026	544	14	125.5	34.2	27.3	Oligocene-early Miocene	Basalt
323	Mar. 6-Mar. 11	113	63°40.84'S 97°59.69'W	4993	731	21	199.5	76.7	38.4	Late Cretaceous	Basalt
324	Mar. 13-Mar. 15	552	69°03.21'S 98°47.20'W	4449	218	10	95.0	48.1	50.6	Pliocene	Sand
325	Mar. 21-Mar. 25	103	65°02.79'S 73°40.40'W	3745	718	10	95.0	34.4	36.2	Oligocene-early Miocene	Claystone
Total		352			2221	55	515.0	193.2	37.5		

discordant results, probably due to incomplete degassing of mantle-derived Ar^{40} during subglacial eruptions. The calculated ages, however, cluster in the 7-10 m.y. range. Site 324 is strategically located to test the existence of the postulated Miocene ice sheet in the region of the Jones Mountains. Such an ice sheet should have calved many bergs, which would have drifted both northward and westward; at least some should have reached the vicinity of Site 324 and dropped their entrained rock debris to the sea floor. The Antarctic Peninsula lies further north than the rest of the continent. It may have had a different history of glaciation during the Cenozoic and Site 325 is favorably located to preserve this glacial record.

4) To investigate the geochemistry of pore waters and related sediments in order to understand postdepositional diagenetic processes in sediments, particularly as related to the alteration of underlying basalts

The Leg 35 geochemistry program was planned to coordinate chemical studies of the interstitial waters with those of the solid phases and with the physical aspects of the sediments. We intended to carry out a study that emphasized the interrelationships of the chemical composition of the interstitial waters *and* the chemistry and mineralogy of the solid phases. In particular, we wished to study those chemical gradients, in the interstitial waters, that may be related to upward migration of elements during crustal alteration.

5) To recover sediments containing high-latitude fossil forms to establish an Antarctic biostratigraphic and paleogeographic framework

The objectives of the paleontological program were to (1) establish and refine high-latitude Antarctic biostratigraphy, (2) increase our understanding of the paleobiogeography of all microfossil groups, and (3) investigate changes in the paleooceans and paleoclimates of the Antarctic during the late Mesozoic and Cenozoic.

SUMMARY OF DRILLING RESULTS

Bellingshausen Abyssal Plain

Site 322

Site 322 was drilled on the eastern end of the Bellingshausen Abyssal Plain where it is bounded by the Hero Fracture Zone to the northeast and the continental rise of Antarctica to the south (Figure 3). Seismic profiles show a nearly horizontal sediment accumulation (0.5 sec) resting on very irregular "basement" topography.

A single hole was drilled in a water depth of 5026 meters and reached a subbottom depth of 544 meters, penetrating 30 meters into basaltic rocks at the bottom. The upper 514 meters consists of Neogene sediments. Of a total 125.5 meters cored, 34.2 meters (27.3%) of core material were recovered.

Four sedimentary units and one igneous unit are recognized from the surface downward. Unit 1 is 295 meters thick and consists of unconsolidated, well-sorted sands and silts interbedded with clays. Unit 2 is 171 meters thick and consists of consolidated dark greenish-gray claystone. Unit 3 is 43 meters thick and consists of interbedded, mainly dark gray sandstones and claystones, and this is underlain by Unit 4 which consists of 4.3 meters of brown pelagic claystone. Unit 5 is at least 30 meters thick and consists of aphanitic, variolitic, and glassy basalt and minor hyaloclastite.

Seismic profiles at the site show a series of gently undulating reflectors which become less coherent downward, and no definite correlations could be established between individual reflectors and the above lithologic units.

The sedimentary sequence is impoverished in fossils with diatoms being the most abundant biogenic remains. A few diatoms found in claystone 2.5 meters above the basalt contact appear to be Miocene in age. Pliocene radiolarians occur in the first core, but they become rare and less diagnostic deeper in the hole. A few silicoflagellates found in Unit 1 and the upper half of Unit 2 yielded ages increasing downward from late Pliocene to late Miocene. Several benthonic arenaceous foraminiferal genera (*Bathysiphon, Ammodiscus,* and *Cyclammina*) were found in the claystone of Unit 3 within a few meters of the basalt contact. Some species of these genera range down into the Oligocene.

The oldest rock penetrated at Site 322 is the basalt in the lowest 30 meters of the hole. On the basis of the presence of glassy veins and hyaloclastite breccia, this rock is interpreted as a submarine lava flow.

The apparent age of the basaltic extrusive rocks from K-Ar dates vary from 10-15 m.y.B.P. (late Miocene). However, microfossils from the overlying sedimentary sequence indicate that the basaltic rock can be no younger than middle Tertiary (i.e., about 25 m.y.B.P.).

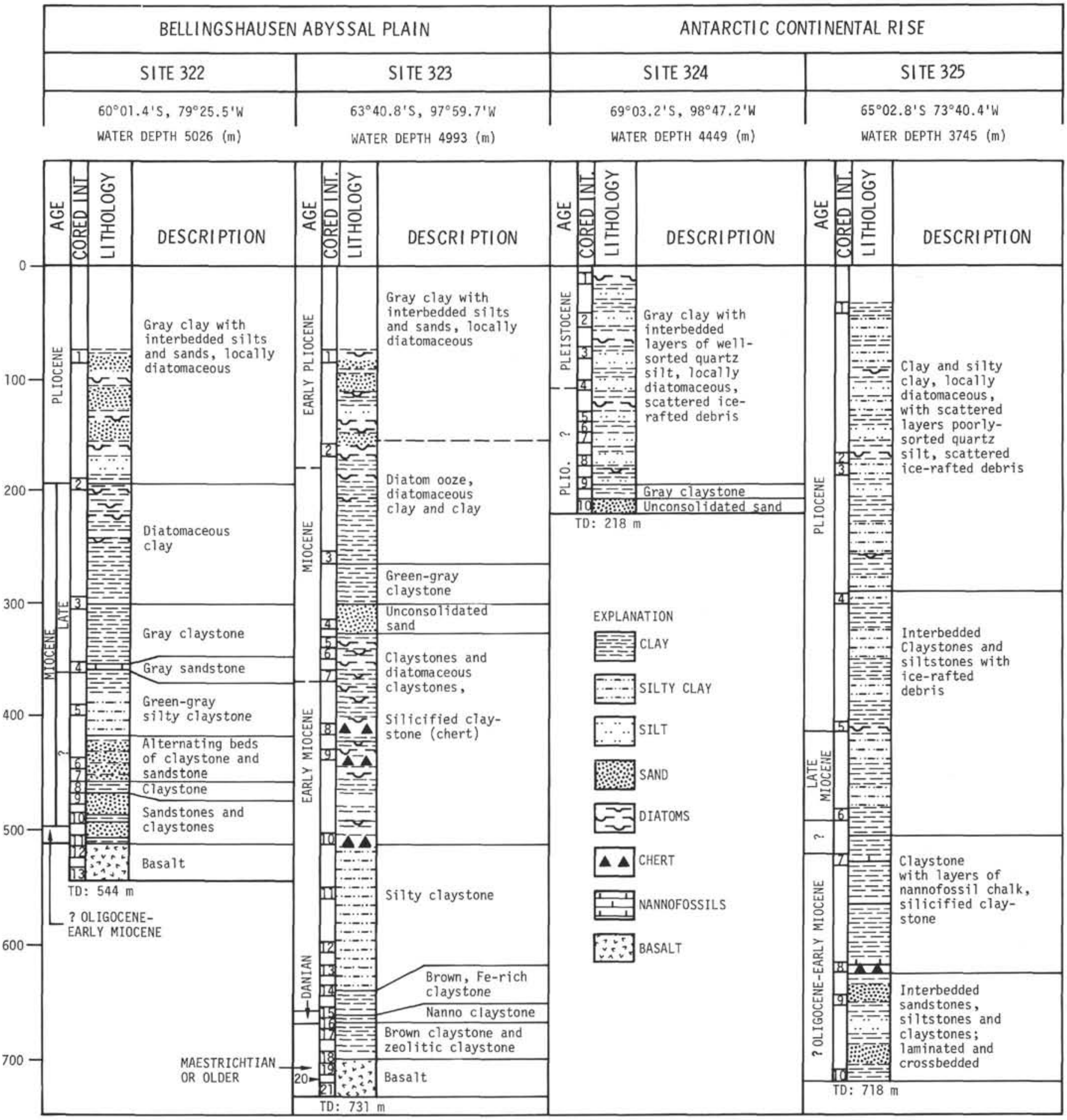

Figure 4. *Stratigraphic columns of the four holes drilled during Leg 35.*

The position of the site on the abyssal plain and the southward continuity of stratigraphic units in the seismic profiles indicate that most of the detritus came from Antarctica. A small amount of ice-rafted material occurs in the upper Miocene sediments. The scarcity of turbidite features in the sediment suggests that bottom currents may be responsible for final deposition. Calculation of exact accumulation rates is complicated by the uncertainty about the true age of most beds in the sequence. Most of the sediment, however, seems to be Neogene in age. All of the sediment appears to have been deposited under bathyal to abyssal conditions well below the carbonate compensation depth.

Site 323

Site 323 is centrally located on the abyssal plain, about 30 miles west of the Eltanin Fracture Zone and about 150 miles north of the Antarctic continental rise. This site, like 322, lies on the deep oceanic part of the Antarctic plate. Seismic profiler records in this region show smooth horizontal reflecting surfaces within the upper 1/4 sec that are underlain by a variety of acoustic units to the deepest observed reflector at 3/4 sec subbottom.

The single hole drilled at Site 323 (4993 m water depth) reached a total depth of 731 meters below the sea floor. Drilling penetrated 701 meters of Cenozoic and Cretaceous sedimentary deposits, and 30 meters of basalt. A total of 199.5 meters was cored and 76.7 meters (38%) of core, including about 10 meters of basalt, was recovered.

Six lithologic units are recognized: five sedimentary and one igneous, which are numbered in descending order. Unit 1 is 266 meters thick and consists of gray unconsolidated sandy silt, diatom clay, and diatom ooze. Unit 2 is 241 meters thick and is comprised of relatively indurated gray diatomitic claystone and cherts. Unit 3 is about 130 meters of gray claystone devoid of biogenic silica. Unit 4 is 28 meters thick and contains yellow-brown iron-rich claystone and nanno-claystone overlying 34 meters of brown zeolitic claystone (Unit 5). The base of this unit rests upon basalt, and there is no sign of contact metamorphism. Unit 6 is at least 30 meters thick and consists of aphanitic aphyric basalt having a range of textures but with no evidence of glass, palagonite, or hyaloclastite.

Seismic profiles near Site 323 have revealed the following acoustic units in descending order: (I) flat-lying reverberant reflectors, (II) acoustically transparent layer, (III) reverberant, gently undulating reflectors, (IV) acoustically transparent layer, (V) acoustically opaque, undulating reflectors. A good correlation exists between these seismic units and the lithologic units described above.

Each of the first 18 cores taken yielded fossils from the five major microfossil groups. Diatoms are the most abundant fossil and are present in all 18 cores. They are, however, pyritized or recrystallized in the material older than early Miocene. A continuous stratigraphic sequence may exist downward through early Miocene or Oligocene. Danian (early Paleocene) foraminifers and nannofossils occur below 650 meters.

The 10 meters of aphanitic aphyric basalt recovered probably corresponds to the deepest observed seismic reflector. The Cretaceous age determined from nannoplankton in the sedimentary unit overlying the basalt indicates an age of at least 65 m.y.B.P. which is close to the predicted crustal age inferred from the closest magnetic anomaly (32), approximately 76 m.y.B.P.

The brown iron-rich pelagic clay just above the basalt was probably deposited in a tranquil environment mostly below the carbonate compensation depth. Either an unconformity, or alternatively, a complete sequence with very *low* accumulation rates is inferred from the presence of Oligocene or Miocene gray silty claystone 21 meters above Danian nannofossil claystone. A subsequent abrupt increase in terrigenous detritus with no biogenic component suggests rapid deposition of continental-rise hemipelagic silt and clays which was probably originally transported downslope from Antarctica by turbidity currents, and penecontemporaneously entrained and redeposited by contour currents flowing as part of the newly developed abyssal circulation.

One ice-rafted granite cobble was found in sediment of middle Miocene age.

Antarctic Continental Rise

Site 324

Site 324 is located on the gently sloping lower continental rise of Antarctica about 160 miles north of Thurston Island, the closest exposed land. This site, like all those drilled on Leg 35, lies on the oceanic part of the relatively stable Antarctic plate. Seismic profiler records over this site reveal a thick (at least 2 sec) total sediment accumulation.

The main purpose for drilling at this site was to gain a better understanding of the paleoenvironments of the Antarctic continental margin from at least the onset of glaciation. However, the single hole drilled at this site, in a water depth of 4449 meters, reached only 218 meters subbottom before hole cavings of sand forced its abandonment. The sequence penetrated consists of Pliocene and Quaternary sediments. Of total of 95.0 meters cored 48.1 meters (51%) were recovered. Nearly all of the sediment recovered consists of silty clays containing thin layers of well-sorted silt. Ice-rafted detritus is common in the upper part of the sequence, but decreases with depth.

Seismic profiles over this site show a near-surface acoustically transparent layer overlain by a thin reverberant layer and underlain by a very thick acoustically reverberant layer. These three seismic units have been identified in the sequence penetrated and they are numbered in descending order. Unit I is the surficial (top 50 m) reverberant layer consisting of soft, watery Pleistocene clay interbedded with diatomaceous ooze. Unit II is the acoustically transparent layer about 120 meters thick comprised of gray unconsolidated clay with thin silty layers. Unit III is the lower reverberant layer (at least 48 m thick) which is composed of lower Pliocene silty clay and sand beds.

Site 325

Site 325 lies within a well-developed submarine canyon system on the central portion of the Antarctic continental rise, about 100 miles off the coast of the Antarctic Peninsula. It is in a region of finely laminated and lens-shaped acoustic intervals (about 1 sec thick) above a relatively smooth basement (deepest observed reflector). This smooth basement zone is about 50 miles wide and lies between the upper continental rise and the base of the continental slope.

Unfortunately, the single hole drilled at this site reached only to a depth of 718 meters subbottom, or about 3/4 of the subbottom distance to basement. The entire sequence penetrated consists of Cenozoic terrigenous deposits. The oldest fossiliferous beds are early Miocene to Oligocene in age. Ninety-five meters of the interval were cored and 34.4 meters (36.2%) of core were recovered.

The sequence was divided into two lithologic units. The upper unit, about 570 meters thick, consists of silty clay, silty claystone, and claystone. Ice-rafted pebbles and coarse sand grains are abundant at the top. The lower unit is 148 meters thick and consists of indurated sandstone, siltstone, conglomerate, and claystone.

All 10 cores from Site 325 contain fossils of which diatoms are the most abundant. The uppermost 500 meters contains a diverse Antarctic floral assemblage ranging in age from late Pliocene to middle Miocene. Radiolarians in the uppermost 400 meters are Pliocene in age, and below this level calcareous and arenaceous benthonic foraminifers of Oligocene to early Miocene age occur. Early to middle Oligocene nannoplankton are common in a few thin calcareous beds below 500 meters.

The deepest observed seismic reflector probably represents a thin sequence (less than 100 m) of Oligocene and possibly older clastic sediments which, by valley-filling may have effectively smoothed the rough underlying igneous basement.

The percentage of quartz embedded within the clay and claystone varies inversely with the frequency of silt laminae. The quantity of quartz silt supplied to this region has apparently been constant, and variations in mode of occurrence are probably directly related to the competence of the depositing currents. An unusually high accumulation rate of 20 cm/1000 yr calculated for early to middle Pliocene suggests vigorous continental erosion during this time. The oldest ice-rafted debris occurs in lower Miocene or upper Oligocene claystones. This agrees well with the age of the first occurrence of ice-rafted sediment in a similar deep-sea environment encountered during Leg 28 off Antarctica.

SUMMARY OF PRINCIPAL RESULTS

Igneous Rocks

Fresh basaltic rock was recovered from the bottom of the hole at two sites on the Bellingshausen Abyssal Plain. Rocks from both sites are essentially bimineralic, with intermediate plagioclase somewhat more abundant than augitic pyroxene. The lack of olivine in both rocks suggests a tholeiitic composition. The rock at Site 322 is considered to be a submarine extrusive, possibly considerably older than the overlying Miocene sediments. The rock at Site 323 occurs below sediments of Late Cretaceous age and may be a sill.

Age of the Crust

The most probable ages for the igneous basement are Cretaceous at one of the western sites (323) and early and middle Tertiary, respectively, at the two eastern sites (322, 325). Magnetic anomaly patterns, depth below sea level, and degrees of alteration suggest that the Site 322 basalt is considerably older than the overlying early Miocene sediments. Although the basalt at Site 323 may be intrusive, seismic data suggest that it probably represents the igneous rocks of Layer 2. Site 324 was a shallow hole, but its tectonic position and the great thickness of sedimentary deposits suggest that the basement may be lower Tertiary or Cretaceous. Site 325 bottomed in Oligocene sedimentary rocks at least 100 meters above igneous rocks and probable basement.

Sedimentary Processes

Most of the sedimentary deposits penetrated at the four sites consist of terrigenous debris derived from Antarctica. This detritus was transported to the deposition site by bottom currents, turbidity currents, and ice-rafting. At the two abyssal plain sites, pelagic claystones of Miocene (Site 322) and Cretaceous (Site 323) age lie just above basalt at the bottom of each hole; a few thin calcareous beds also occur within the Cretaceous pelagic deposits.

Antarctic Glaciation

A record of continental glaciation in Antarctica during the Cenozoic is present in cores taken close to that continent in the form of dropstones and other ice-rafted debris. Site 325 on the upper continental rise off the Antarctic Peninsula yielded ice-rafted debris from many horizons in the uppermost 500 meters of the sequence; the oldest beds with such debris are of early or middle Miocene age.

Biostratigraphy

Moderately well preserved middle Miocene to Pleistocene siliceous microfossil assemblages were recovered at all four sites and the established Southern Ocean biostratigraphic zonal schemes were found to be applicable throughout the region. All siliceous microfossils in strata older than middle Miocene are so altered or recrystallized that precise identification and age assignments are impossible. Moderately to well preserved calcareous planktonic foraminifers were found in Pliocene-Pleistocene beds at Sites 324 and 325, and in Paleocene beds at Site 323. Oligocene or early Miocene bathyal to abyssal arenaceous foraminifers occur at Sites 322, 323, and 325.

Interstitial Waters

Alkalinity and ammonia values from all four sites show maxima at depths of 100 to 300 meters. These profiles suggest increased sulfate reduction in the upper few hundred meters of the sedimentary sequence. All sites showed large downhole increases in dissolved calcium and decreases in dissolved magnesium; gradients are especially steep in the deeper parts of holes which penetrate basalt. Submarine alteration or halmyrolysis of basalt is considered an important factor in creating these calcium and magnesium gradients.

SUMMARY OF OPERATIONS

Leg 35 (including the Callao port call) was carried out during 56.3 days of which 16.5 days were spent on station and 28.2 days cruising. The sites drilled on this leg were all south of 60°S. While on site the ship lost 2.2 days because of mechanical breakdown and another 0.8 days because of bad weather. A more complete summary of operations is contained in Table 2.

Drilling

A standard bottom-hole assembly was used at two of the four sites. This assembly consisted of a bit, bit sub (with float valve), core barrel, three 8¼″ drill collars, two 5′ stroke bumper subs, three 8¼″ drill collars, two 5′ stroke bumper subs, two 8¼″ drill collars, one 7¼″ drill collar, and a joint of heavy wall drill pipe. The standard nonrotating inner core barrel was used at all sites.

TABLE 2
Summary of Operations, Leg 35

Total days Leg 35	56.3
Total days in Port	11.6
Total days cruising (survey time included)	28.2
Total days on site	16.5
Trip time	4.8
Drilling time	2.9
Coring time	4.9
Mechanical downtime	2.2
Waiting on weather	.8
Other (includes running logging unit)	.9
Total distance traveled (nautical miles)	5239
Average speed (knots)	7.7
Sites investigated	4
Holes drilled	4
Number of cores attempted	55
Number of cores with recovery	52
Percent of cores with recovery	94
Total meters cored	515
Total meters recovered	193.2
Percent of core interval	37.5
Total meters drilled	1696.5
Total meters of penetration	2212
Percent of penetration cored	23
Maximum penetration (meters)	731
Minimum penetration (m)	219
Maximum water depth (m)	5036
Minimum water depth (m)	3755

Recovery was not as good as expected which was attributed to several factors. Primarily, very little coring was attempted in the soft clays and oozes near the mud line where recovery is usually high. Secondly, at three of the four sites, silt and sand interbeds were encountered which required more circulation than is normally used when coring soft formations. Reduced circulation resulted in a tendency of the bit to plug and the drill string to stick. Thirdly, coarse ice-rafted debris lodged in the core catcher and prevented entry of sediment into the core barrel thereby hampering the coring of the soft sediments. Also, the extended port call in Callao substantially reduced the time available for actual drilling. Only 8 days were spent with pipe in the sea floor. Consequently, time was not available for continuous coring and only 18% of the total penetration was cored.

Basement was penetrated at Sites 322 and 323 and drilling was terminated when Site 324 was abandoned because of unstable hole conditions at 218 meters below the mud line. In addition, the drill string was subjected to excessive torque when, despite attempts to wash it out, the bit became plugged. However, the poor hole condition was the primary reason drilling was terminated at Site 324. There was no recovery on the last core attempted.

Drilling at Site 325 was terminated after we encountered 20-ft swells and 60-mph gusty wind.

Positioning

Difficulties with the positioning system were experienced at three of the four sites. At Site 322, a malfunction in the Number 1 hydrophone receiver timing signal resulted in erratic computer signals and it was necessary to position in semi-automatic mode for much of the time at that site.

At Site 324, positioning became difficult as the wind velocities increased and seas became choppy. The problem was ultimately found to be caused by excessive drive current to the stern thruster static exciter which resulted in erratic maximum thrust in both semi-automatic and manual modes.

At Site 325, in 60-mph winds and 16 ft to 18 ft swells, positioning was again erratic. A second beacon was dropped and the ship maintained position satisfactorily until the wind shifted so that both current and wind were coming from the same direction. Unfortunately, the ship was unable to maintain heading against both wind and current with only one operable stern thruster, and it was necessary to abandon the site. At the time Site 325 was abandoned, it was necessary to position in automatic mode with winds up to 60 mph and 22-ft swells which caused the ship to pitch 10°.

Underway

En route to the first site (322) the ship cruised at full speed (210 turns) when weather would permit. Winds up to 75 mph required a reduction of speed to prevent the ship from taking severe rolls. In some cases, the ship experienced rolls of up to 35°.

On 1 March 1974 the NSF R/V *Hero* rendezvoused with the *Challenger* at 60°S and 79°W. The *Hero* accompanied the *Challenger* during the remainder of the leg south of 60°S, and cruised approximately 5 to 15 miles ahead to scout for ice.

First ice, a bergy bit, was reported by the bow lookout on 15 March at 67°S and 96°W. Later the same day, a medium-sized iceberg was spotted 4 miles on the starboard side. Although this was the only ice observed, for reasons of safety the ship's speed was reduced to 5 knots at night or during heavy snow squalls until after we had moved north of 60°S.

While steaming between Sites 324 and 325, the Number 6 propulsion motor became inoperative. During the remainder of the voyage the ship's speed was reduced by 10%. However, because of sea conditions, poor visibility, and/or ice hazard during approximately 80% of the cruising time, the vessel was not operated at top cruising speed. Because the ship was constantly rolling 10° to 20° or pitching 5° to 10°, repairs were extremely difficult to effect throughout the leg.

Heave Compensator

The heave compensator system was not used at Site 322 because a suction hose on the hydraulic pumps burst causing the loss of approximately 390 gallons of pydraul leaving insufficient fluid to operate the system. Following delivery of 300 gallons of pydraul by the *Hero*, the system was utilized at Site 323 in 4993 meters of water. Here the drill string weight was approximately 375,000 pounds. The system operated in both active and passive modes and instrumented recordings of the performance made during 22-hr test indicated that it operated within the designed specifications. In soft sediments the heave compensator apparently does not improve core recovery or result in less core disturbance. In firm or hard formations, however, bit life is extended and core recovery is improved.

REFERENCES

Adie, R.J., 1970. Antarctic Peninsula. *In* Geologic maps of Antarctica, Folio 12, Antarctic Map Folio Series: New York (Am. Geogr. Soc.)

Craddock, C., 1972. Geologic map of Antarctica, scale 1:5,000,000: New York (Am. Geogr. Soc.).

———, 1975. Tectonic evolution of the Pacific margin of Gondwanaland. *In* Campbell, K.S.W. (Ed.), Gondwana Geology: Canberra (Australian National University Press), p. 609-618.

Craddock, C., Bastien, T.W., and Rutford, R.H., 1964. Geology of the Jones Mountains. *In* Adie, R.J. (Ed.), Antarctic geology: Amsterdam (North Holland Pub. Co.), p. 171-187.

Dalziel, I.W.D. and Elliot, D.H., 1973. Scotia Arc and Antarctic margin. *In* Nairn, A.E.M. and Stehli, F.G. (Eds.), The ocean basins and margins, vol. 1: New York (Plenum Pub. Corp.), p. 171-246.

Gansser, A., 1973a. Facts and theories on the Andes: J. Geol. Soc. London, v. 129, p. 93-131.

———, 1973b. Orogene Entwicklung in den Anden, im Himalaja und den Alpen, ein Vergleich: Ecolog. Geol. Helv., v. 66, p. 23-40.

Gonzalez-Ferran, O., 1972. Distribucion del volcanismo activo de Chile y la reciente erupcion del volcán Villarrica: *In* El Primer Symposium Cartográfico Nacional, Santiago, p. 191-207.

Goodell, H.G., Houtz, R., Ewing, M., Hayes, D., Naini, B., Echols, R.J., Kennett, J.P., and Donahue, J.G., 1973. Marine sediments of the Southern oceans, Folio 17, Antarctic Map Folio Series: New York (Am. Geogr. Soc.).

Gordon, A.L., 1967. Structure of Antarctic waters between 20°W and 170°W, Folio 6, Antarctic Map Folio Series: New York (Am. Geogr. Soc.).

———, 1972. On the interaction of the Antarctic circumpolar current and the Macquarie Ridge. *In* Antarctic Oceanology II, Antarctic Res. Ser.: Am. Geophys. Union, p. 71-78.

Griffiths, D.H. and Barker, P.F., 1972. Review of marine geophysical investigations in the Scotia Sea. *In* Adie, R.J. (Ed.), Antarctic geology and geophysics: Oslo (Universitetsforlaget), p. 3-11.

Hayes, D.E, Frakes, L.H., et al., 1975. Initial Reports of the Deep Sea Drilling Project, Volume 28: Washington (U.S. Government Printing Office).

Heezen, B.C. and Tharp, M., 1972. Morphology of the sea floor. *In* Folio 16, Antarctic Map Folio Series: New York (Am. Geogr. Soc.).

Hollister, C.D. and Heezen, B.C., 1967. The floor of the Bellingshausen Sea. *In* Hersey, J.B. (Ed.), Deep sea photography: Baltimore (Johns Hopkins Univ. Press).

Herron, E.M., 1971. Crustal plates and sea floor spreading in the southeastern Pacific. *In* Antarctic Oceanology I, Antarctic Res. Ser.: Am. Geophys. Union, p. 229-237.

Kennett, J.P., Burns, R.E., Andrews, J.E., Churkin, M., Jr., Davies, T.A., Dumitrica, P., Edwards, A.R., Galehouse, J.S., Packham, G.H., and van der Lingen, G.J., 1972. Australian-Antarctic continental drift, paleocirculation changes and Oligocene deep sea erosion: Nature, v. 239, p. 51-55.

Krumbein, W.C., and Pettijohn, F.J., 1938. Manual of sedimentary petrology: New York (D. Appleton-Century Co.).

LeMasurier, W.E., 1972. Volcanic record of Cenozoic glacial history of Marie Byrd Land. *In* Adie, R.J. (Ed.), Antarctic geology and geophysics: Oslo (Universitetsforlaget), p. 251-259.

Margolis, S.V. and Kennett, J.P., 1970. Antarctic deep sea cores: Science, v. 170, p. 1085-1087.

Pitman, W.C., Herron, E.M., Heirtzler, J.R., 1968. Magnetic anomalies in the Pacific and sea floor spreading: J. Geophys. Res., v. 73, p. 2069-2085.

Reid, J.L. and Nowlin, W., 1971. Transport of water through the Drake Passage: Deep-Sea Res., v. 18, p. 51-64.

Rutford, R.H., Craddock, C., White, C.M., and Armstrong, R.L., 1972. Tertiary glaciation in the Jones Mountains. *In* Adie, R.J. (Ed.), Antarctic geology and geophysics: Oslo (Universitetsforlaget), p. 239-243.

Weissel, J.K. and Hayes, D.E., 1972. Magnetic anomalies in the southeast Indian Ocean. *In* Antarctic Oceanology II, Antarctic Res. Ser., Am. Geophys. Union, p. 165-196.