1. INTRODUCTION AND OBJECTIVES[1]

Shipboard Scientific Party[2]

During Leg 113, nine sites were drilled using *JOIDES Resolution* in the Weddell Sea (Figs. 1 and 2; Table 1). These sites form a depth transect for studies of vertical water-mass stratification, climatic evolution, and oceanographic history of Antarctica and the surrounding ocean during the late Mesozoic and Cenozoic. Approximately 1950 m of sediments and 2 m of igneous rocks were recovered in a total of 22 holes. The cruise comprised 44 operational days and 21 days of transit, between 5 January and 11 March, 1987, beginning in Punta Arenas, Chile, and ending in East Cove, Falkland Islands.

CRUISE OBJECTIVES

Leg 113 was designed to address the following major questions:

1. When did the Antarctic ice-sheets first form, and have they been permanent since formation?
2. When did marine glacial conditions develop sufficiently for the initial formation of cold Antarctic Bottom Water in the Antarctic region, particularly in the Weddell Sea? How have bottom- and intermediate-water temperatures changed in response to Antarctic glacial development?
3. What has been the history of oceanic planktonic productivity in the Weddell Sea sector of the Southern Ocean? How is this development linked to the evolution of Antarctic climates and the oceanic environment, particularly the Polar Front?
4. What has been the evolution of the Antarctic planktonic and benthic biota and their biogeographic patterns? How is this linked with the environmental changes?

REGIONAL BACKGROUND

Cenozoic oceanographic and climatic evolution is largely a record of progressive cooling and glaciation of the polar regions and perhaps slight warming in the tropics, which result in an increase in the planet's latitudinal thermal gradient (Savin et al., 1975; Shackleton and Kennett, 1975; Kennett, 1977; Loutit et al., 1983). The climatic and glacial evolution of Antarctica is crucial to our understanding of long-term climatic change (Hayes, Frakes, et al., 1975; Kennett, Houtz, et al., 1975; Kennett, 1977). In this region, powerful climatic feedback mechanisms occur such as those related to ice albedo and bottom-water formation. Also, the high latitudes are among the most sensitive to externally imposed change.

Global cooling during the Cenozoic did not proceed uniformly but was marked by discrete and sudden periods of cooling that may have originated in the polar regions, particularly Antarctica. A better understanding of the history of Antarctica and the surrounding Southern Ocean over the past 100 m.y. is central to the study of global climate and circulation.

The Antarctic continent is virtually devoid of useful marine sedimentary sequences of Late Mesozoic-Cenozoic age; a few shallow-water sections are known at the periphery of the Antarctic continent, but these contain only very rare planktonic microfossils. Because of this, stratigraphic sequences must be obtained from the deep sea. Five previous deep sea drilling expeditions (Table 2; Fig. 3) have provided almost all our information about the Cenozoic evolution of the Antarctic marine environments. There is understanding of some of the main paleoceanographic changes during the last 23 m.y. (Neogene), but our understanding of earlier stages of ocean cooling and development has been limited by the paucity of suitable stratigraphic sections.

The tectonic development of Antarctica had a major impact on its climatic evolution. Antarctica was originally part of Gondwanaland and subsequently became increasingly isolated within the oceanic realm as fragments of Gondwanaland dispersed northward. For the past 90 m.y., Antarctica has remained near the south geographic pole. The circum-Antarctic circulation system developed as the southern land masses moved away, permitting unrestricted latitudinal flow. Major changes that impacted this region include the opening of the Tasman Seaway (Kennett, Houtz, et al., 1975; Kennett, 1977), the opening of Drake Passage (Barker and Burrell, 1977; 1982), extension between Antarctica and Australia, and possibly the subsidence of the Kerguelen Plateau. The development of the Antarctic Circumpolar Current effectively thermally isolated Antarctica by decoupling the warmer subtropical gyres from near the continent (Kennett, 1977). This led, in turn, to Antarctic glaciation and the formation of ice-sheets. Such a climatic change has a profound effect on the environment, and thus the biogeography, of high latitudes. The climatic change included the cooling of waters surrounding the continent, extensive seasonal sea-ice production, and wind-driven upwelling of nutrient-rich intermediate waters which have a profound effect on biogenic productivity in the Southern Ocean.

The history of development of Antarctic continental glaciation and of water masses in the Southern Ocean is still poorly known. Prior to Leg 113 no high-resolution stratigraphic sequences had been obtained using the hydraulic piston corer (HPC), advanced hydraulic piston corer (APC), or extended core barrel (XCB). In addition, virtually no stable isotopic measurements had been made on Cenozoic sequences in the area of the present-day Antarctic water mass. Previous work by many investigators led to the development of general scenarios of climatic and oceanographic evolution of the Antarctic region. Interpretation of oxygen isotopic stratigraphy and the distribution of ice-rafted detritus in the Southern Oceans have led many workers to believe that the first appearance of calving glaciers occurred during the Oligocene (~30 Ma), followed by the initial formation of the East Antarctic ice-sheet in the middle Miocene (16.5–13.5 Ma; Shackleton and Kennett, 1975; Savin et al. 1975; Kennett, 1986). The marine ice-sheet of West Antarctica formed during the late Miocene (~9–6 Ma; Rutford et al., 1972; Shackleton and Kennett, 1975; Ciesielski and Weaver, 1983; Ciesielski et al., 1982).

Recent interpretations of the oxygen isotopic record have led workers to suggest that major Antarctic ice-sheets developed at times during the Oligocene (Miller and Fairbanks, 1983; Keigwin and Keller, 1984; Miller and Thomas, 1985; Shackleton et

[1] Barker, P. F., Kennett, J. P., et al., 1988. *Proc. ODP, Init. Repts.*, 113: College Station, TX (Ocean Drilling Program).
[2] Shipboard Scientific Party is as given in the list of Participants preceding the contents.

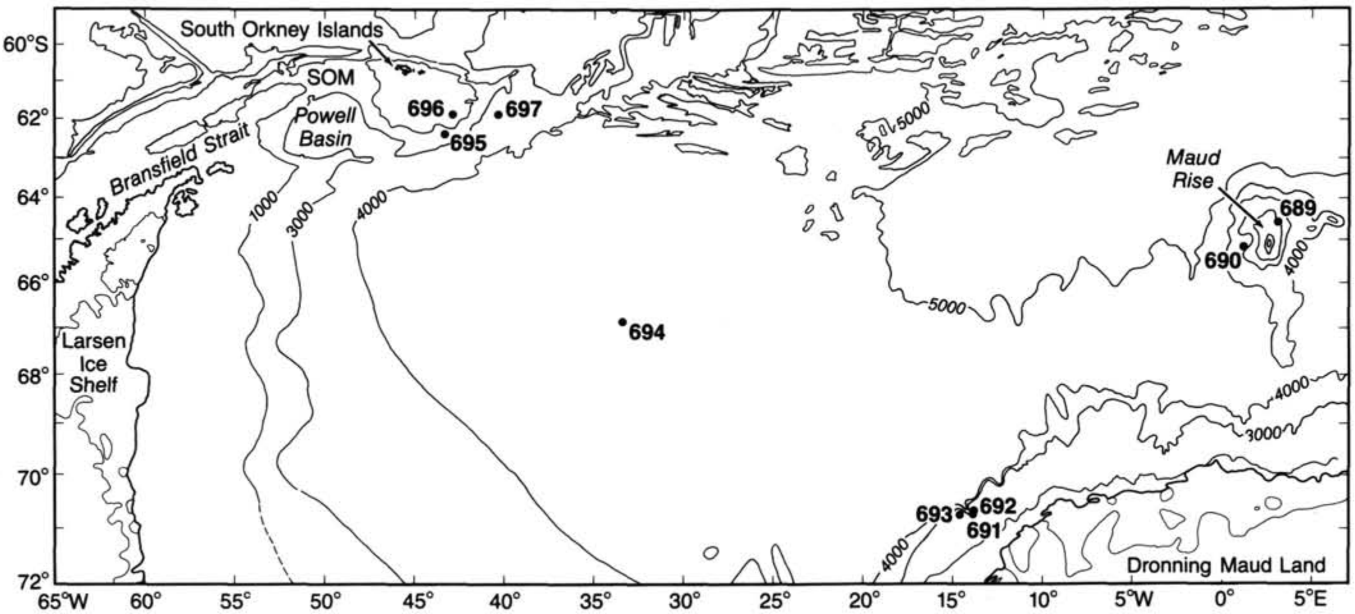

Figure 1. Location of Leg 113 Sites (689 to 697) in Weddell Sea. All sites lie in the present-day Antarctic water mass, south of the Polar Front. SOM = South Orkney microcontinent.

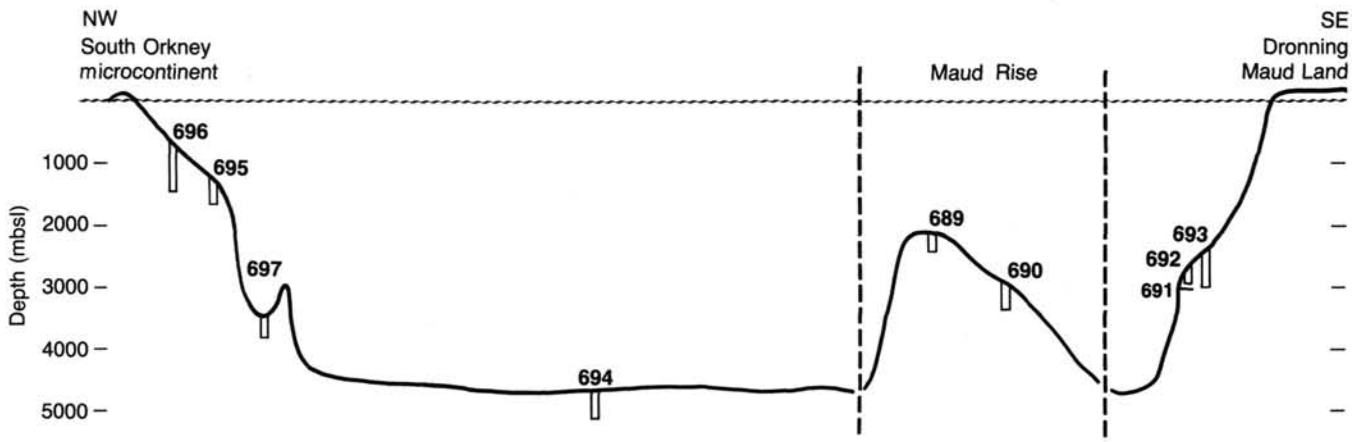

Figure 2. Schematic northwest-southeast transect across the Weddell Sea showing the relative position and depth distribution of Leg 113 sites. The location of Maud Rise has been projected to the west (see Fig. 1). mbsl = meters below sea level.

al., 1984; Murphy and Kennett, 1986). Such conclusions are based upon isotopically derived bottom-water temperatures cooler than those of the present oceans, although there is little sedimentary evidence to support the existence of large accumulations of Antarctic ice during the Paleogene (Kennett, Houtz, et al., 1975; Hayes, Frakes, et al., 1975). These general scenarios were disputed by Matthews and Poore (1980) who interpreted the oxygen isotopic curves differently, suggesting that a major, permanent ice-sheet had formed on East Antarctica by at least the earliest Oligocene and probably earlier.

Despite these differences of opinion, there has been general agreement that an ice-sheet has continuously covered the East Antarctic continent since the middle Miocene. More recently however, the discovery of marine diatoms of possible Pliocene age in tills at high elevations on the Transantarctic Mountains (Harwood, 1986) led Webb et al. (1984) to infer extensive deglaciation of East Antarctica. They inferred that during much of the Pliocene extensive marine reentrants occurred deep into the East Antarctic craton in the Wilkes and Pensacola Basins. As yet, no evidence exists from the marine oxygen isotopic or ice-rafted detritus records to support this scenario of major late Neogene deglaciation of East Antarctica.

These debates have important implications with regard to our understanding of Cenozoic climatic evolution. Sea level has undergone major fluctuations during the entire Cenozoic (Vail et al., 1977; Pitman, 1978). It is not known when glacio-eustatic changes commenced during the Cenozoic to affect the record of marine transgressions and regressions. The interpretation of the

Table 1. Leg 113 site location and coring summary.

Hole	Date (1987)	Latitude	Longitude	Water depth (m)	Penetration (m)	No. of cores	Cored (m)	Recovered (m)	Recovery (%)
689A	Jan. 15–16	64°31.01′S	3°06.00′E	2080	11.8	1	9.5	9.4	98.4
689B	16–18	64°31.01′S	3°06.00′E	2080	297.3	33	297.3	229.4	77.2
689C	18	64°31.01′S	3°06.03′E	2080	27.6	3	27.6	20.5	74.4
689D	18–19	64°31.01′S	3°06.03′E	2080	133.8	12	115.7	116.0	100.0
690A	19–20	65°09.63′S	1°12.30′E	2914	9.9	1	7.7	9.9	128.0
690B	20–21	65°09.63′S	1°12.30′E	2914	213.4	25	213.4	214.6	100.5
690C	21–23	65°09.62′S	1°12.29′E	2914	321.2	24	200.6	185.6	88.3
691A	25–26	70°44.54′S	13°48.66′W	3035	0.1	1	0.1	0.1	100.0
691B	26	70°44.64′S	13°48.56′W	3038	1.7	1	0	0	0
691C	26	70°44.58′S	13°48.68′W	3025	12.7	1	0	0	0
692A	26	70°43.45′S	13°49.21′W	2880	6.7	1	6.7	0.7	10.0
692B	26–30	70°43.43′S	13°49.20′W	2875	97.9	13	97.9	29.3	30.0
693A	Jan. 30–Feb. 5	70°49.89′S	14°34.41′W	2359	483.9	51	483.9	213.5	44.1
693B	Feb. 5–6	70°49.89′S	14°34.46′W	2359	403.1	19	167.4	92.2	55.1
694A	9–10	66°50.83′S	33°26.79′W	4653	9.8	1	9.8	9.8	100.0
694B	10–14	66°50.84′S	33°26.83′W	4653	179.2	24	179.2	67.1	37.4
694C	14–18	66°50.82′S	33°26.76′W	4653	391.3	23	212.1	71.7	33.8
695A	20–23	62°23.48′S	43°27.10′W	1305	345.1	42	341.1	254.4	73.7
696A	23–24	61°50.95′S	42°55.98′W	650	103.0	12	106.0	58.3	55.0
696B	Feb. 24–Mar. 2	61°50.96′S	42°56.00′W	650	645.6	62	569.0	156.7	27.5
697A	Mar. 3–4	61°48.63′S	40°17.27′W	3481	20.9	3	28.1	26.6	94.7
697B	4–7	61°48.63′S	40°17.75′W	3483	322.9	32	304.9	188.3	61.7

[a] Depth = bottom felt (m, drill pipe from the dual elevator stool)—11.1 m.

Table 2. Leg numbers and sites drilled near Antarctica during the Deep Sea Drilling Project.

Leg no.	Date	Site	Latitude	Longitude	Water depth (m)	Penetration (m)	Recovery (m)	Oldest sediment
28	12/72	265	53°32.45′S	109°56.74′E	3582	462.0	108.0	Pliocene
28	1/73	266	56°24.13′S	110°06.70′E	4173	384.0	145.2	Miocene
28	1/73	267	59°15.74′S	104°29.30′E	4564	219.5	25.9	Oligocene
28	1/73	267A	59°15.74′S	104°29.30′E	4564	70.5	11.6	Miocene
28	1/73	267B	59°14.55′S	104°29.94′E	4539	323.0	53.5	Eocene
28	1/73	268	63°56.99′S	105°09.34′E	3544	474.5	65.6	Oligocene
28	1/73	269	61°40.57′S	140°04.21′E	4285	397.5	38.8	Miocene
28	1/73	269A	61°40.57′S	140°04.21′E	4285	958.0	55.4	Miocene
28	2/73	270	77°26.48′S	178°30.19′W	634	422.5	236.7	Oligocene
28	2/73	271	76°43.27′S	175°02.86′W	554	265.0	15.3	Pliocene
28	2/73	272	77°07.62′S	176°45.61′W	629	433.0	162.0	Miocene
28	2/73	273	74°32.29′S	174°37.57′E	495	76.0	27.9	Miocene
28	2/73	273A	74°32.29′S	174°37.57′E	495	346.5	55.5	Miocene
28	2/73	274	68°59.81′S	173°25.64′E	3326	421.0	279.1	Oligocene
29	3/73	275	50°26.34′S	176°18.99′E	2800	63.0	17.5	Cretaceous
29	3/73	276	50°48.11′S	176°48.40′E	4671	23.0	1.0	Paleogene
29	3/73	277	52°13.43′S	166°11.48′E	1214	472.5	258.5	Paleocene
29	3/73	278	56°33.42′S	160°04.29′E	3675	438.5	277.8	Oligocene
29	3/73	278A	56°33.42′S	160°04.29′E	3675	44.0	7.5	Oligocene
29	3/73	279	51°20.14′S	162°38.10′E	3341	1.0	0.6	Miocene
29	3/73	279A	51°20.14′S	162°38.10′E	3341	202.0	110.0	Miocene
29	3/73	280	48°57.44′S	147°14.08′E	4176	10.0	5.5	Miocene
29	3/73	280A	48°57.44′S	147°14.08′E	4176	524.0	97.2	Eocene
29	4/73	281	47°59.84′S	147°45.85′E	1591	169.0	105.6	Eocene
29	4/73	281A	47°59.84′S	147°45.85′E	1591	45.5	7.1	Miocene
35	3/74	322	60°01.45′S	79°25.49′W	5026	544.0	34.2	Oligocene
35	3/74	323	63°40.84′S	97°59.69′W	4993	731.0	76.7	Cretaceous
35	3/74	324	69°03.21′S	98°47.20′W	4449	218.0	48.1	Pliocene
35	3/74	325	65°02.79′S	73°40.40′W	3745	718.0	34.4	Oligocene
36	4/74	326	56°35.00′S	65°18.20′W	3812	9.5	0.5	Pleistocene
36	4/74	327	50°52.28′S	46°47.02′W	2400	5.5	5.5	Pleistocene
36	4/74	327A	50°52.28′S	46°47.02′W	2400	469.5	128.1	Neocomian
36	4/74	328	49°48.67′S	36°39.53′W	5103	397.0	62.1	Campanian
36	4/74	328A	49°48.67′S	36°39.53′W	5103	17.0	7.4	Pleistocene
36	4/74	328B	49°48.67′S	36°39.53′W	5103	471.0	63.0	Turonian
36	5/74	329	50°39.31′S	46°05.73′W	1519	464.5	215.1	Paleocene
36	5/74	330	50°55.19′S	46°53.00′W	2626	575.5	85.5	Precambrian
36	5/74	330A	50°55.19′S	46°53.00′W	2626	53.0	4.0	Eocene
71	1/80	511	51°00.28′S	46°58.30′W	2589	632.0	385.62	Oxfordian
71	1/80	512	49°52.19′S	40°50.71′W	1846	78.0	68.0	Eocene
71	1/80	512A	49°52.19′S	40°50.71′W	1846	90.0	7.8	Eocene

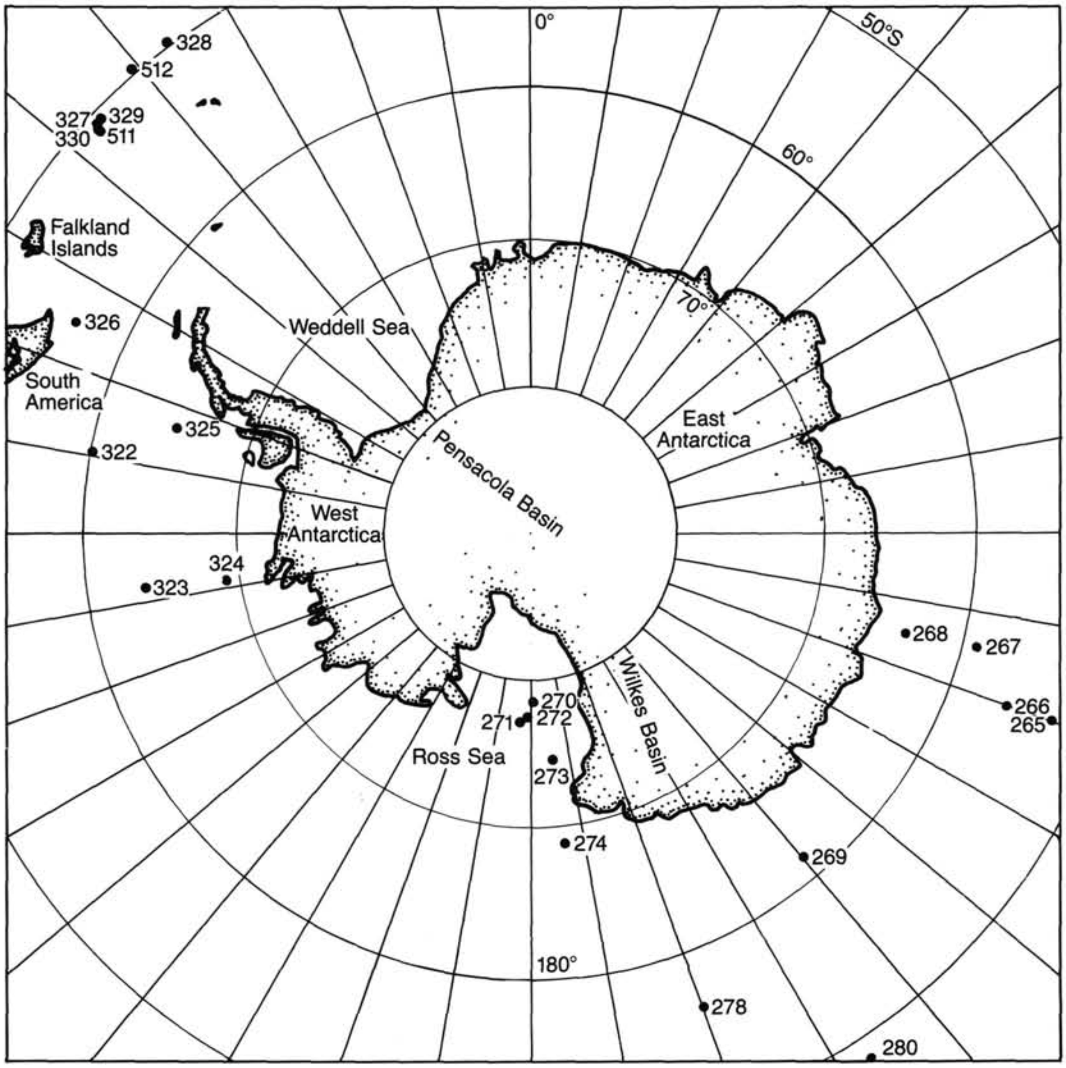

Figure 3. Location of Antarctic sites drilled by the Deep Sea Drilling Project.

oxygen isotopic record for paleotemperature data is based on assumptions about the volume of major ice accumulations on the polar continents at times in the past. It is not clear, however, when such accumulations of ice began to affect the oxygen isotopic record.

PRESENT-DAY ENVIRONMENTAL SETTING

The Antarctic and Southern Ocean area is presently distinguished by a number of well-known environmental and biotic characteristics that include:

1. Major ice-sheets on both East and West Antarctica;
2. Major ice shelves;
3. Extensive seasonal sea-ice development;
4. A continent essentially lacking vegetation;
5. The Antarctic Circumpolar Current system, the primary mixing arena between present-day oceans, affecting chemical budgets in each ocean and biogeographic patterns;
6. A major locus of formation of the world's abyssal and deep waters resulting from sea-ice formation—a critical component of the world's oceans thermohaline circulation;
7. A steep surface-water temperature gradient between polar and tropical latitudes;
8. A Polar Front to Antarctic Divergence, a major site of oceanic upwelling and principal site of siliceous biogenic productivity and sedimentation, which sharply separates dominantly siliceous and calcareous biogenic sedimentation;
9. A relatively shallow calcium carbonate compensation depth (CCD) in areas immediately adjacent to Antarctica;
10. Distinctive Antarctic, Subantarctic, and cool temperate water masses;
11. Iceberg sediment rafting to northern Subantarctic waters;
12. Cold-water faunas and floras;
13. Distinctive planktonic assemblages in Antarctic, Subantarctic, and temperate water masses and circumpolar biogeographic provinciality;
14. Low diversity of calcareous planktonic microfossil assemblages with calcareous nannoplankton essentially absent in Antarctic water masses; and
15. Strong endemism in Antarctic radiolarians and diatoms.

Each of these characteristics of the present-day Antarctic region has not been permanent throughout the Cenozoic, but is the result of continuing dynamic evolution of the high-latitude environmental and biotic regime (Kennett, 1977; 1978). The previous drilling results in the Southern Ocean, based upon the analyses of the 28 sites distributed throughout Antarctic and Subantarctic areas (e.g., Hayes, Frakes, et al., 1975; Kennett, Houtz, et al., 1975; Craddock and Hollister, 1976; Barker, Dalziel, et al., 1977 for example), suggest that none of the listed characteristics, so fundamental to the present-day global environment, are older than the Oligocene. The pre-Oligocene oceanographic and terrestrial regime of the Antarctic is unfamiliar; with relatively warm high-latitude surface waters, a more gentle and continuous meridional temperature gradient, warmer thermospheric deep-sea circulation, less continental glaciation lacking ice-sheets, continental vegetation, warmer marine assemblages with higher diversity of calcareous forms, and other distinctly different characteristics. Understanding the interrelations between the variables, and their broader global significance, was one of the primary objectives of Leg 113.

SUMMARY OF MAJOR RESULTS

During Leg 113 we investigated the climatic, glacial, and oceanographic history and biotic evolution of the Weddell Sea region, Antarctica, at nine sites (Figs. 1, 2, and 4; Table 1) representing a wide range of sedimentary environments. These included open-ocean pelagic biogenic sediments at Maud Rise (Sites 689 and 690), hemipelagic and terrigenous sediments on or close to the continental margins of both East and West Antarctica (Sites 691–693 and 695–697) and a deep-sea turbiditic to hemipelagic sequence in the Weddell abyssal plain (Site 694).

Sediments from these sites (Fig. 4) provide a rich data base for evaluation of the environmental history of Antarctica and the adjacent ocean from the Early Cretaceous through the Pleistocene. The sequences were dated aboard ship using integrated bio- and magnetostratigraphy. Calcareous microfossil biostratigraphy was primarily employed for dating sediments of Cretaceous and Paleogene age; siliceous microfossils were used for the Neogene. We studied general sediment facies (including pelagic calcareous and siliceous biogenic sediments, ice-rafted detritus, and clay mineralogy); sedimentation rates; the abundance, preservation, and diversity of several planktonic microfossil groups and benthic foraminifers, palynomorphs, and neritic and fresh-water diatoms; physical properties; and paleomagnetics. The organic and inorganic chemistry have also provided information about environments of deposition. The results of these

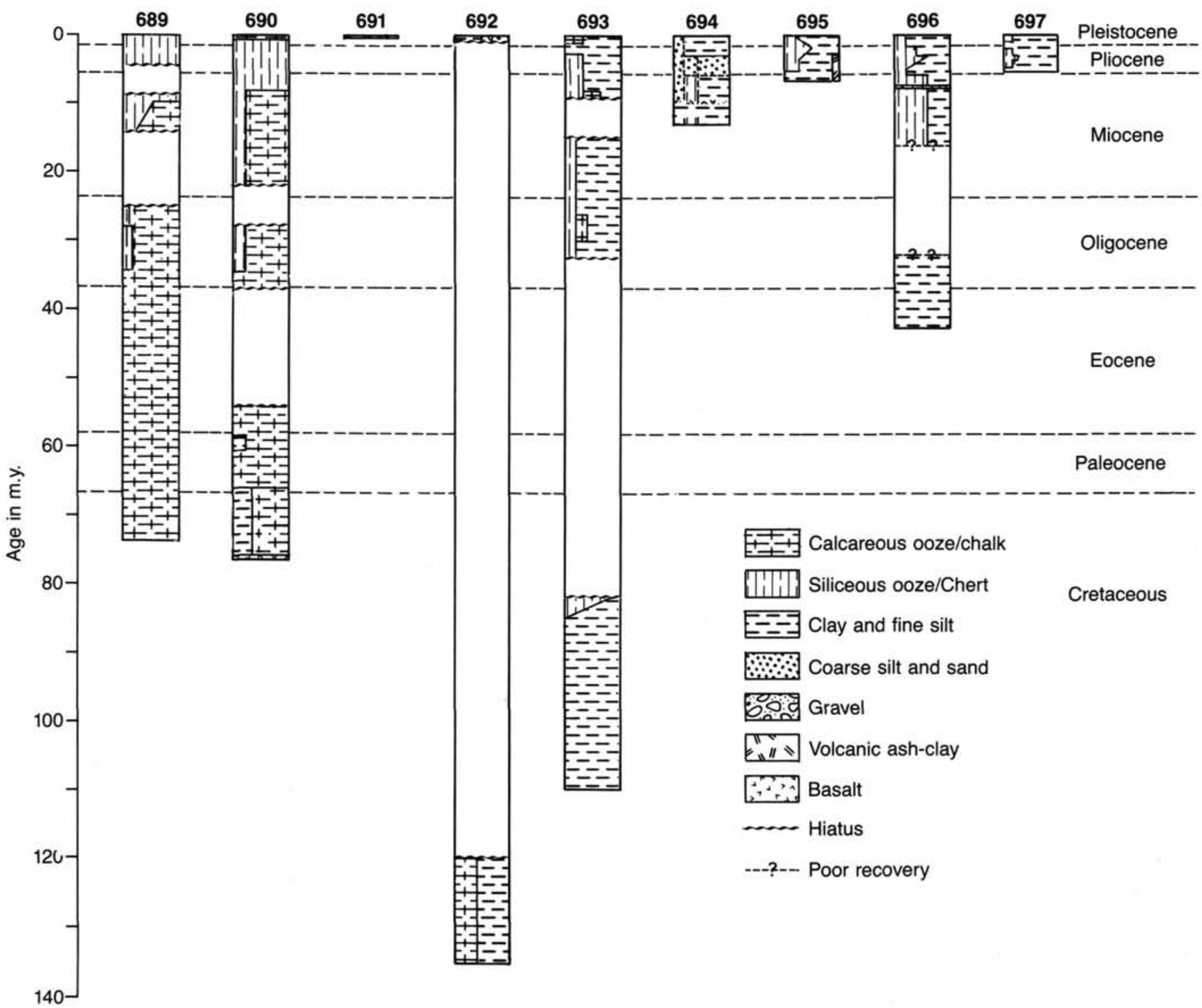

Figure 4. Simplified stratigraphy from ODP Sites 689–697.

shipboard studies are given in the site chapters (this volume). Additional parameters were studied after the cruise, including oxygen, carbon, and strontium isotopes. The results of these and other studies will be included in the Proceedings of the Ocean Drilling Program, Scientific Results, Volume 113.

During Leg 113 we concluded that there was a sequential cooling of Antarctica and surrounding oceans during the Cenozoic that profoundly affected the sediments and the biota. Glacial development probably began during the late Paleogene in East Antarctica and during the Neogene in West Antarctica.

Organic-rich Lower and middle Cretaceous sediments indicate deposition under anoxic or weakly oxic conditions. These sediments may have been deposited at times of fluctuating surface-water salinities in environments that were similar to those on the Falkland Plateau at that time. By the late Campanian, open-ocean pelagic biogenic sediments were being deposited on Maud Rise.

On Maud Rise, a siliceous biogenic facies progressively replaced a carbonate facies during the Cenozoic, with initial siliceous sedimentation in the latest Eocene–earliest Oligocene leading to an almost completely siliceous biofacies by the late Miocene.

Diverse calcareous planktonic and benthic microfossil assemblages reflect the relative warmth of the surface- and bottom-water masses adjacent to Antarctica during the Late Cretaceous to the Eocene. During the Late Cretaceous to Paleocene, East Antarctica was a rich source of fine-grained terrigenous sediment. The clay is dominated by smectite. Kaolinite (associated with chlorite) appeared during the Paleocene, suggesting the climates were warm and that humidity increased during the Paleocene on East Antarctica to the south, which was probably totally unglaciated. Rich reddish colors of some Paleocene clays may indicate laterite formation.

Eocene clays are dominated by smectite both on Maud Rise and the South Orkney microcontinent, indicating the continuation of warm climatic conditions and a predominance of chemical over physical weathering processes. An Eocene palynoflora at Site 696 indicates the presence of temperate beech forests with an undergrowth of ferns on the northern Antarctic Peninsula. A coeval moderately diverse, abundant assemblage of neritic calcareous benthic foraminifers reflects the presence of waters that were not undersaturated in $CaCO_3$ and were probably warm.

During the early Oligocene, diversity began to decrease in planktonic microfossil assemblages as the Antarctic ocean cooled. Nearly all sediments of Oligocene and younger age from both East and West Antarctic margin sites contain only agglutinated benthic foraminiferal assemblages and virtually no calcareous planktonic microfossils. All younger assemblages are dominated by, or are exclusively made up of, agglutinated forms. The change in the benthic foraminiferal assemblages probably reflects the production of highly undersaturated and probably cool water even at the very shallow water depths of Site 696 (present depth 650 m). It is likely that the change in bottom-water characteristics over the margin occurs at the Eocene/Oligocene boundary, but our stratigraphic resolution is not adequate to determine this.

On Maud Rise, illite first appeared as a major clay in the early Oligocene, while smectite decreased, suggesting that hydrolysis strongly decreased on East Antarctica due to major cooling and/or increased aridity. This supports previous isotopic and biogeographic data for global cooling at the beginning of the Oligocene, widely considered to be related to Antarctic glacial development. Smectite continued its dominance until the middle Miocene, however, at Site 696, which is more influenced by West Antarctic climate, suggesting that warm conditions prevailed longer there than in East Antarctica.

Oligocene sequences drilled during Leg 113 on the Antarctic continental margin (Sites 692, 693, and 696) are not of high enough quality to provide details about glacial development during the Oligocene, particularly to determine if any minor ice-sheets accumulated on the continent at this time. We found no evidence for major ice build-up during the Oligocene. Upper Oligocene sediments on Maud Rise, rather remote from the continent, contain rare ice-rafted detritus (Site 689 only). The presence of ice-rafted detritus at Site 693, also, indicates the existence of some ice on East Antarctica during the late early Oligocene, the earliest detected during Leg 113. Reworked benthic diatoms of Oligocene to early Miocene age at Site 693 reveal that part of the continental shelf was shallow and at least partly ice free. Rare, reworked freshwater diatoms of possible Oligocene or early Miocene age, at Site 696, indicate the presence of freshwater lakes on the northern Antarctic Peninsula.

Near the beginning of the Neogene, a pronounced increase occurred in the siliceous relative to the calcareous biofacies on Maud Rise. This coincides with the development of the siliceous biofacies observed in other sectors of Antarctica and is perhaps related to the northward expansion of cool surface waters.

A further step in Antarctic evolution occurred during the middle Miocene as suggested by data from Sites 693 and 696. The middle Miocene is missing in a hiatus at Site 693, and a noticeable increase occurs in the abundance of ice-rafted detritus in the lower upper Miocene sediments immediately above. A significant cooling probably also occurred during the middle Miocene in West Antarctica; smectite is replaced by illite and chlorite at Site 696. This indicates that strong physical weathering, inferred to have resulted from climatic cooling, developed much later than in East Antarctica. The continued absence of ice-rafted detritus at Site 696, however, through the middle and early late Miocene suggests that major glaciation might not yet have begun on West Antarctica.

Leg 113 data suggest that the East Antarctic ice-sheet, once formed, did not undergo significant deglaciation, even during the early Pliocene for which we have expanded sequences. The data also indicate that the West Antarctic ice-sheet probably did not begin to form until the late Miocene. This tentative conclusion is based on sedimentary evidence from Site 694, the distribution of reworked neritic diatoms, and changes in clay minerals. Site 696 exhibits an increase in hemipelagic sedimentation, an abundant ice-rafted component, and further increases in concentration of illite and chlorite during the late Miocene. The West Antarctic ice-sheet may have been unstable during the early stages of its development, as indicated by the variability of sediments at Site 694. The highest rates of turbidite deposition at this site (180 m/m.y. or greater) may have occurred within an interval of only 0.5 m.y. or less during the early Gilbert Chron (C3R4) before 4.8 Ma, in the latest Miocene to earliest Pliocene. These high sedimentation rates possibly resulted from an expanding, yet unstable, West Antarctic ice-sheet and occurred during an interval marked elsewhere by major cooling, increased and highly variable $\delta^{18}O$ values, and low sea level.

In the earliest Pliocene at about 4.8 Ma, turbidite deposition virtually ceased at Site 694, suggesting that the West Antarctic ice-sheet may have become a permanent and stable feature. At Site 696, diatomaceous sediments were largely replaced by diatom-bearing silty and clayey muds as a result of development of this ice-sheet on the South Orkney microcontinent and northern Antarctic Peninsula. Sedimentation rates increased markedly in the early Pliocene at most Leg 113 sites due to increased terrigenous sedimentation and biosiliceous productivity.

This was followed throughout the region by markedly lower sedimentation rates and diatom abundances and poor microfossil preservation during the last 2.4 m.y. This seems to represent another step in glacial intensification and an expansion of sea-ice, and perhaps is related to global climatic cooling documented at this time.

The Pleistocene is marked by low sedimentation rates and intervals of abundant *Neogloboquadrina pachyderma* and a calcareous benthic foraminiferal assemblage at nearly all Weddell Sea sites shallower than about 3400 m. The continued high rates of hemipelagic deposition at Site 697 in Jane Basin during the Pleistocene reflect the continued transport of sediment down the West Antarctic margin and perhaps a stronger northward flow of Antarctic Bottom Water.

CONCLUSION

Leg 113 is the first of four legs during the initial 5 years of ODP to directly address questions about Antarctic glacial history. The other three legs will drill sites in the southern South Atlantic Ocean (Leg 114), the Kerguelen Plateau (Legs 119 and 120), and Prydz Bay (Leg 119). The combined results from these four cruises should provide an excellent data base to evaluate and understand the late Mesozoic and Cenozoic climatic evolution of our planet.

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