Passage around 20 million years ago. The significance of a transantarctic passage would diminish with growth of ice sheets and grounded ice shelves in the Ross Sea, Marie Byrd Land, and the Weddell Sea late in the Cenozoic (*14*).

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15. We thank B. Ward, H. T. Brady, W. M. Showers, J. L. Ardai, Jr., and J. W. Clough for assistance in the collection of cores at site J9. Gravity cores and representative samples from the sphincter cores have been deposited with the Antarctic Core Storage Facility, Florida State University, Tallahassee. Smear slide information summarized here was prepared by J. Hattner, F. A. Kaharoeddin, S. Graves, and E. Goldstein under the supervision of D. Cassidy. P. J Barrett provided helpful comments during the writing of the manuscript. I. E. Odom provided x-ray diffraction analyses of fine fractions. We thank R. Anderhalt for the grain size analyses and discussion; L. DeLaca, S. Lipps, and J. Ronan for their tolerance and for discussions; and W. E. Reed for reviewing the manuscript. Our participation in the project was supported by the NSF Office of Polar Programs, under grants DP76-20657 and DP76-17231.

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Ross Sea Region in the Middle Miocene: A Glimpse into the Past

Abstract. *Fossil diatoms and pollen from sea-floor sediments beneath the Ross Ice Shelf indicate that a permanent ice cover was not present in the Ross Sea and that vegetation including angiosperms, gymnosperms, and ferns existed on at least some parts of the largely glaciated Antarctic mainland in the late middle Miocene.*

In December 1977, gravity cores (< 102 cm) were obtained in the sea floor beneath the Ross Ice Shelf at 82°22.5′S and 168°37.5′W (site J9 in Fig. 1). The sediment is a compact marine mud with a high percentage of glacial flour and some small pebble erratics. The sediment-water interface is characterized by a thin desert-type lag of pebbles in the upper few centimeters. The sea floor has probably been winnowed by bottom currents concentrating erratics typical of the basement system and the sedimentary Beacon Supergroup of the Transantarctic Mountains. Recovered pebbles include granite, schist, phyllite, and coal; rounded sand grains (typical of the Beacon Sandstones) are common (*1*).

Ten spaced samples from these cores have been examined for diatoms. Fossil planktonic diatoms are abundant and well preserved except in the uppermost 14 cm, where all but the most resistant species are fragmented. The diatom flora consists of approximately 50 species dominated by *Melosira sulcata* (Ehrenberg) Kutzing, *Liradiscus* sp., *Rhizosolenia hebetata forma hiemalis* Grun, *Stephanopyxis* spp., and a new species of *Nitzschia*. Critical zone taxa are not common, but they include *Denticula lauta* Bailey, *Denticula hustedtii* Simonsen and Kanaya, and *Nitzschia maleinterpretaria* Schrader. The flora is similar to that described by McCollum (*2*) for the late middle Miocene from Deep Sea Drilling Project (DSDP) cores drilled in the Southern Ocean and the Ross Sea region, and it corresponds to his *Denticula lauta-Denticula hustedtii* partial range zone flora. Although these two species range into the early part of the late Miocene, the presence of *N. maleinterpretaria* and *Mesocena pappi* (common middle-Miocene silicoflagellate) supports a late middle-Miocene date (~ 14 million years). Late Miocene diatoms occurring in Southern Ocean DSDP cores and in Dry Valley Drilling Project (DVDP) hole II drilled in the Miocene-Pliocene fjord of Taylor Valley (77°38′S, 162°51′E), which contains magnetic anomaly 5 and perhaps magnetic anomaly 7, are absent in cores from beneath the Ross Ice Shelf (*3*).

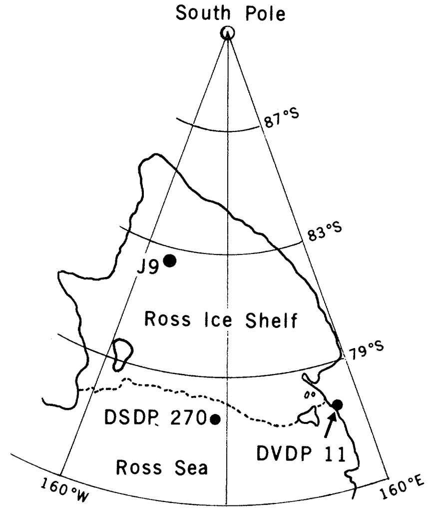

Fig. 1. Important drilling sites in the Ross Sea region; *DSDP*, Deep Sea Drilling Project; *DVDP*, Dry Valley Drilling Project.

Table 1. Spores and pollen recovered from J9 and their botanical affinities.

Fossil name	Affinity
Spores	
Cyathea paleospora Martin	*Cyathea* sp.
Laevigatosporites ovatus Wilson & Webster	Unknown
Lycopodiumsporites sp.	*Lycopodium*
Stereisporites antiquasporites (Wilson & Webster) Dettman	*Sphagnum*
Gymnosperms	
Podocarpidites sp.	*Podocarpus*
Phyllocladidites mawsonii Cookson	*Dacrydium franklinii*
Microcachryidites antarcticus Cookson	*Microcachrys*
Angiosperms	
Nothofagidites asperus (Cookson) Stover & Evans	*Nothofagus* (*menziesii* type)
Nothofagidites emarcidus (Cookson) Harris	*Nothofagus* (*brassii* type)
Nothofagidites heterus (Cookson) Stover & Evans	*Nothofagus* (*brassii* type)
Nothofagidites vansteenisii (Cookson) Stover & Evans	*Nothofagus* (*brassii* type)
Nothofagidites flemingii (Couper) Potonié	*Nothofagus* (*fusca* type)
Beaupreaidites cf. *B. elegansiformis* Cookson	Proteaceae cf. *Beauprea*
Proteacidites ivanhoensis Martin	Proteaceae cf. *Helicia-Orites*
Proteacidites pseudomoides Stover	cf. Proteaceae
Proteacidites spp.	cf. Proteaceae
Unidentified tricolpate	
Unidentified tricolporate	

Fossil diatoms indicate that an active photic zone was present in the Ross Sea region during the late middle Miocene. Erratics suggest floating ice, but it is not possible to prove the existence of winter pack ice.

One sample, taken 92 cm below the sediment layer of the sea bottom and examined for pollen, contained a fairly low pollen content in a moderate state of preservation (Table 1). *Nothofagidites* spp. far outnumber all the others. This assemblage is similar to a late Oligocene assemblage from the Ross Sea (*4*), except that it is less diverse.

Assemblages of this general character are found in southeastern Australia from the middle Eocene to the middle Miocene, and the poor representation of *Proteacidites* spp. favor the latter part of this time range. Barrett and Kemp (*4*) found that *Proteacidites* spp. were well represented in their late Oligocene assemblage, so that poorer representation in J9 is consistent with a later age. The decreased diversity would be consistent with the hypothesis that conditions for plant growth were harsher with a larger ice cap in the middle Miocene than with a lesser ice cap in the late Oligocene (*5*), provided that the decreased diversity not be the result of comparing the one sample here with a composite assemblage of more than one sample (probably four) examined by Barrett and Kemp. The most notable difference between the late Oligocene assemblage and J9 is the lack of *Myrtaceidites* spp. (Myrtaceae) in the latter.

These spores and pollen may have been derived from vegetation nearby or they may have been recycled in the glacial flour or erratics. Modern sediments on the Antarctic continental shelf contain recycled spores and pollen ranging in age from Palaeozoic to early Tertiary (*4*). Nonetheless, no forms have been obviously recycled or are of a different age in the J9 sample.

The assemblage suggests vegetation of low diversity, probably restricted to the most favorable habitats by the coast and between the glaciers. It appears to have changed little since the Eocene, and taxa that had evolved in the Eocene or later (for example, Gramineae and Compositae) were probably unable to become established under the harsh conditions there. The reduction in diversity probably continued until all vegetation was eliminated from Antarctica.

The pollen assemblage in these sediment cores is wholly consistent with the middle Miocene age of the diatoms. At that time the Ross Sea, with a productive photic zone, was not covered with permanent ice but was receiving a steady input of glacial flour and erratics from the continent. Continental vegetation would have been similar to that of Australia, New Zealand, and South America but with a much reduced diversity.

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Ross Ice Shelf Sea Temperatures

Abstract. *Two temperature profiles recorded by a sensitive bathythermograph at the Ross Ice Shelf Project site (82°22.5′S, 168°37.5′W) are presented. From the shape of the profiles it is concluded that an inflow of water at intermediate depths provides a source of heat to drive a regime in which ice is melted from the interface at a depth of 360 meters. Melting maintains the temperature of a thick layer under the ice at about −2.14°C, close to the ambient freezing temperature. A very well mixed layer about 35 meters thick was found at the seabed.*

The hydrology of the water under the Ross Ice Shelf has long been a matter for conjecture. In December 1977 a hole was drilled through the ice at 82°22.5′S, 168°37.5′W as part of the Ross Ice Shelf Project (RISP). This is a report on some measurements obtained with a bathythermograph designed to have high sensitivity. The sensitivity was gained at the expense of response time, which was about 4 seconds.

An instrument was assembled to record temperature (20 bits) and pressure (12 bits) internally once per second on a digital tape cassette. The temperature transducer was a quartz crystal oscillator system made with components from a previously described instrument (*1*). Pressures were detected by an oscillating taut-wire transducer. The least significant bit corresponded to a change of 4×10^{-5} °C for the temperature data channel and 0.4 decibar (equivalent to about 0.4 m of water depth) for the pressure channel. It was intended to lower the instrument at a steady rate and to use smoothing during processing to specify the spacing between sampling depths, thus overcoming the limited pressure resolution.

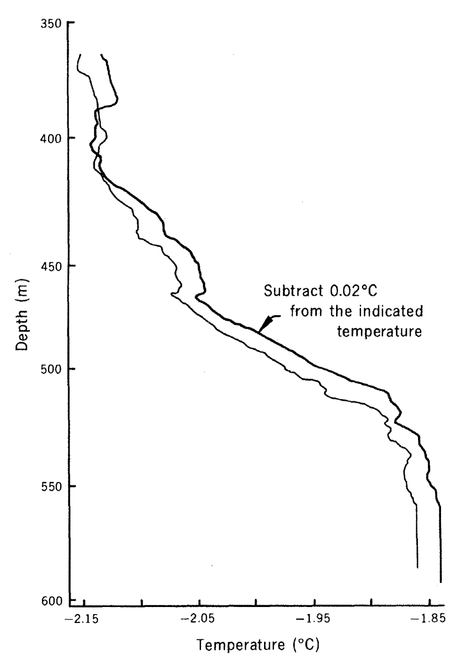

Fig. 1. Temperature-depth profiles at 82°22.5′S, 168°37.5′W.

Data are shown in Fig. 1. The first profile was obtained at approximately 0400 hours Greenwich mean time, 24 December 1977, and the second, which has been offset to the right in Fig. 1 by 0.02°C, was obtained 8 hours later. The ice thickness was 420 m, the ice-water interface was at 360 m, and the sea depth was 597 m.

The first profile was obtained by lowering the instrument at about 0.08 m/sec, the minimum rate possible with the winch. Because the rate was not quite regular, the second profile was obtained by raising the instrument at about the same rate. To penetrate the slush ice at the water surface in the hole, the instrument was used with an additional lead weight suspended below the temperature sensor level. This would not affect the profiles very much because of the low travel rates. The raw data from