Miocene Glaciomarine Sediments from Beneath the Southern Ross Ice Shelf, Antarctica

Abstract. *Glaciomarine sediments with middle Miocene microfaunal assemblages are exposed at the sea floor below the southern Ross Ice Shelf. Plio-Pleistocene sediments are not present. Post-Miocene glacial sediments may have been deposited but removed by relatively recent ice shelf grounding. A meager Recent microfauna is present in some core tops.*

Bottom sediments were collected from beneath the Ross Ice Shelf at Ross Ice Shelf Project (RISP) site J9 (82°22′S, 168°38′W) during the 1977–1978 austral summer. This site is located some 400 km from the open waters of the Ross Sea and hence is the first truly sub-ice marine environment sampled directly. Here the ice shelf is 420 m thick, the water column is 237 m, and the mud line is 597 m below present sea level (*1*). The site lies over the center of a broad glacial channel, which was probably eroded during a relatively recent grounding of the Ross Ice Shelf. To the southeast the sea floor rises gently to 400 m and falls to 700 m in a northeasterly direction (*2*).

An access hole 28 cm in smallest diameter was burned through the ice shelf with a Browning flame jet, and the sampling gear was lowered 657 m to the sea floor by winch. Two bottom sampling devices were utilized. A cylindrical sphincter corer with an internal diameter of 22.5 cm was used in obtaining about 1/3 m^2 of sea floor in ten samples cored to a mean depth of 10 cm. Deeper bottom penetration was achieved with a conventional gravity corer 4 cm in internal diameter; 11 such cores were collected, the longest being 102 cm (*3*). As the ice shelf moved northeastward at about 1 m per day, bottom sediments were obtained along a track about 12 m in length. Some cores were taken only 20 cm apart, and in some instances puncture holes in the sea floor were clearly visible on the underwater television monitoring system (*4*). At the time of collection the upper few centimeters were sloppy to soft, whereas the lower sediments were observed to be plastic but firm. Sediments of similar age at Deep Sea Drilling Project (DSDP) sites 270 to 273 in the Ross Sea are semilithified (*5*).

The short sedimentary succession obtained may be subdivided into two distinct lithologic units: an upper, light olive gray diatomaceous sandy mud less than 16 cm thick, and a lower olive gray diatomaceous sandy mud at least 86 cm thick (Fig. 1). A thin (< 1 cm) brown-orange, iron-rich unit occurs at the base of the upper unit and provides a sharp color boundary between the two units. Granite, gneiss, schist, and sedimentary pebble, granule, and coarse sand-size clasts, all angular or subrounded, are distributed throughout the cored succession. The igneous and metamorphic material in the sediment is similar to crystalline basement rock types known from the Transantarctic Mountains and parts of Marie Byrd Land. No evidence of Paleozoic to Mesozoic Beacon Supergroup sediments or Jurassic Ferrar Dolerites was observed. This would support a provenance for Miocene J9 sediments in Marie Byrd Land, rather than the Transantarctic Mountains.

Both gravity and sphincter cores were examined by x-radiography. Gravity cores were x-rayed while still in their liners; the larger near-surface sphincter cores were pared with an electroosmotic knife into 24 2-cm-thick vertical slices. The radiographs revealed that the sediment has the texture of a diamicton. They also showed that the color change between the two units probably corresponds to a chemical discontinuity (iron-stained laminae) rather than an actual grain size difference.

Angular to subrounded sediment fragments (up to 5.2 cm in longest dimension) are ubiquitous in all cores. They are soft to moderately indurated and are white to buff in color. Dried fragments display varying degrees of buoyancy when placed in fresh or salt water. At least some are diatomaceous ooze with subordinate amounts of clay. They are not evenly distributed throughout the core length; more than 71 percent occur in the top 3.5 cm of the succession. Furthermore, the fragments from near the sediment-water interface are larger in mean size (0.81 cm) than those found deeper in the succession (0.56 cm). Underwater television camera studies at the sampling site showed numerous indurated sediment blocks at the sediment-water interface. These blocks were also visible at the top of the sphincter core samples investigated by radiography.

Grain size distributions were determined for six subsamples from a vertical sediment slice from sphincter core 6-2 and from gravity core 11. From the sphincter core, samples of 10 to 12 g were removed from discrete 2-cm-thick intervals down to a core depth of 12 cm. Gravity core subsamples were taken from just above (2 to 4 cm in depth) and below (7 to 9 cm in depth) the sharp color boundary that separates the two units in the succession. The cumulative grain size distributions for the sphincter core and the frequency distributions for the coarse fraction of the two gravity core units are shown in Fig. 2.

In the six sphincter core samples the percentages of gravel, sand, silt, and clay were (mean ± standard deviation): 17.5 ± 12.3, 20.2 ± 2.3, 16.9 ± 5.4, and 45.5 ± 9.3, respectively. In the gravity core, the frequency distributions were nearly identical for both units, suggesting that the two are part of the same depositional phase.

Standard smear slide preparations of matrix material were examined at numerous levels in all gravity cores. Petrographic observations revealed no compositional or proportional differences between the upper light olive gray and lower olive gray units. Examination of 30 samples revealed the following compositional ranges: clay, 49 to 76 percent; quartz and feldspar, 10 to 25 percent;

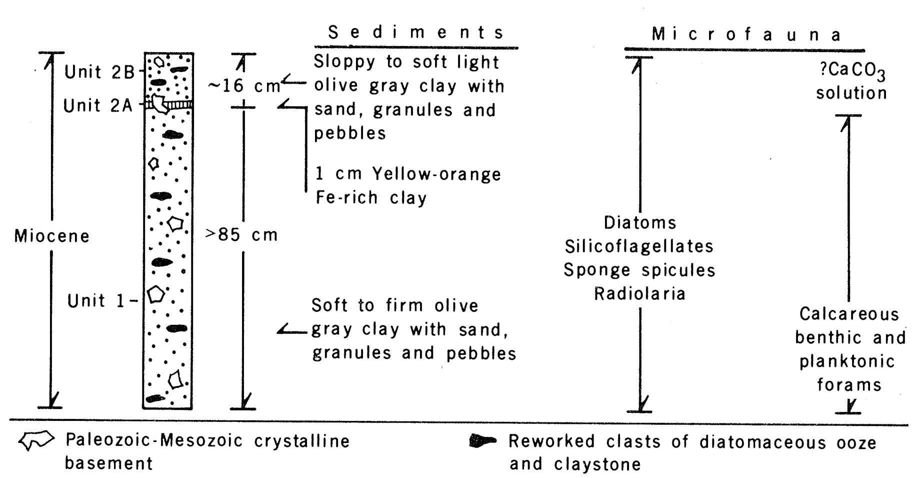

Fig. 1. Schematic representation of sedimentary succession obtained at RISP site J9.

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and diatoms, 6 to 23 percent. Components making up 3 percent or less include volcanic glass, zeolites, sponge spicules, silicoflagellates, radiolaria, and unspecified carbonate. A high proportion of the sand and silt size quartz grains display a chipped and fracture-faceted morphology, generally indicative of glacial origins.

X-ray analysis of the < 2 μm fraction of samples from upper and lower units of gravity core 11 indicated the presence of quartz, feldspar, illite, chlorite, and smectite (montmorillonite). The only discernible difference was that the upper light olive gray sandy mud contains minor chlorite and vermiculite. Kaolinite was not detected in either unit. Cook *et al.* (*6*) reported quartz, feldspar, mica, chlorite, and montmorillonite, but not vermiculite, in Miocene sediments at DSDP sites 270 to 273.

Abundant siliceous (principally diatoms and to a lesser extent silicoflagellates) and calcareous (principally benthic foraminifera) microfossils are distributed through the lower olive gray diamicton, whereas only siliceous taxa are present in the upper 10 to 20 cm (*6*). Diatoms suggest a middle Miocene age (*7*). Benthic foraminifera in the lower unit indicate an early to middle Miocene age (*3*). No bioturbation features were recognized in any of the core materials. There is no microfaunal evidence supporting the presence of either Pliocene or Pleistocene sediments.

Two contrasting interpretations of the sedimentary succession are advanced on the basis of micropaleontological and sedimentary evidence. One possibility is that a thin (< 20 cm thick) post–middle Miocene diamicton (containing recycled middle Miocene sediments) is separated by a disconformity from a much thicker middle Miocene diamicton. A second explanation is that the entire section is middle Miocene, that the light olive gray diamicton of the upper 10 to 20 cm is an in situ alteration product of the underlying sediment, and that small amounts of middle and post–middle Miocene fine material have been added to it by relatively recent bottom current processes. Sedimentary observations support the second suggestion. The composition of the sand, granule, and pebble clasts is identical in both units, suggesting a common provenance. Large clasts straddle the boundary between the two units, indicating that the boundary is not a disconformity. The absence of calcareous Miocene foraminifera and the presence of vermiculite in the upper unit indicate solution and alteration. The highly fragmented nature of the diatoms in the upper unit can be explained by a combination of chemical alteration in near-surface sediments and recycling of fine fractions. The grain size distribution for the sand-pebble grade range (4 to −3 on the phi grade scale) is nearly identical in both units. Both show dominance in the fine to medium sand, and both exhibit almost identical percentages of coarse sand, granules, and pebbles. Analyses of particle sizes in Cenozoic diamictons in the Ross Sea (DSDP site 270) show that diamictons 1 or 2 m apart are closely related in size-frequency distribution (*8*). Conversely, diamictons separated by tens or hundreds of meters or by appreciable intervals of time show strongly contrasting frequency distribution. We conclude that this is a middle Miocene succession in which there has been near-surface alteration and solution and some subsequent transport of the silt and clay fraction. Physical movement and resorting of semibuoyant middle Miocene diatomaceous ooze and granule- and pebble-size clasts also seem to have occurred in near-surface sediments.

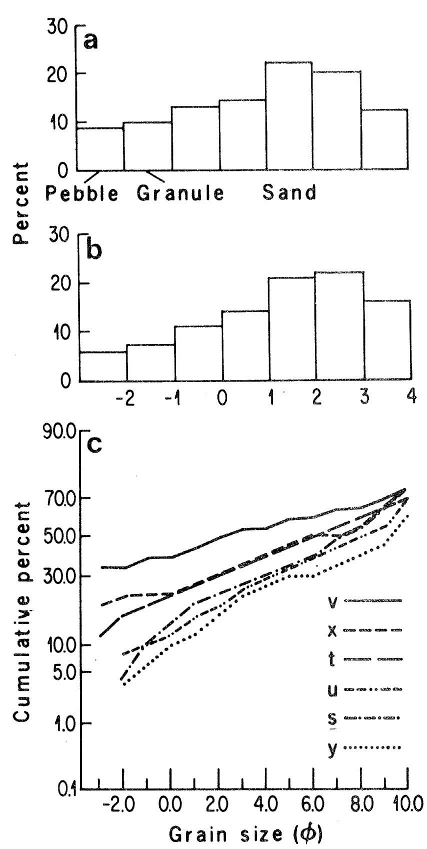

Fig. 2. Cumulative grain size distributions for RISP sphincter sample 6-2 and frequency distributions for two successional units in RISP gravity core 11. (a and b) Frequency distributions (histograms) for the coarse fraction of the gravity core. (a) Grain size analysis of a subsample from within the upper gravity core unit. (b) Grain size analysis of a subsample from the top of the lower gravity core unit. Note that the frequency distribution for sand and gravel clasts is nearly identical in both units. The upper unit, which is 5 cm thick in this core, and the lower unit are separated by a 1-cm-thick brown-orange, iron-rich layer. (c) Lines *s* and *y* are grain size analyses of subsamples drawn at 2-cm intervals from the sediment-water interface down to a depth of 12 cm in the sphincter core. The grain size analyses are typical of a poorly sorted glacial deposit.

The entire diamicton has a glacial origin with sedimentation occurring below floating ice. The very abundant and diverse photic zone plankton assemblages in these sediments indicate that this ice was neither thick nor permanent (*7*). Brady (*7*) suggests open marine water conditions over the site, at least during the summer months. The benthic microfauna of the lower unit suggests a water depth no shallower than 400 to 500 m.

Glacial conditions certainly existed in the montane areas peripheral to the Cenozoic Ross embayment or transantarctic basin. LeMasurier and Rex (*9*) demonstrated ice sheet conditions in Marie Byrd Land from at least the middle Oligocene. In the Taylor Valley region of the Transantarctic Mountains the glacial record has not been documented earlier than the late Miocene (*10, 11*), although deeper stratigraphic drilling will almost certainly provide this evidence. Late Oligocene to Recent glaciomarine environments have been conclusively demonstrated at site 270 in the southern Ross Sea (*5*).

Recent geological and geophysical investigations suggest that during the Cenozoic and perhaps in the latest Mesozoic, parts of the Ross Sea margin of East Antarctica and parts of Marie Byrd Land were uplifted, whereas large areas between subsided to form the Ross Sea embayment, the Byrd Basin, the Bentley Trench, and other depressions (*5, 9, 12, 13*). In the western Ross Sea area this major tectonic episode has been referred to as the Victoria orogeny. The results from RISP site J9 are of significance since they originate from a site that lay near the center of this depression and far to the south of related Miocene sedimentary successions drilled in the southern and western Ross Sea. An important question at this time centers on the full geographic extent of this major Cenozoic basin. There is the possibility that a basin or plexus of basins extends across Antarctica.

A Cenozoic transantarctic marine passage that provided a link between the ancestral Pacific and Atlantic Oceans would play a major role in southern high-latitude biological dispersal. Part of the ancestral circum-Antarctic current might be expected to follow this route, particularly before the opening of the Drake

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*).

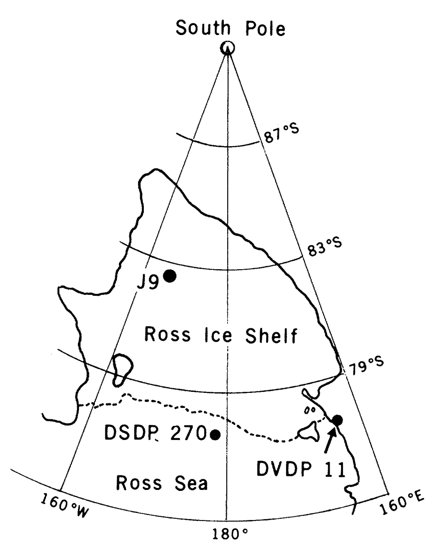

Fig. 1. Important drilling sites in the Ross Sea region; *DSDP*, Deep Sea Drilling Project; *DVDP*, Dry Valley Drilling Project.

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	

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