turn implies that evaporation-precipitation may have been supplanted by ocean currents as the dominant process of heat transport across latitudes. This might imply oceans with overall cooler temperatures, but temperature contrasts within the oceans might have been less than those observed today. Newell (*8*) has suggested a similar possible state to explain the effects of glacial-interglacial intervals.

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Antarctic Soft-Bottom Benthos in Oligotrophic and Eutrophic Environments

Abstract. *The benthos of the east and west sides of McMurdo Sound, Antarctica, is characterized by dramatically different infaunal assemblages. The eutrophic East Sound has higher infaunal densities than almost any other benthic assemblage in the world. In contrast, the oligotrophic West Sound, bathed by currents from beneath the Ross Ice Shelf, has patterns of mobile epifauna and low infauna density similar to bathyl deep-sea communities.*

The benthos of the Antarctic continental shelf has been isolated from other continental shelf faunas by cold temperatures and by the circumpolar current systems for approximately 40 million years (*1*). With the exception of the embayments of the Weddell and Ross seas, the continental shelves are relatively narrow, and most of the obligatory shallow-water benthic species apparently became extinct during the massive Pliocene and Pleistocene glaciations (*2, 3*). Subsequent to these extinctions the temperature and current barriers prevented reintroduction of temperate shallow-water species. It was probably the extremely constant physical regime of the Antarctic Sea, closely approximating deep-sea conditions (*3, 4, 5*), that made possible a colonization of the shallow water by largely endemic benthic species with deep-sea affinities or large vertical depth ranges (*2, 6*), which escaped extinction from ice-age glaciation. There have been alternating expansions and retreats of large continental ice shelves. Denton *et al.* (*1*) estimate that there were at least four major advances of the Ross Ice Shelf in the last 1.2 million years, the last major expansion occurring over 47,000 years ago. The Ross Ice Shelf floated free of the ground at least 5,000 years ago, and there is little geological evidence of important changes since then (*7*). The Ross Ice Shelf thus has been in existence for a considerable period; knowledge of the organization of the benthic communities in its vicinity can give valuable insights into important natural geological and biological processes.

This is a preliminary report of our benthic research in the vicinity of the northwestern edge of the Ross Ice Shelf in McMurdo Sound. Specifically we contrast the extremely dense infaunal populations of the East Sound at Cape Armitage, Ross Island, in an area of seasonally high primary productivity, with very low-denisty infaunal patterns along a series of oligotrophic West Sound sites that seem to be bathed by a unidirectional current from under the Ross Ice Shelf (Fig. 1). We compare these data and those collected from a depth of 500 m in the Ross Sea with recorded density data from bathyl and high-productivity temperate systems.

The West Sound area is dominated by the Ross Ice Shelf, always a conspicuous feature of the McMurdo Sound region. Historically, the general location of the Ross Ice Shelf in the McMurdo Sound region has been remarkably constant since James Ross visited the area in 1841, and the early maps of the Scott and Shackleton expeditions show that only minor changes in the Ross Ice Shelf west of the Dailey Islands have occurred through 1970. Between 1970 and 1973 a large part of the shelf broke out from the Dailey Islands southwest to Garwood Valley (*8*). We examined aerial photographs taken of the McMurdo Sound region from 1956 through 1970. They show a predictable pattern of breakout of annual ice from October through January along Ross Island and the Hut Point Peninsula. This pattern is similar to that observed by the early British expeditions. The photographs documented very few West Sound breakouts by February, when aerial surveys stopped for the winter. Our diving observations from Garwood Valley northward reveal 2- to 3-year ice in floes of different ages, which suggests occasional breakups after February with different amounts of ice remaining in the area. Thus, our Garwood Valley site was under the Ross Ice Shelf at least through 1970, and the other West Sound sites, under annual ice during most of the year, have been under glacier or shelf ice during recent geologic time (*1, 7, 8*).

The very different shallow (< 100 m) current regimes also provide contrast between the East and West Sound sites. There are rather strong, sometimes oscillating, tidal currents along the Hut Point Peninsula of Ross Island, which have a marked southerly trend (*4, 9*). We corroborated the southerly trend of the shallow current on a dive at White Island, 22 km south of the northern edge of the Ross Ice Shelf. Here we observed signs of a plankton bloom impossible in the aphotic conditions existing under the shelf at White Island. In addition, the common epifaunal species seen at White Island were plankton feeders also common at Cape Armitage (*10*), such as the sponges *Polymastia invaginata* and *Latrunculia apicalis*, the alcyonarian *Alcyonium paessleri*, the actinarians *Artemidactis victrix, Isotealia antarctica*, and *Urticinopsis antarctica*, the stoloniferan *Clavularia frankliniana*, the hydroids *Lampra* spp. and *Halecium arboreum*, and the large bivalve *Laturnula elliptica*.

The abundant presence of these large plankton feeders strongly suggests planktonic advection via a southerly current. In striking contrast, these large shallow-water filter feeders are relatively rare at the West Sound sites. Current measurements along the west edge of the ice shelf document a slow but constant northerly current along the West Sound (*4, 9, 11*). Littlepage (*4*) noticed that a station relatively close to shore had a predominantly northeasterly current in December. This and slightly lower oxygen values at White Island led him to hypothesize a northern current from under the shelf. Our observations of phytoplankton, zooplankton, and abundant large filter feeders tend to negate this hypothesis; we suggest that the respiration of these organisms causes the oxygen depletion Littlepage noticed in this area.

The striking differences between Ross Island and the west side of the Sound with regard to the ice cover and current regimes result in different amounts of primary productivity reaching the benthos. The much longer and more predictable seasonal period of ice-free time along the East Sound (Fig. 1) allows much greater in situ benthic productivity than can occur on the ice-covered benthos of the West Sound. Indeed, even when the West Sound ice does break out, it does so late in the season just before the sun sets for the winter, so that very little light reaches the benthos. Bunt (*12*) calculates that most of the planktonic productivity reaching the Hut Point Peninsula area is advected from the north, but such planktonic blooms and advected organic material may rarely reach the West Sound sites, which have weak but constant northerly currents. The East Sound phytoplankton bloom noticed by all workers since Hodgson (*4, 13*) does not occur at New Harbor, in the West Sound, where we had 60- to 100-m visibility through the entire 1975–76 and 1976–77 summer seasons. Certainly, some material may be advected from the productive East Sound, but if so, it does not have much effect. Our preliminary measures of benthic chlorophyll a standing-crop data collected in austral midsummer corroborate these patterns, as we measured a mean of 515 mg of chlorophyll a per square meter with a mean ratio of chlorophyll a to pheophytin of 5.38 ($N = 4$) at 40 m at East Sound Hut Point and a mean of 21.0 mg of chlorophyll a per square meter with a mean ratio of chlorophyll a to pheophytin of 0.87 ($N = 4$) at 40 m at West Sound New Harbor (*14*).

The McMurdo Sound infaunal samples were taken in replicates by divers who used standard handheld corers, which sample 0.018 m^2 to a depth of 18 cm. The deep Ross Sea samples were taken from the U.S. Coast Guard icebreaker *Burton Island* by a 0.1 m^2 Smith-McIntyre grab. Immediately after being collected, the sediment samples were screened through 2.0-, 1.0-, 0.50-, and 0.25-mm mesh. Meiofauna taxa and the 0.25-mm sample fractions are not considered here; very few macrofauna taxa pass through the 0.5-mm mesh. Epifauna densities were obtained photographically from 10- to 50-m permanent transects done in triplicates at various depths at each site.

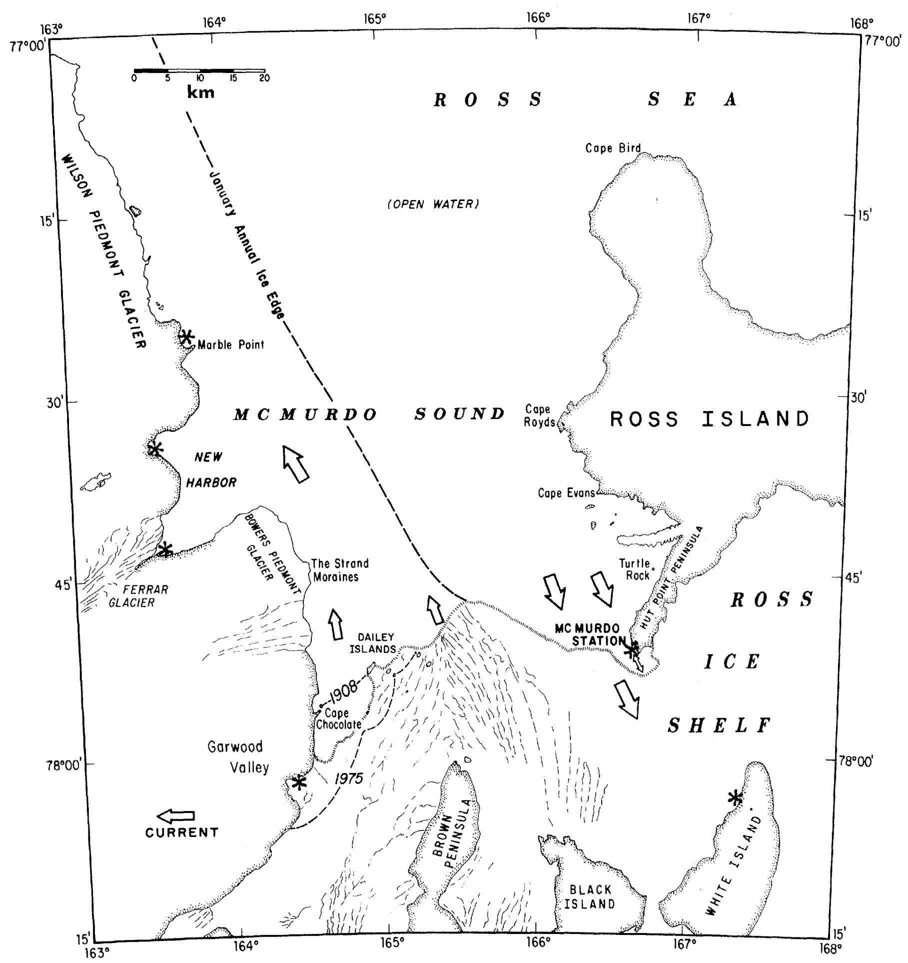

Fig. 1. McMurdo Sound, Antarctica. Study sites are marked with asterisks. The East Sound sites are Cape Armitage (McMurdo Station) and White Island; the West Sound sites are Garwood Valley, Ferrar Glacier, New Harbor, and Marble Point. The Ross Ice Shelf has receded on the east since 1908. The dotted 1975 line shows a breakout, which occurred between 1970 and 1973. The January breakout of annual ice along the East Sound has been remarkably constant since 1956. The arrows indicate the direction of the prevailing shallow-water currents.

The densities of the infauna from various sites (Fig. 1) on either side of McMurdo Sound are summarized in Table 1. The most obvious trend is the difference of an order of magnitude between the West and the East Sound sites. The most dramatic differences between the West Sound and the East Sound are seen in the densities of Crustacea. The mollusks are poorly represented in the Antarctic, and almost all the bivalves recorded in Table 1 are recently settled and metamorphosed pectens, *Adamussium colbecki*. Another trend is the density increase along the south-to-north gradient of the West Sound. The deep shelf Ross Sea site closely compares with the West Sound Garwood Valley site, which was well under the permanent ice shelf through at least 1970. These data support our contention that the West Sound area is bathed by an oligotrophic current from beneath the Ross Ice Shelf and suggest a hypothesis of a northern increase in productivity and a concurrent increase in benthic invertebrates. The productivity increase probably results from both advected material and increased photosynthesis; the latter, in turn, probably results from a northerly thinning of sea ice and earlier ice breakout, which would allow more light into the system.

The dramatic differences between the oligotrophic West Sound and the eutrophic East Sound are of further comparative interest because the southerly

West Sound standing crops compare with deep shelf and bathyl habitats (Table 1). This similarity is enhanced by the striking visual parallels between the appearance of those sites and photographs of the bathyl deep sea (*15*). In both cases the soft-bottom relief is dominated by biological structure such as the tubes of arenaceous foraminifera and metazoans, fecal pellets, and depressions left by irregular echinoids and ophiuroids. Although no echinoderms were sampled in the cores (Table 1), they are a conspicuous component of the West Sound benthos, and the parallels between the bathyl deep sea and the 30- to 45-m benthos at New Harbor are reinforced by similarities of the ophiuroids. The deep-sea *Ophiomusium lymani* occurs at densities of 1.7 to 2.4 per square meter at approximately 1800 m on the Gay Head–Bermuda transect (*15*); at New Harbor *Ophionotus victoriae*, which is remarkably similar in size and morphology to *O. lymani*, occurs at a relatively constant density, 1.7 per square meter. Like *O. lymani* at high densities, *O. victoriae* appears to have an even distribution pattern at New Harbor.

The macrofauna were identified and enumerated from cores taken from each side of the Sound. There are 37 species and 2828 individuals in a core taken in 20 m of water from Cape Armitage and 50 species and 176 individuals in a core taken in 40 m of water from New Harbor. Thus numerical species richness is higher along the West Sound. Furthermore, the New Harbor numerical richness compares to the bivalve-polychaete diversity observed by Sanders and Hessler (*16*) for deep slope and shallow tropical environments. If, in keeping with Sanders and Hessler, one considers only the bivalve-polychaete fraction of our samples, the similarities remain unchanged.

The nearby East Sound macro-infaunal densities contrast with those of the West Sound sites, as the East Sound benthos has infaunal densities almost double some of the highest published densities (Table 1). This is particularly remarkable because the East Sound site receives only a summer pulse of primary productivity (*4, 5, 13*), whereas at least the shallow temperate site in California (Table 1) has high year-round productivity (*17*). This comparison is especially interesting because these estuarine communities are usually characterized by high standing crop and the numerical dominance of one or two species; but in addition to a high standing crop, the East Sound benthos has many species which occur in great abundance.

The Antarctic shares more potentially

Table 1. Number of organisms, in different microfaunal taxa per square meter. Data are from the Ross Sea and McMurdo Sound, Antarctica; the Gay Head–Bermuda transect (*22*); and two temperate embayments, one in California (*23*), the other in Massachusetts (*24*). The category "Other Vermes" refers to all other soft-bodied worms such as Nemertea, *Edwardsia*, Phoronidae, and Oligochaeta. Miscellaneous categories include porifera, bryozoa, ascidea, and coelenterates. Depths at which samples were collected are in parentheses.

Taxon	Gay Head–Bermuda transect		McMurdo Sound								Temperate embayments	
				West Sound				East Sound				
	D#1 (487 m)	G#1 (2086 m)	Ross Sea (74°58'S, 170°48'E) (500 m)	Garwood Valley (30 m)	Ferrar Glacier (30 m)	New Harbor (30 to 40 m)	Marble Point (30 m)	McMurdo Station Jetty (20 m)	Cape Armitage soft bottom (20 m)	Cape Armitage sponge mat (30 m)	Elkhorn Slough, California (5 m)	Barnstable Harbor, Massachusetts (intertidal)
Ostracods	0	0	70	18	110	132	6,586	948	55	4,354	21	0
Cumacea	7	6	40	55	367	885	2,150	31,548	12,950	937	41	0
Tanidacea	154	58	25	73	239	282	579	19,932	53,512	69,596	0	150
Isopoda	63	67	43	18	110	132	1,185	23,392	19,399	33,285	0	150
Amphipoda	507	123	56	184	294	207	3,059	11,728	9,975	8,432	14	43,350
Other Arthropoda	4	0	16	55	37	55	55	0	496	6,282	48	0
Total Arthropoda	735	254	250	403	1,157	1,693	13,614	87,548	96,387	122,886	124	43,650
Total Mollusca	2,388	175	560	128	184	1,102	184	136	770	7,660	6,407	27,600
Polychaeta	4,956	1,418	1,070	1,598	3,896	4,718	27,142	11,276	52,134	9,500	9,506	9,050
Other Vermes	149	261	70	55	147	2,060	3,913	19,752	6,281	5,735	68,672	150
Total Vermes	5,105	1,679	1,140	1,653	4,043	6,778	31,055	31,028	58,415	15,235	78,178	9,200
Echinodermata	32	31	8	0	0	0	0	0	0	0	0	0
Miscellaneous	393	15	2	0	643	463	441	0	0	0	0	0
Total	8,653	2,154	1,960	2,184	6,027	10,036	45,294	118,712	155,572	145,781	84,709	80,450
Number of samples	1	1	6	3	3	5	2	10	2	2	8	?

important characteristics with the deep sea than does any other shallow-water environment. The most striking are the cold temperature, constant physical environment, low terrestrial sedimentation, and high taxonomic affinities (*2, 6*). Many Antarctic species also have depth distributions into at least bathyl environments (*18*). An obvious dissimilarity between the Antarctic benthos and the deep sea is the seasonal productivity of the Antarctic. This seasonal plankton bloom is much reduced along the West Sound, where the relatively high diversity, low standing crop, and the parallel epifaunal patterns make these sites similar to bathyl deep-sea communities. To be sure, there are differences between the West Sound and the abyssal deep sea, which has much lower densities; furthermore, in the bathyl deep-sea habitats the individual animals are smaller than those from the West Sound. But relative to any other shallow area in the world, the West Sound is remarkably similar to deep-sea habitats. Animals have been collected previously from under the shelf ice at McMurdo Sound (*19*), and four fish were trapped below the shelf ice in King George Sound (*20*); but this report presents what we believe to be the first quantitative description of benthic life likely to be found under at least the northern part of the Ross Ice Shelf. In addition, the deep-sea parallels are exciting because the West Sound sites are within diving depths, making possible important natural history observations regarding such questions as microhabitat differentiation, dispersal patterns, various developmental and growth rates, megafaunal behavior patterns, and so forth. Most important, it allows experimental tests of alternate hypotheses (*21*) regarding mechanisms organizing the deep-sea and other benthic communities.

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Netschaëvo: A New Class of Chondritic Meteorite

Abstract. *The ratios of refractory elements to silicon and of zinc to silicon indicate that the silicate portion of the Netschaëvo meteorite is an ordinary chondrite. The scarcity of chondrules, the large dimensions (about 100 micrometers) of plagioclase grains, and the low indium content (0.09 nanogram per gram) indicate that Netschaëvo belongs to petrologic type 6. On a diagram of reduced iron versus oxidized iron, Netschaëvo lies along an extrapolation of the LL-L-H ordinary chondrite fractionation trend. The abundances of siderophile elements (nickel, germanium, iridium, and gold) are about 1.6 to 2.0 times greater than in H-group chondrites, and siderophile/nickel ratios are, with one exception, those expected from LL-L-H trends. This evidence indicates that Netschaëvo is an extremely iron-rich member of the ordinary chondrite sequence, and that plausible models to account for the ordinary chondrite sequence must produce materials having iron/silicon ratios 25 percent greater than those in CI carbonaceous chondrites. The existence of Netschaëvo emphasizes that the chondritic meteorites in terrestrial collections are a biased and incomplete selection of primitive solar system materials.*

The Netschaëvo meteorite consists of angular silicate masses set in a metallic matrix; Buchwald (*1*) estimated the amount of silicate material to be 25 percent by volume. Figure 1 shows a silicate-rich portion of the meteorite.

Olsen and Jarosewich (*2*) investigated the major-element mineralogy, petrography, and composition of the Netschaëvo silicate materials, confirmed the presence of chondrules (*3*), and concluded that the properties of this meteorite were intermediate between those of E-group (enstatite) and H-group ordinary chondrites. We find that their evidence shows that the relationship to the ordinary chondrites is much closer than to the E-group chondrites; they in fact noted that Netschaëvo's high total Fe/Si ratio makes it "more H" than the H (for high-Fe) chondrites.

In an attempt to clarify the relationship of the silicate portion of Netschaëvo to the ordinary chondrites, we determined by radiochemical and instrumental neutron activation analysis (RNAA and INAA) a total of 26 elements in duplicate samples (Table 1). We also report data on the metallic matrix "iron meteorite" portion of Netschaëvo including Ni determined by atomic absorption spectrometry; Ga, Ge, and Ir by RNAA;