to the east and 10° of latitude farther to the south. This latter finding probably can be linked to the prevailing wave pattern of atmospheric circulation and to the related position of the circumpolar discontinuity between polar easterlies and subpolar westerlies.

The figure suggests that the area in which annual temperature varies in the same rhythm is relatively small. This agrees with the results of an analysis of all temperature records available since 1957, which unfortunately do not include any coastal station between 170°E. and 70°W. Within this period, only 1960 shows all 16 stations south of 65° with below normal temperatures; in that year the temperature at Orcadas was above normal, and the duration of ice in Scotia Bay was only 75 days.

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Numerical calculation of ice deformation

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Computer programs are being developed for numerical calculation of deformation within glaciers and ice sheets. The finite element method is being used; this method has the advantage that a single program can handle problems involving complex boundary shapes, various assumptions concerning the form of the flow law, and spatial distribution of flow law parameters such as temperature. Also, such a program can be used by people who are not familiar with the details of numerical solution of partial differential equations.

Programs for two simplified types of flow geometry are being developed. One is applicable when the flow is basically rectilinear, as would be the case when longitudinal gradients of velocity and stress are negligible. This program is now operational and includes efficient routines for convenient input and graphical display of results. The second is applicable when the flow is planar and longitudinal gradients of velocity and stress are of major importance. Although the programs are functional, we are making improvements necessary for effective application to practical problems. Both programs are being made as system-independent as possible so that other glaciologists can use them on other computers with only minimal modifications. We are not attempting to develop a general program for fully three-dimensional flow, because the application of such a program to practical problems would require unreasonably large amounts of computer space and time.

The programs have not yet been applied to problems of specific interest in Antarctica, but once completed they can be used for detailed analysis of a variety of problems. Some examples are deformation at the margins of an ice sheet, at the grounding line between grounded ice sheet and floating ice shelf, or at a transition from slip to no-slip basal boundary conditions. The programs will make possible detailed and accurate calculation of effects from longitudinally or laterally varying bed topography. Calculation of deformation in ice shelves lying within complicated embayments represents another attractive potential application.

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Analysis of permafrost cores from antarctic dry valleys

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Multidisciplinary laboratory investigations of dry valley permafrost cores are being carried out at the Quaternary Research Center to help determine depositional environments and glacial history represented by the recovered sediments. The cores were collected during the Dry Valley Drilling Project. Primary emphasis has been placed on studying the long cores from lower Taylor Valley, where terrestrial and marine sediments appear interstratified. Principal studies concern micropaleontology, oxygen isotope analysis, sedimentology, and stratigraphy.

Hole 3, Ross Island (micropaleontology). H. Y. Ling examined 19 samples. Radiolarians were observed

only at depths of 249 to 279 and 339 to 350 meters. The occurrence of rare (Eocene) (?) Radiolaria in a sample at a depth of 198.42 meters can be interpreted only as due to reworking or contamination.

Holes 4 and 4A, Lake Vanda (micropaleontology). H. Y. Ling examined 13 samples at various depths from 70.25 meters to approximate core bottom. The examination failed to show Radiolaria or silicoflagellates.

Hole 8, New Harbor (micropaleontology). H. Y. Ling examined 24 samples. Radiolaria were noted at a depth of about 24 meters in unit 1 (medium to coarse sand and gravel) and between 54 and 132 meters in unit 2 (diamicton). The number of specimens so far recovered is too low to permit positive age identification of the sediments. A few Eocene and Miocene forms were observed, but are believed to be reworked from the surrounding source area.

Silicoflagellates were recovered, but only from a depth of about 24 meters in the uppermost part of unit 1.

Hole 8, New Harbor (oxygen isotopes). M. Stuiver and I. C. Yang performed these studies. The δ oxygen-18 ratios of the permafrost waters vary between 0 and -25 per mill with regard to SMOW (standard mean ocean water). The isotope ratios of the water in the upper 54 meters are close to values found for undiluted ocean waters (about 0 per mill). Evidently the sediments of this interval were deposited under fully marine conditions. Between depths of 54 and 85 meters, slightly less saline conditions are indicated, with freshwater dilution of about 15 percent. The diamicton between 55 and 82 meters was deposited in this type of lower salinity marine environment.

Between depths of 85 and 130 meters, the isotope ratios start approaching freshwater values, but mixing with some marine waters is probable, since present day δ oxygen-18 values of Ross Ice Shelf ice and Lake Vanda water are still lower. Perhaps this episode occurred when the Ross Ice Shelf was fully grounded, leading to reduced access of seawater to the New Harbor area.

For the lower portion of this core (130 to 155 meters) a low salinity environment (about 30 percent freshwater dilution) is indicated by the oxygen isotope ratios).

Hole 8, New Harbor (sedimentology and stratigraphy). S. C. Porter and J. Beget are making investigations directed mainly toward determining the origin of the diamicton units that comprise a substantial portion of the middle and lower part of the core. Although the diamictons are till-like in character, several very likely are of glacial-marine origin. Lithology of the sand fraction is being used to distinguish between sediments derived largely from Taylor Valley and those sediments having a source to the east in McMurdo Sound. Preliminary results indicate fluctuations of mineral and rock components consistent with changes in provenance between a Taylor Valley source and a Ross Sea source. Microfabric analyses are being made of the diamicton units to determine fabric strength, the assumption being that basal tills deposited by grounded ice are likely to display moderate to strong fabrics whereas glacial-marine drift is not likely to have a fabric. Fabrics are weak or absent in most diamicton units. But they are well developed between about 114 and 123 meters, suggesting grounded ice. Scanning electron microscope studies of surface textures and sand grains from the core are being used as a further aid in distinguishing grains from glacial, nonglacial, and mixed environments.

Hole 9, New Harbor (micropaleontology). H. Y. Ling examined three samples from depths of about 13, 21, and 29 meters. These examinations failed to show Radiolaria or silicoflagellates.

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Deposition and metamorphism of the Polarstar Formation (Permian), Ellsworth Mountains

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The Permian Polarstar Formation is the uppermost unit in a 13,000-meter sequence of carbonate rocks, conglomerates, sandstones, siltstones, shales, and argillites exposed in the Sentinel Range of the Ellsworth Mountains (Craddock, 1969). The strata range in age from upper Precambrian (?) to Permian; no definite unconformities are known. The 1,700-meter-thick Polarstar Formation is mainly siltstone to fine-grained sandstone interbedded with shale and silty argillite. The lower 150 meters consists of black, fissile shale to slate, and the upper 400 meters contains plant fossil beds and thin coal seams. Several thin, light-gray to light-yellow, soft clay beds are present in the upper half of the for-

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