Temperature Profiles Obtained from Boreholes on the Ice Shelf in the Vicinity of Sanae, western Dronning Maud Land

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The mean annual surface temperature for the region, determined by measurement of temperatures at depths of 10 m in boreholes at eight localities on the Fimbulisen, was found to be approximately −16°C at the coast, decreasing inland at a rate of −0,13°C / km for at least 30 km from the sea.

Temperature profiles obtained in valleys near the edge of the ice-shelf display a strong positive gradient and indicate a temperature of approximately −2° at sea-level. Below these valleys the firn is probably brine-soaked up to sea-level.

Die gemiddelde jaarlikse oppervlaktemperatuur vir die gebied is bepaal deur die temperatuur op dieptes van 10 m in boorgate op agt plekke op die Fimbulisen te meet. Hierdie temperatuur is ongeveer −16°C by die kus en neem na die binneland af teen 'n koers van −0,13°C / km oor minstens 30 km van die see af.

Die temperatuurprofiele ten opsigte van valleie na aan die rand van die ysbank vertoon 'n sterk positiewe gradiënt en dui op 'n temperatuur van ongeveer −2°C by seevlak. Onder hierdie valleie is die firn waarskynlik tot by seevlak met seewater deurweek.

Introduction

The South African Antarctic base, Sanae (70° 18′ S, 02° 22′ W), is situated on the Fimbul Ice Shelf approximately 15 km from the sea and 52 m above sea-level. After this study had been completed, Sanae base was moved to a new site, approximately 1 km further south (January 1971). The ice-shelf terminates in a number of buktas to the north and extends some 140 km inland. Although the ice-shelf is generally flat-lying, minor undulations occur and strike south-west, parallel to the coast. Two ice-rises resulting from local grounding (Fig. 1) occur 20 km west and 60 km south of the base respectively.

Temperatures vary from 0°C in the summer to −50°C in the winter. Prevailing winds blow from the south-east.

Instrumentation

A temperature-sensitive thermistor-probe was designed and built by the Electronic Instrumentation Division of the National Institute for Mathematical Sciences of the Council for Scientific and Industrial Research (CSIR). It was built at very short notice and the components used were those readily available rather than those best suited to the task. Its resistance could be measured with a Wheatstone bridge.

The probe, which utilized a Standard Telephones and Cables F 22 thermistor, was initially designed so that the thermistor was isolated from the rest of the probe. The idea was that temperatures could thus be read long before the whole probe unit had reached the ambient temperature. It was found, however, that only readings taken within three minutes of lowering the probe into a sub-zero environment represented true values. Thereafter the probe-point started dissipating heat from the rest of the probe, which took 35 minutes to reach the ambient temperature.

A new probe was designed by Mr E Bester (member of the 4th South African National Antarctic Expedition, 1963), based on the principle that the entire probe had to reach the ambient temperature before accurate measurement became possible. This probe was found to stabilize after three minutes, and all subsequent readings were therefore taken after a lapse of a few minutes.

Calibration of Thermistor-Probes

Two thermistor-probes, built to the new design, were calibrated during January 1964 against two lagged alcohol thermometers known to be accurate to 0,2°C. Calibration check-readings of the probes against one of the original thermometers were taken at various times during the year.

The mean deviation from the calibration curves (0,13°C and 0,14°C respectively) can be attributed to the reading inaccuracy of the lagged alcohol thermometers, the measuring bridge and thermistor-probes. However, it may be assumed that readings will normally not differ by more than 0,2°C from the correct value and that the accuracy aimed at was achieved.

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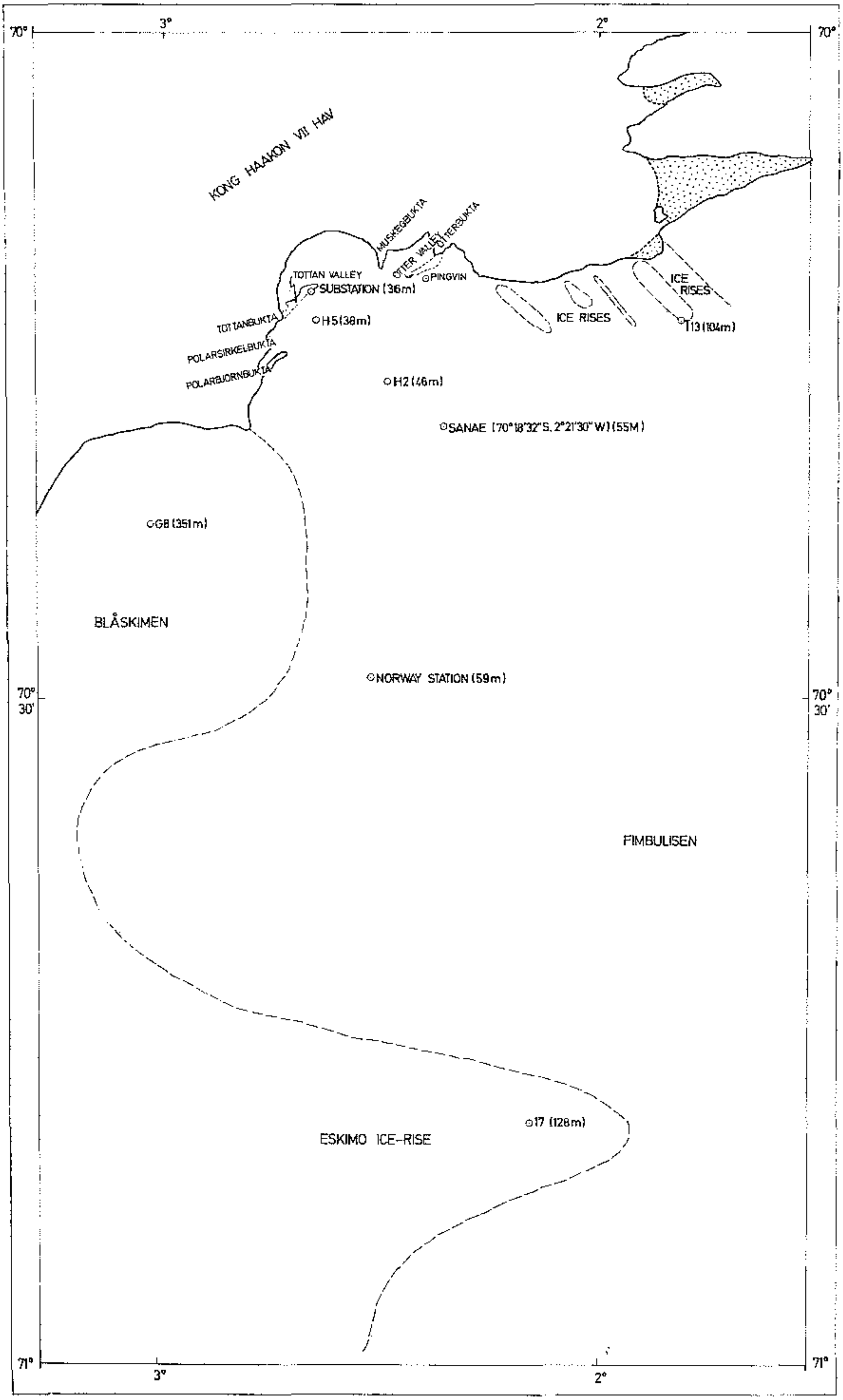

Fig. 1. Locality map showing sampling stations.

Temperature Profiles

It was assumed that air temperatures at any depth in a borehole, if given adequate time to stabilize, represent those of the adjacent wall. A stable condition is normally reached two hours after a borehole has been sealed (Fig. 2). In the majority of cases, however, boreholes were left closed for at least six hours prior to temperature measurements.

Temperature profiles (Figs. 3 and 4) were observed at eight localities on the ice-shelf (Fig. 1).

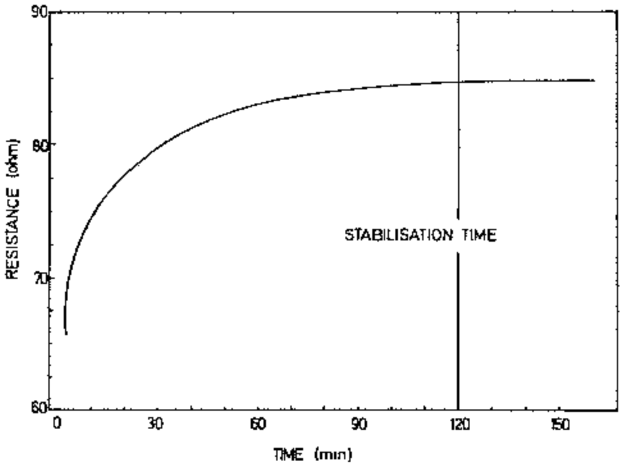

Fig. 2. Stabilization time for a 10 m borehole after it has been sealed.

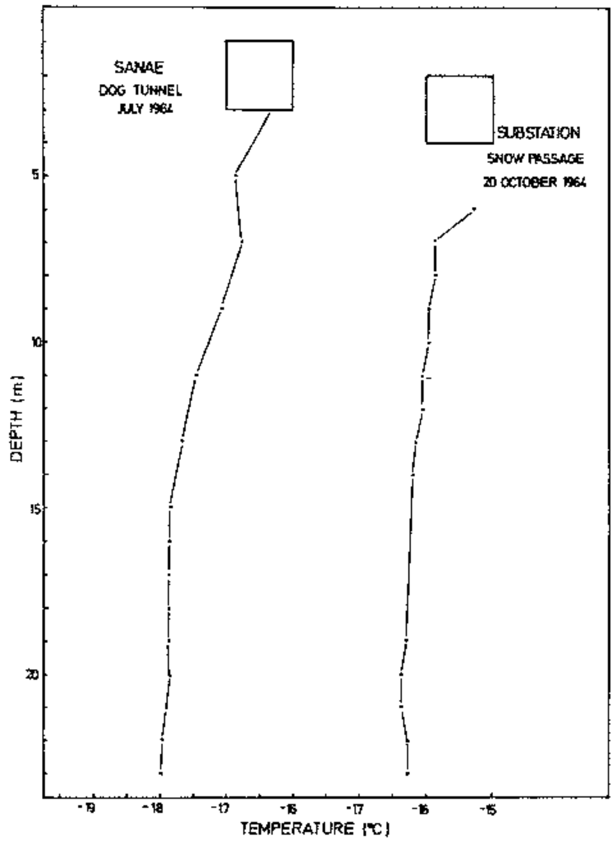

Fig. 3. 20 m temperature profiles at Sanae and at Substation.

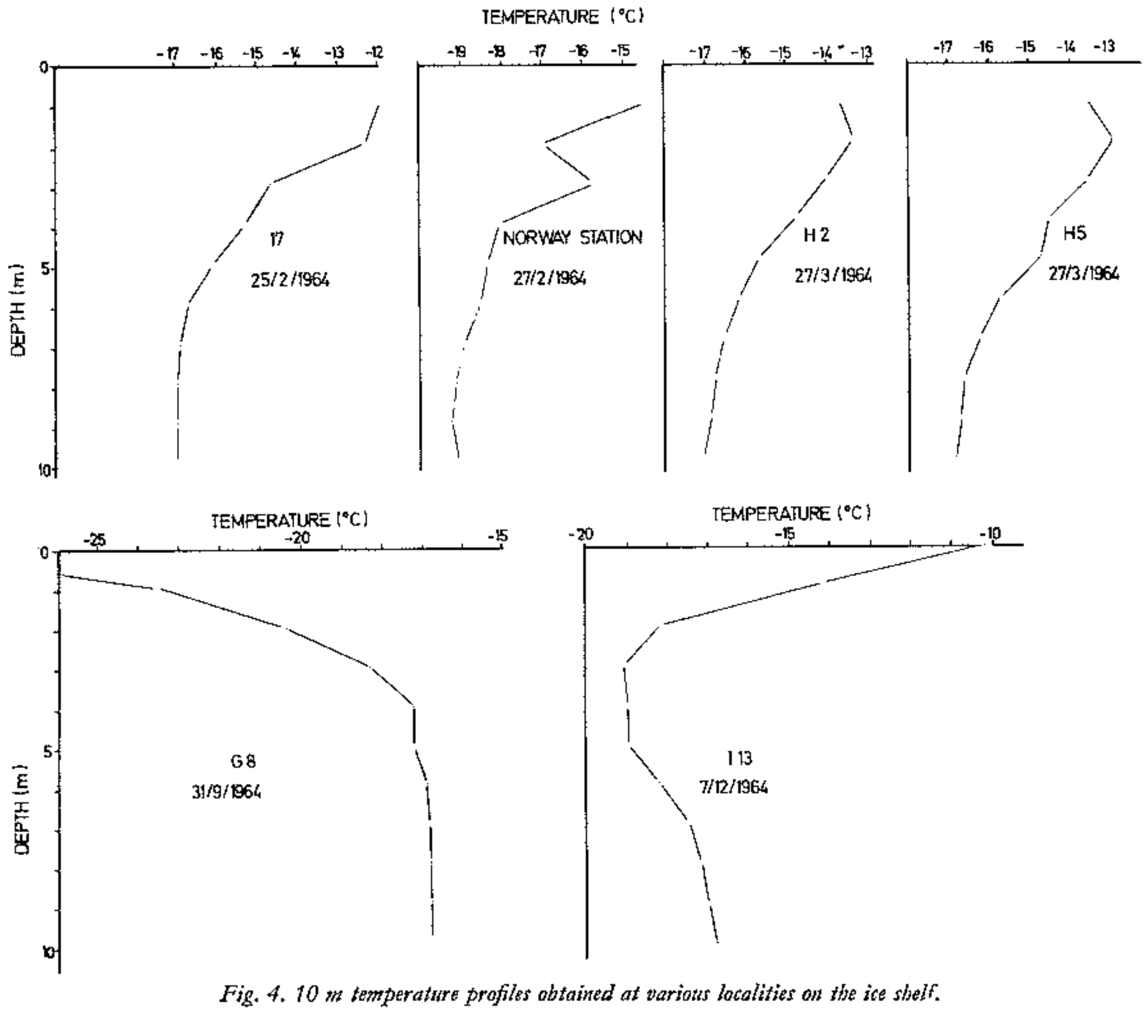

Fig. 4. 10 m temperature profiles obtained at various localities on the ice shelf.

Bottom temperatures, collar elevations of the boreholes, and distance from the nearest coastline are given in Table 1.

Discussion

Sanae lies in the percolation facies above the saturation line as defined by *Benson* (1962, p. 13) and it may be assumed that the temperature of the firn at a depth of 10 m or more approximates the mean annual surface temperature. The maximum deviation from the mean at 10 m probably does not exceed 0,5°C. At Maudheim the temperature range at 10 m was found to be of the order of 1°C (*Schytt*, 1958) while a maximum variation from the mean of 0,3°C was found for stations on the Greenland Plateau (*Benson*, 1962, p. 49).

Table 1

Location	Distance to nearest coastline (km)	Height above sea-level (m)	Bottom temperature (°C)
Station 17	64,2	128 ± 5	−17,05
Norway Station	24,2	59 ± 2	−18,95
Sanae	15,0	55 ± 1	−17,95
Station H2	10,5	46 ± 2	−17,15
Station G8	8,0	351 ±10	−16,80
Station I13	5,2	104 ± 5	−16,90
Station H5	3,5	38 ± 1	−16,85
Substation	2,2	36 ± 2	−16,25

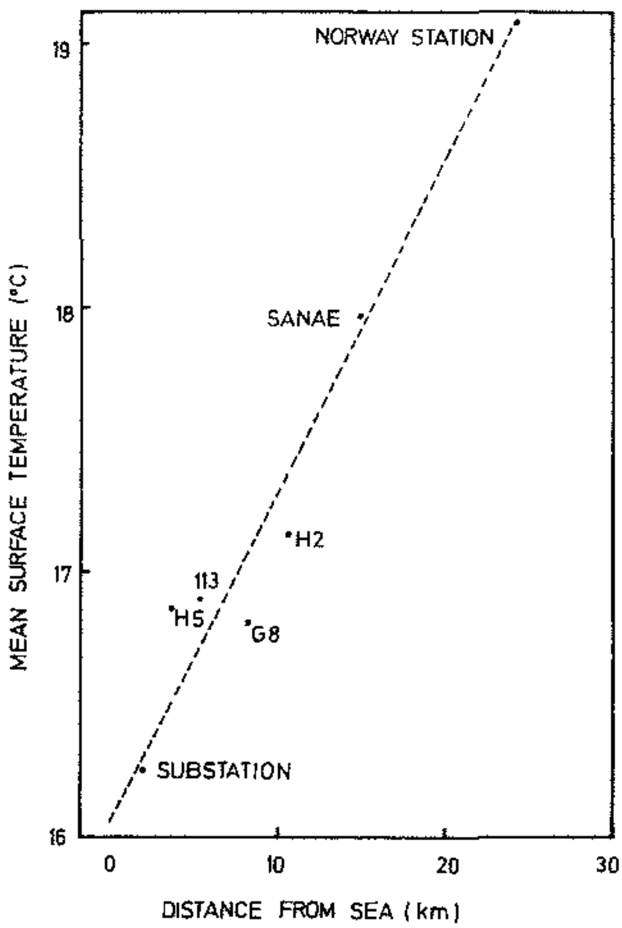

Fig. 5. Mean annual temperature at various localities plotted against distance from the sea.

In Greenland and Antarctica temperature changes with latitude at a rate of roughly 1°C per degree of increased latitude (*Mellor*, 1962, p. 111). Elevation also influences climate and a lapse rate of approximately —1°C per 100 m is normally found in Antarctica in areas where katabatic winds predominate, while regions exposed to maritime influence and the uplifting of cyclonic air masses, as in the region of Sanae, appear to have smaller lapse rates (*Mellor*, 1962, p. 114).

The normal effects of elevation and latitude do not explain the differences in temperature recorded at the various stations in the vicinity of Sanae. The temperature at Substation differs by 1,7°C from that recorded at Norway Station, although the two are a mere 20 km apart and their elevations differ by only 20 m. There is a fairly regular decrease in temperature with distance from the coast, indicating that the differences in mean annual temperature as recorded at the various stations can be attributed largely to the modifying effect of the proximity of the sea (Fig. 5). The mean annual surface temperature on the ice-shelf in the region of Sanae is approximately —16°C at the coast and decreases inland at a rate of —0,13°C per km for at least 30 km from the sea. Sanae, which is 15 km inland, has a mean annual surface temperature of —17,95°C.

The mean annual air temperatures obtained from meteorological records were —18,52°C for Norway Station in 1960 and 1961, and —18,05°C for Sanae in 1963, 1964 and 1965 (personal communication, Mr H J Joubert of the Weather Bureau, Department of Transport). These values compare favourably with bottom temperatures of —18,95°C and —17,95°C respectively.

The relatively high bottom temperature recorded at Station 17 seems anomalous, as the effects of latitude, elevation and continentality would all indicate a lower temperature than —17,1°C. This could, however, be explained by the fact that the station is situated on a local ice-rise (Fig. 1) and is thus possibly influenced by intense air temperature inversions over the ice-shelf. This could also apply to Station G8.

Temperature Profiles obtained from two Boreholes in valleys leading into Buktas

A 13,5 m deep borehole was drilled in the valley leading into Otterbukta, 1 km from the edge of the ice-shelf and exactly 13 m above sea-level. A bottom temperature of —2,2°C (Fig. 6) was recorded; the firn was completely brine-soaked below sea-level and unaffected above it. A similar result was obtained in the valley of Polarsirkelbukta where brine was encountered at sea-level in a 10 m borehole (*Langenegger*, 1963). A bottom temperature of —3,2°C (Fig. 6) was recorded while the surface temperature was —40°C.

In the valley leading into Tottanbukta an 18 m hole was sunk approximately 23 m above sea-level,

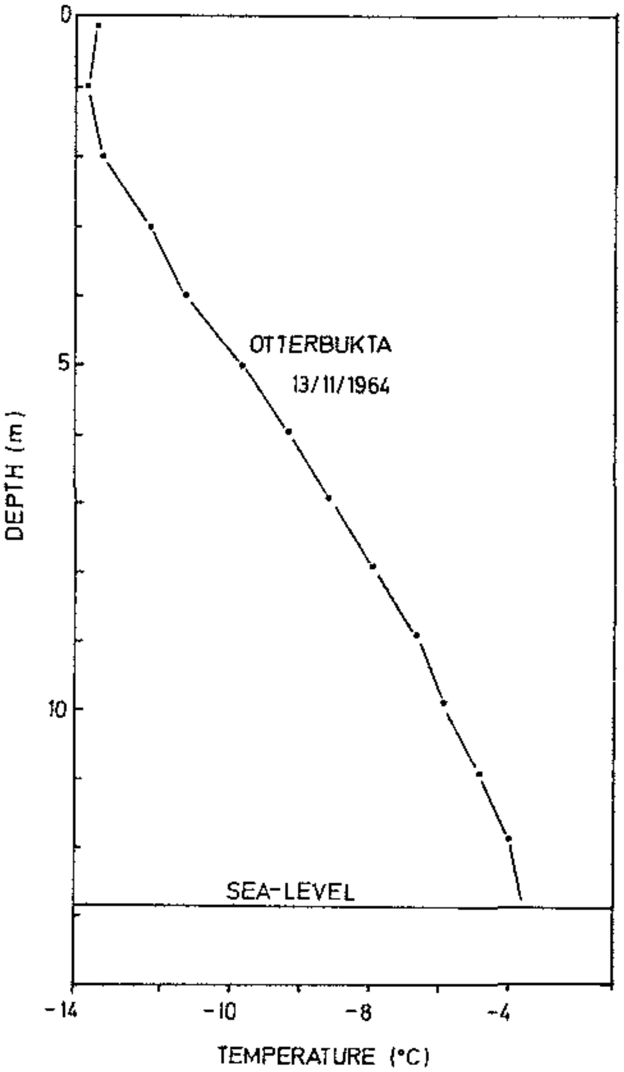

Fig. 6. Temperature profile from the surface to sea-level in the valley of Otterbukta.

and approximately 3 km from the edge of the ice-shelf. A bottom temperature of —4,7°C (Fig. 7) was recorded and this, along with the steady near-linear temperature increase downward of 0,66°C per metre, would indicate a temperature in the region of —2°C at 22 m. In this case also brine would be expected to occur at sea-level.

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References

Benson, CS Stratigraphic studies in the snow and firn of the Greenland ice sheet. U S Snow, Ice and Permafrost Research Establishment, Research Report, No. 70, 1962.

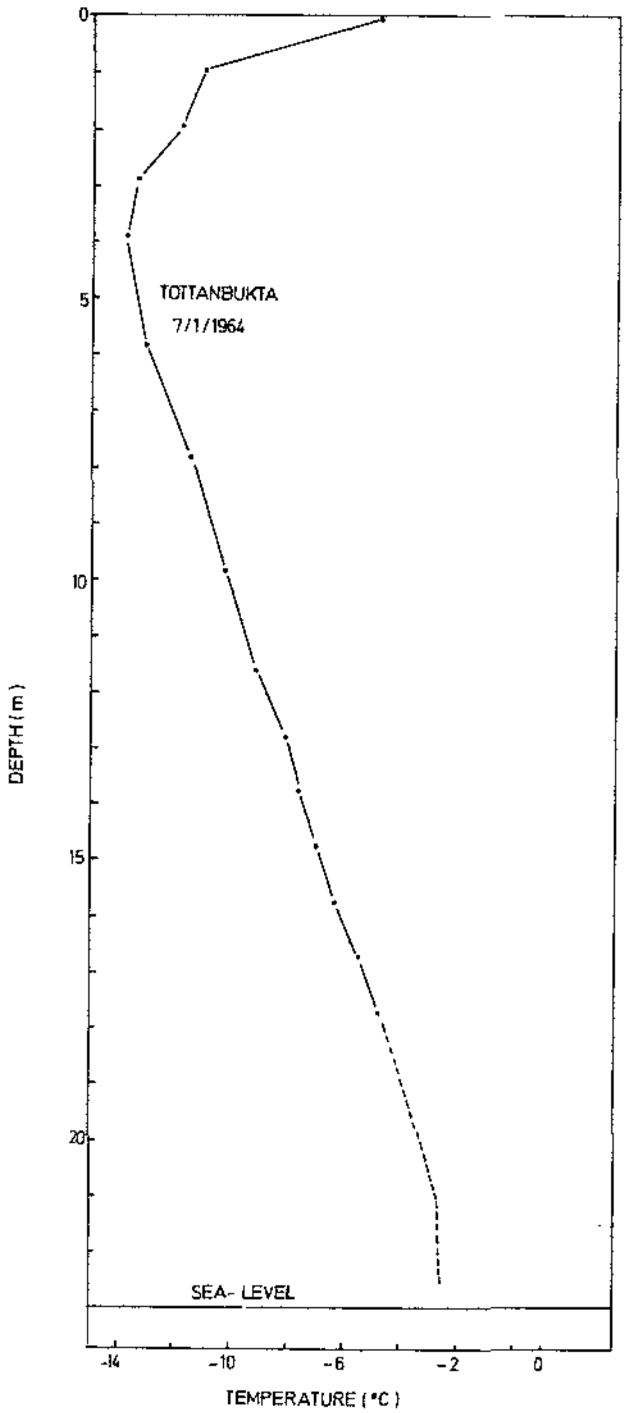

Fig. 7. Temperature profile from the surface to sea-level in the valley of Tottanbukta.

Langenegger, O Geological and glaciology investigations of the Fourth South African Antarctic Expedition. Field Report IV-1, Geological Survey, Pretoria, 1964.

Mellor, M Snow and ice on the earth's surface. In *Cold regions science and engineering,* edited by FJ Sanger, Part 2, Section C. Hanover, U S Army Materiel Command, 1964.

Schytt, V Glaciology II: A. Snow studies at Maudheim; B. Snow studies inland. *Norw.-Br.-Swed. Antarct. Exped., Scientific Results,* **IV.** Oslo, Norsk Polarinstitutt, 1954.

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