tread marks. In general, this type of groove is remarkably similar to the "jigger marks" described on the Alaskan shelf by Reimnitz and Barnes (1974). "Jigger marks" are grooves which possess equally spaced morphologic features along their length similar to the treads described above. Reimnitz and Barnes (1974) suggested that these grooves are summer features formed in open water within the pack ice by unstable icebergs wobbling along their tracks. Our observations suggest that, in some instances, wave action and the "bouncing" of icebergs may be an important component in "jigger mark" formation.

Grooves without tread

This type of groove occurred less commonly and was particularly variable in form (Fig. 2e and f). They ranged from very fine sharp grooves to broad flat tracks. The largest groove observed was 0.4–0.5 m wide and 7 m long, a broad shallow track 50 mm deep. Its outer flanks were asymmetric ridges (80 mm high) and were paralleled by several faint basal grooves. Very faint transverse treads or ridges were noted and suggest that the iceberg moved with a stick–slip motion. The slip phases probably occurred when the basal friction of the iceberg was reduced by a passing wave.

Discussion

As we suggested earlier, these features are significant because: first, as illustrated above, they provide direct analogues, and secondly, we believe them to be a significant factor in sedimentation within proglacial lakes.

Impact structures and grooves have been observed in many other proglacial lakes but are rarely exposed as clearly as those at Heinabergsjökull. Where the density of icebergs is high (i.e. Jökulsarlon — Breidamerkurjökull), the potential of iceberg ploughing to turbate and mix the sedimentary sequence or structures present is considerable. For example, at Jökulsarlon there is an average of at least 30 icebergs per 100 m^2 along its shoreline (icebergs 20–<1 m^2; Heinabergsjökull: 8 icebergs per 100 m^2), all of which have a potential geomorphological impact. Moreover, the presentation potential of the iceberg tool marks formed by such icebergs is theoretically good, due to the high sedimentation rates in such environments. However, with the exception of Thomas and Connell (1985), few workers have recorded such structures within a sedimentary succession. It is the opinion of the authors that this reflects insufficient understanding, at present, of the criteria necessary to identify such structures in the sedimentary sequence.

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SIR,

Glaciological reconnaissance on the Loonney ice cap, Alexandra Land, Franz Josef Land

A glaciological expedition from the Institute of Geography, U.S.S.R. Academy of Sciences, renewed investigations on the Franz Josef Land archipelago glaciation, after a 30 year break. A new field camp was established at the westernmost island of Franz Josef Land — Alexandra Land, 12 km south of the Nagurskaya meteorological station and 5 km north of Loonney (Lunar) ice cap. Preliminary investigations of the glacier were carried out

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in April–May 1990 with the purpose of choosing a location for deep drilling, as planned for subsequent years.

Loonney ice cap has an area of 658 km^2 and comprises three connected ice-cap summits consolidated as a ridge 40 km long (Grosval'd and others, 1973). The expedition studied only the northern summit. Barometric levelling carried out with the help of a microbarometer M-111 (accuracy of pressure determination 0.001 mbar) showed that the uppermost point on the northern part of the glacier was 375 m a.s.l. (Fig. 1). The glacier edge at the summit field-camp profile was situated at an elevation of 31 m.

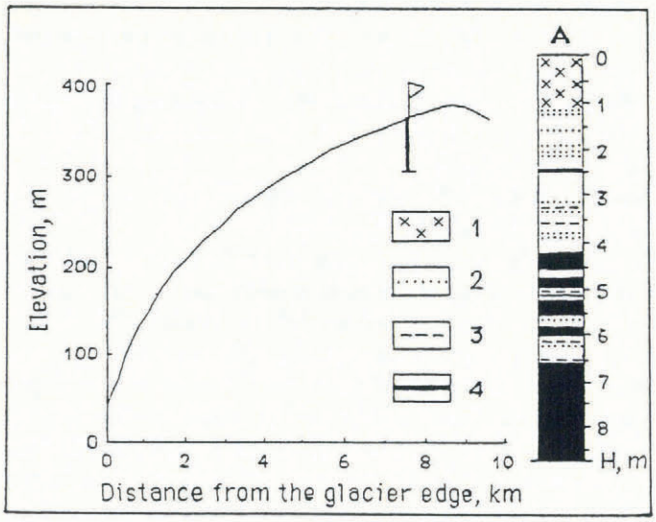

Fig. 1. Surface-elevation profile of the northern slope of the Loonney ice cap and stratigraphy of firn layers from a core near the deep-hole site (A): 1; snow 2–4, ice layers with a thicknesses less than 1 cm, 1 cm and more than 1 cm, respectively.

1 km north of the summit, at an elevation of 362 m, a hole was drilled to a depth of 53.6 m for temperature measurements (Fig. 2). During drilling, the bottom 5–10 m of the hole was filled with a water–glycerine–alcohol mixture which was pumped out each evening. During the drilling, and 1 and 3 d after drilling terminated, temperatures were measured with a digital read-out platinum thermometer. The temperature profile showed a negative temperature gradient similar to that observed on several nearby glaciers — Vestfonna, Austfonna, Jackson and Academii Nauk (Grosval'd and others, 1973; Kotlyakov, 1985; Zagorodnov and Arkhipov, 1989; Zagorodnov and others, 1990). The temperature gradient measured 0.6°C at a depth of 20–53.6 m. The temperature of the lower margin of the active layer (10 m) was –2.0°C; in a dry hole located 5 m from the deep one, it was –2.1°C at 8.7 m depth.

Firn-layer stratigraphy was studied in cores from three holes, two of which were drilled 4–5 m from the deep hole and the third 1.5 km to the north, in the down-slope direction. In all the cores, the firn included ice layers with a thickness up to 50 cm. The change from firn to solid ice occurred at a depth of 6–6.5 m (see Fig. 1a). Indirect evidence, a sudden loss of drilling fluid, suggests that permeable firn layers can exist to a depth of 12–14 m.

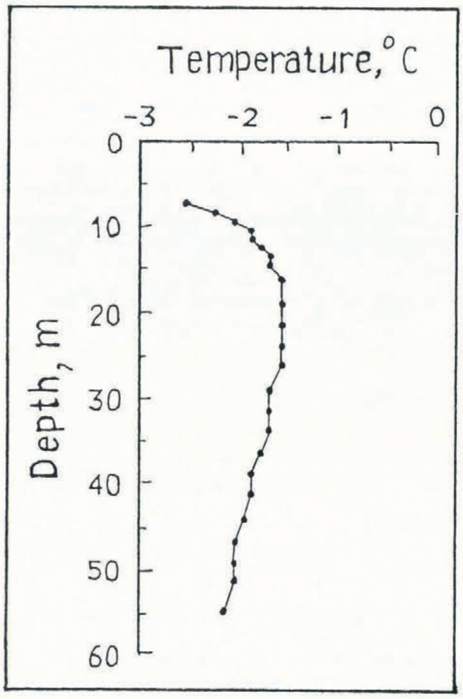

Fig. 2. Temperature distribution in the Loonney ice cap.

Based on the stratigraphic and 10 m temperature data, we speculate that all the investigated cores were formed in a firn–ice zone (lower percolation) similar to that observed at Austfonna (Arkhipov and others, 1987; Sin'kevich, in press). This zone is characterized (i) by melt water and liquid-precipitation percolation through the entire layer thickness, and (ii) by active ice-layer formation both within the firn and at the upper margin of the solid ice. The results of our investigations showed that, if one of the ice layers is more than 1 m thick and has negative temperature, it can be accepted as the upper margin of the solid (waterproof) ice (Sin'kevich, in press). It is worthwhile noting that almost the same stratigraphy and temperature regime were observed on Jackson ice cap, Franz Josef Land, in 1958–60 (Grosval'd and others, 1973).

Because of the lack of time, the boundaries of the firn basin could not be determined. However, at the summit field camp, the following information was obtained: (i) 6 km from the glacier edge, at an elevation of 330 m, the snow–firn thickness was 6 m, almost similar to that observed at the deep-hole site; (ii) 2.5–4.5 km from the glacier edge, at an elevation of 230–300 m, we observed a firn layer 10–30 cm thick. This rapid decrease in thickness of the firn layer over a distance of 1.5 km and between 300 and 330 m is similar to that observed at Svea–Kongsvegen glacier (Korolev and others, 1988) and Austfonna (Sin'kevich, in press). The firn line of 1989 can be established at a height of 220–230 m.

The rapid decrease in thickness of the firn layer evidently occurs because of the increased summer melting accompanied by a decrease in precipitation down-slope. The latter cicumstance is corroborated by the snow-thickness data measured down-slope from the summit field camp on 20–25 May; snow thickness measured 110–120 cm at the summit, decreased to 95–115 cm at 230–300 m elevation, and to 70–95 cm near the glacier edge.

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The mean snow density was 400 kg m^{-3}. Thus, the winter accumulation in 1990 on the Loonney ice cap equalled 0.4–0.5 m water equivalent within the firn basin. This value is close to the accumulation measured at the same location in 1961 (Markin, 1964) but is more than twice as large as that measured in 1962 (Govoruha, 1964).

From data presented here, we have concluded that contemporary accumulation, firn stratigraphy and 10 m temperatures are very similar to those obtained earlier on the opposite shore of the Barents Sea — on the Vestfonna and Austfonna ice caps of Nordaustlandet, Svalbard. The deep-hole temperature profile from Vestfonna (Kotlyakov, 1985) paralleled the Alexandra Land profile (the latter is colder) to a tenth of a degree. Future deep drilling, involving detailed core investigations and new data on the englacial temperature distribution should enable us to determine whether there is also a similar history of development on the Loonney ice cap.

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SIR,

Unusual discoveries of corpses immersed in glacier ice after fatal accidents — glaciological aspects

The rare occurrence of a corpse becoming exposed on a glacier surface is closely connected with the glaciological situation at the scene of the accident. The discovery in August 1990 of two corpses on the Mitterkarferner (Oetztal Alps, Tyrol) initiated a glaciological comparison of this recent discovery with earlier discoveries made on Tyrolean glaciers. There are three known cases, which can be characterized as follows: accident in the accumulation area (fall over a rock face) and discovery in the accumulation area near the equilibrium line (1990); accident in the ablation area (fall down a crevasse) and discovery in the ablation area (1973); accident in the accumulation area and discovery on the ice-free terrain at the very end of the glacier (1952). Furthermore, a further case is described which is glaciologically obscure.

Case 1. Following a fall down a rock face with a gradient of 45–50° and a height of 260 m, the casualties (a married couple) came to rest in the accumulation area of the Mitterkarferner, close to the base of the headwall (3400 m a.s.l.). The accident occurred on 25 August 1965 and the casualties were recovered in the accumulation area at altitudes of 3320 and 3340 m a.s.l., respectively, on 21 September 1990. They had therefore been immersed in glacier ice for 25 years. In view of the immersing component of the flowlines, it is to be expected that the casualties would have been exposed in the ablation area at a much later date. It is because of the high rate of ablation in the years 1984–85 to 1989–90 (personal communication from G. Markl) that the casualties were only discovered in the accumulation area near the equilibrium line after 25 years. Flow path and time yield a mean flow velocity of <6 m year^{-1}, which agrees with measurements taken on the Kesselwandferner, a glacier located in the near vicinity (Schneider, 1970).

The Mitterkarferner has a length of 2.1 km and a maximum width of 1.2 km. The upper part (>3300 m a.s.l.) is exposed to the southwest and the lower part to the southeast. The lowest part is strongly covered by rock debris, deposited by rockfalls from the slopes above and transferred by the stream lines. Above the discovery location, the glacier has a gradient of 35–40°. This could have caused the casualties to slide down several meters in the course of the accident and could have led to a lower averaged flow velocity. There is no bergschrund.

The mean equilibrium-line altitude for the periods 1965–66 to 1989–90 is estimated at 3150 m a.s.l. on the basis of exposures and steepness. For comparison, the

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