Journal of Glaciology, Vol. 37, No. 125, 1991

Correspondence

The Editor,
Journal of Glaciology

SIR,

Iceberg tool marks: an example from Heinabergsjökull, southeast Iceland

Iceberg tool marks have a variety of forms, occur in a wide range of environments, and at many different scales. For example, at a macro-scale, they have been recorded on continental shelves using both side-scan sonar and seismic records, and are formed by both sea ice and single icebergs. Observed grooves range in size from <20 to 100 m in width and from 2 to 10 m in depth (e.g. Beiderson and others, 1973; Harris and Jollymore, 1974; Kovacs and Mellor, 1974; Reimnitz and Barnes, 1974; Wadhams, 1980; Weeks and others, 1983).

At the other extreme, small iceberg-pushed ridges have been described on both marine and lacustrine beaches (e.g. Nichols, 1953; Owens and McCann, 1970; John and Sugden, 1975). The observation of grooves at this scale is, however, less common. We suggest that these features are significant on two principal counts: first, they provide direct analogues for the features observed more remotely on continental shelves, and secondly, they are clearly a significant factor in sedimentation within proglacial lakes.

This note describes several small iceberg grooves formed along the margin of the proglacial lake of Heinabergsjökull in southeast Iceland. The features appeared as a consequence of a jökulhlaup from the ice-dammed lake of Vatnsdalur (Fig. 1).

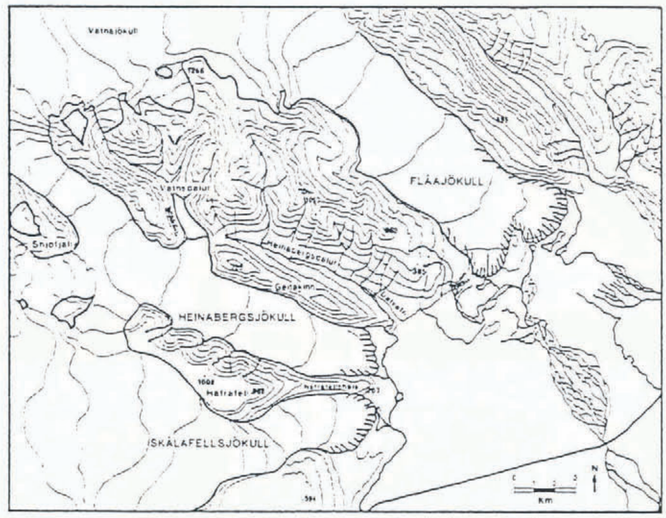

Fig. 1. Heinabergsjökull and the ice-dammed lake of Vatnsdalur, southeast Iceland.

A jökulhlaup at Heinabergsjökull, June 1990

On 23 June, the ice-dammed lake of Vatnsdalur drained catastrophically. This flood drained through the proglacial lake in front of Heinabergsjökull, raising its level by over 3 m and increasing its area from 1.8 to 2.2 km^2 (Fig. 1). This lake level was sustained for only a few hours and was followed by a rapid (77 mm h^{-1}) fall to about 0.7 m below its original level. This fall was apparently induced by pronounced erosion along the bed of the channel draining the proglacial lake. Apart from this channel incision, the geomorphological impact of the jökulhlaup was minimal, which may reflect its regular occurrence (Thome, 1972).

This event occurred during a period of gale-force winds blowing from the centre of the Vatnajökull ice cap. These winds brought numerous icebergs (10–30 m long), generated during and after the jökulhlaup, into contact with the gravel beaches of the proglacial lake. As the water level fell, series of remarkable iceberg tool marks were revealed.

Iceberg tool marks

The iceberg tool marks along the shore of the proglacial lake of Heinabergsjökull fall into three broad categories:

(1) Impact or push structures.
(2) Grooves with tread.
(3) Grooves without tread.

Impact or push structures

These consist of irregular groups of small oval or elongated depressions (<0.1 m) flanked by low (0.15 m) mounds of gravel (Fig. 2). They often truncate prominent grooves and are associated with small gravel berms. The mounds of gravel flanking the craters occur either on the up- or down-beach side of the depressions. These depressions and mounds were formed as icebergs became finally grounded at the water's edge. The mounds of gravel are either pushed up in front of the asperities on the icebergs or behind them as the iceberg settles back down into the beach. The latter is more common where the beach gradient is steep.

In general, these pushed ridges are similar to those described by Nichols (1953) but are generally much smaller and less continuous. This reflects the different driving forces propelling the icebergs into the beach. Those described by Nichols (1953) were due to the

Fig. 2. Iceberg tool marks at Heinabergsjökull: (a) impact structures; (b) grooves with tread; (c) tread with a confining groove; (d) broad tread without a confining groove; (e and f) two grooves of a very different character without tread.

movement of continuous pack ice as opposed to the individual wind-propelled icebergs at Heinabergsjökull.

Grooves with tread

Some of the most prominent iceberg grooves observed had pronounced cross-groove ridges in their base (Fig. 2b and c). They reach up to 0.5 m in width and 0.45 m in depth. These marks appear to have been formed as the icebergs are propelled up the beach when the mean water level is barely sufficient to lift them. However, intermittent large waves are capable of moving the icebergs in series of hops. The tread marks form on the down-beach side of the icebergs as they settle back into the gravel following each hop. The tread marks vary in size, prominence, and the context in which they occur. Several examples were recorded in which a marked linear groove was absent; only a simple series of impact craters or treads had formed (Fig. 2d). The presence or absence of an associated groove will clearly depend on the weight of the iceberg, the size of the waves, and the nature of the keel or basal asperity. If the iceberg is lifted completely away from the surface of the beach, no continuous groove will form and a simple series of impact marks will be generated. The shape of the basal asperity controls the form of the impact or tread mark. In Figure 2d, the compact disc-like treads are clearly formed by a very flat, wide asperity that contrasts with the marks in Figure 2b.

These observations suggest that it is the action of wave energy upon grounded icebergs that gives rise to such 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.

Department of Geology and Geophysics, MATTHEW R. BENNETT
University of Edinburgh,
Edinburgh EH9 3JW, Scotland

Department of Geography, JOANNA E. BULLARD
University of Edinburgh,
Edinburgh EH8 9XP, Scotland

2 October 1990

REFERENCES

Belderson, R. H., N. H. Kenyon and J. B. Wilson. 1973. Iceberg plough marks in the northeast Atlantic. *Palaeogeogr. Palaeoclimatol. Palaeoecol.*, **13**(3), 215–224.

Drewry, D. 1986. *Glacial geologic processes.* London, Edward Arnold.

Harris, I. M. and P. G. Jollymore. 1974. Iceberg furrow marks on the continental shelf northeast of Belle Isle, Newfoundland. *Can. J. Earth Sci.*, **11**(1), 43–52.

John, B. S. and D. E. Sugden. 1975. Coastal geomorphology of high latitudes. *Prog. Geogr.*, **7**, 53–132.

Kovacs, A. 1972. Ice scoring marks floor of the Arctic shelf. *Oil Gas J.*, **70**, 92–106.

Kovacs, A. and M. Mellor. 1974. Sea ice morphology and ice as geologic agent in the southern Beaufort Sea. *In* Reed, J. C. and J. E. Sater, *eds. The coast and shelf of the Beaufort Sea.* Arlington, VA, Arctic Institute of North America, 113–164.

Nichols, R. L. 1953. Marine and lacustrine ice-pushed ridges. *J. Glaciol.*, **2**(13), 172–175.

Owens, E. H. and S. B. McCann. 1970. The role of ice in the Arctic beach environment with special reference to Cape Ricketts, southwest Devon Island, Northwest Territories, Canada. *Am. J. Sci.*, **268**, 397–414.

Reimnitz, E. and P. W. Barnes. 1974. Sea ice as a geologic agent on the Beaufort Sea shelf of Alaska. *In* Reed, J. C. and J. E. Sater, *eds. The coast and shelf of the Beaufort Sea.* Arlington, VA, Arctic Institute of North America, 301–353.

Thomas, G. S. P. and R. J. Connell. 1985. Iceberg drop, dump, and grounding structures from Pleistocene glacio-lacustrine sediments, Scotland. *J. Sediment. Petrol.*, **55**(2), 243–249.

Thome, K. N. 1972. Asymmetries in glacier structure and their influence on glacier movement and glacier deposition. *In Proceedings of the 24th International Geological Congress, Canada. Section 12*, 198–211.

Wadhams, P. 1980. Ice characteristics in the seasonal sea ice zone. *Cold Reg. Sci. Technol.*, **2**, 37–87.

Weeks, W. F., P. W. Barnes, D. M. Rearic and E. Reimnitz. 1983. Statistical aspects of ice gouging on the Alaskan shelf of the Beaufort Sea. *CRREL Rep.* 83-21.

The accuracy of references in the text and in this list is the responsibility of the authors, to whom queries should be addressed.

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