OBSERVATIONS ON AN ICE-DAMMED LAKE, HINDLE GLACIER, SOUTH GEORGIA

By P. STONE

ABSTRACT. Old shorelines above a lake dammed by Hindle Glacier are described. The significance of perched ice blocks and small moss cushions is discussed and it is suggested that a recent filling and draining of the lake was the first event of its kind for some years. This may have some bearing on the ice-flow pattern of Hindle Glacier.

To the south-east of Hindle Glacier on the north-east coast of South Georgia a small ice-dammed lake has been formed approximately 2 km. from the snout of the glacier in Royal Bay (Figs. 1 and 2). The lake occupies the north-west end of the valley formed by the retreat of Hindle Glacier from one side of what was originally a nunatak. The area was first visited on 11 December 1973, when the water-level in the lake was measured barometrically as a little below 200 m. a.s.l. Above the lake surface, 28 distinct benches observed in the surrounding screes are regarded as old shorelines of the lake formed during periods of higher water-level.

DESCRIPTION OF THE SHORELINES

The shorelines can be subdivided into two groups (Fig. 3). The upper group, ranging from 35 m. above water-level (a.w.l.) down to 25 m. a.w.l., step down at intervals of 0·2–1·5 m. They are cut in places by scree runs and when the area was visited they were still partly obscured by compacted winter snow. This group is best developed on the steep screes to the east of the lake (Fig. 4). The lower benches, ranging from 23 m. down to 2 m. a.w.l., have a slightly wider separation and the most pronounced are the lowest four at 7, 5, 3·5 and 2 m. a.w.l., respectively. These are best developed on the more gently sloping south and west shores of the lake. Ice blocks are stranded on all of the shorelines in this lower group (Fig. 5), particularly on the lowest three. The largest ice block, approximately 12 $m.^3$ in volume, was lying on the 2 m. bench. All of the larger ice blocks had moved slightly, under their own weight, down the very gently sloping terraces and, in so doing, had pushed up low ridges of shingle in front of them. Behind these ridges, the blocks had settled into hollows which were probably accentuated by melt water from the stranded ice. On the upper levels of the lower group, small pieces of ice occupied hollows of a similar size to those beneath the large stranded icebergs lower down. A direct comparison between these features suggests that large ice blocks (up to 12 $m.^3$ in volume) originally stranded up to 23 m. a.w.l. have virtually wasted away.

None of the scree benches was vegetated and no lichen cover was observed on any of the boulders or rock outcrops which would have been submerged. However, on the south-west side of the lake several moss cushions, approximately 3 cm. in diameter, were growing on rock outcrops up to 8 m. a.w.l.

A second visit was made to the lake on 14 December 1973 and no appreciable change in level was observed. It is therefore possible that base level had been reached and that the lake does not drain completely.

SHORELINE FORMATION

Scree benches, marking previous shorelines of ice-dammed lakes, have been reported from the margins of Neumayer and Lyell Glaciers in South Georgia (Brook, 1971; Clapperton, 1971). The overall fall of water level in these lakes has generally been related to glacier retreat, and D. J. Coleman (personal communication to C. M. Clapperton) considered that Gulbrandsen Lake, dammed by Neumayer Glacier, may empty periodically since icebergs have been seen stranded close to the glacier margin.

An indication of the timing of events in the Hindle Glacier lake can be obtained from the stranded ice blocks and the small moss cushions.

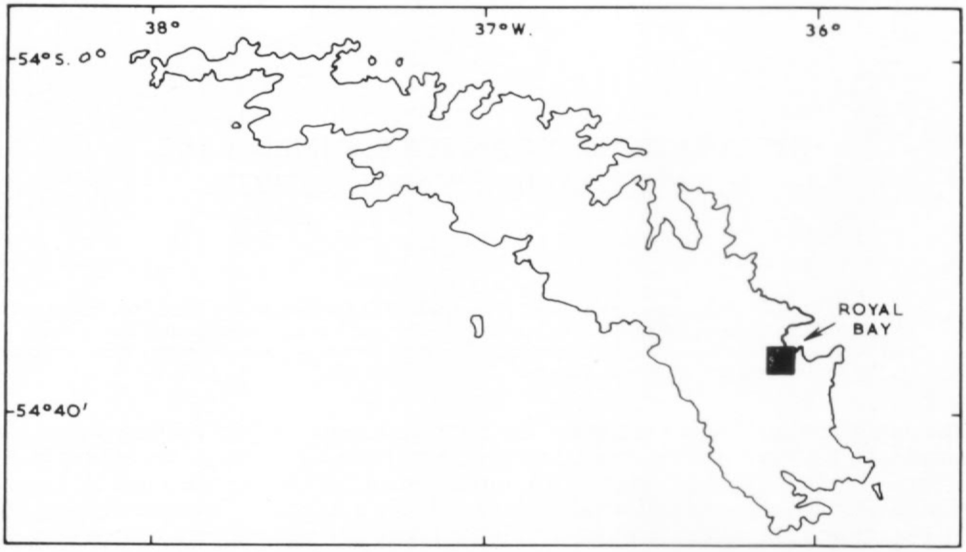

Fig. 1. Sketch map of South Georgia, showing the location of the area around the Hindle Glacier ice-dammed lake (solid black)—see Fig. 2.

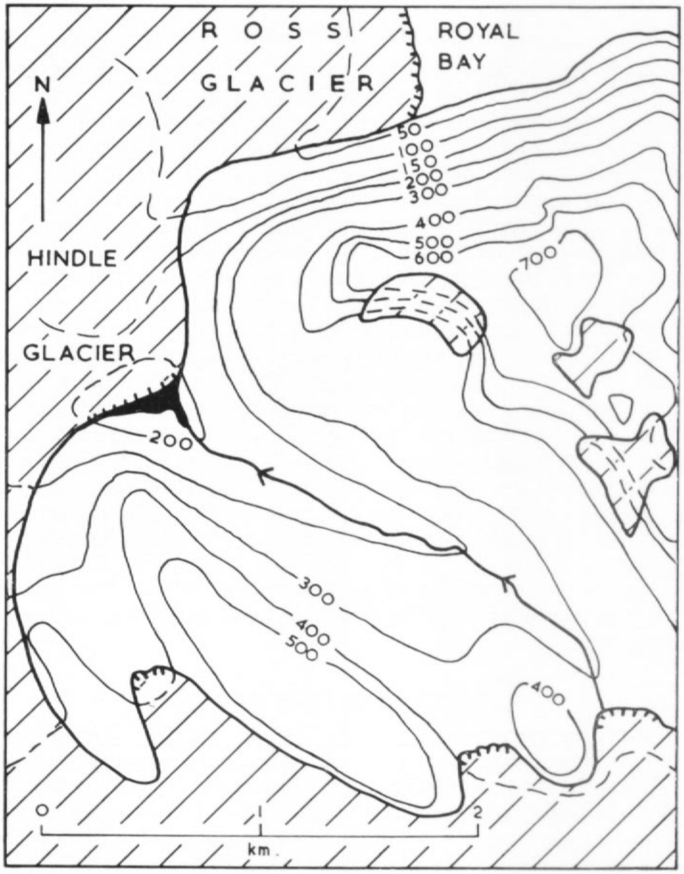

Fig. 2. Sketch map of the area south-east of Hindle Glacier showing the location of the ice-dammed lake (solid black). Glacier ice and permanent snow patches are hatched. The contours are in metres.

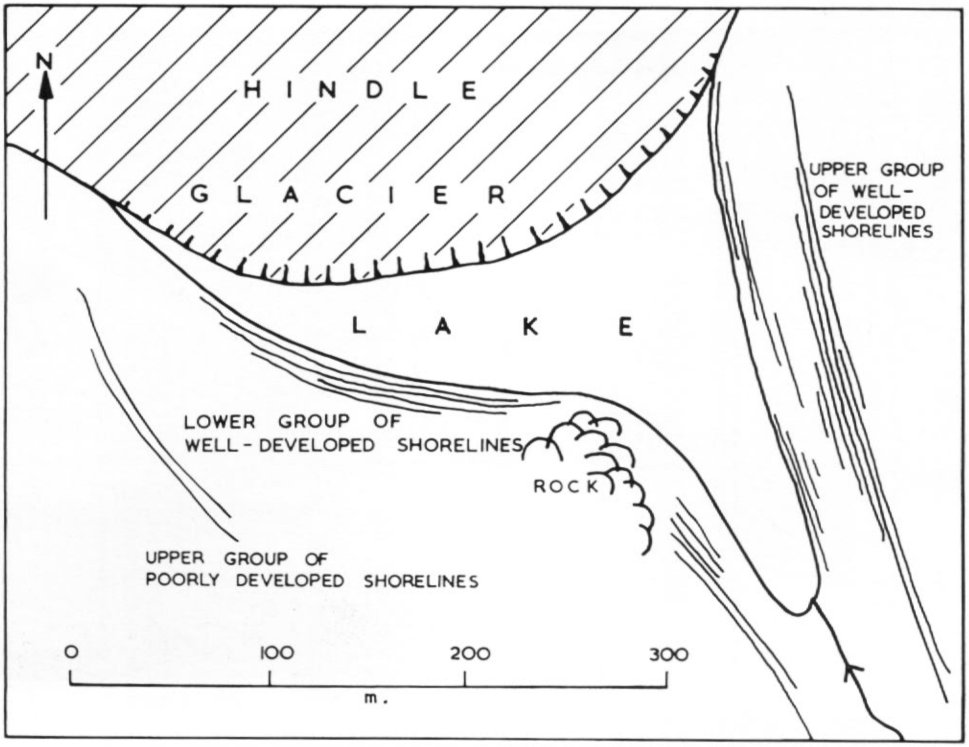

Fig. 3. Sketch map of the Hindle Glacier ice-dammed lake with the positions of the shorelines shown diagrammatically.

In typical overcast conditions at South Georgia during early December the ice blocks would receive a daily radiation input of 200 cal. cm.$^{-2}$ [$8 \cdot 36 \times 10^{6}$ J m.$^{-2}$] (personal communication from I. Hogg). A 12 m.$^{-3}$ block measuring approximately 2 m. by 2 m. by 3 m. would therefore have a maximum life expectancy of 16 days, with 10 days probably a more realistic figure. Clearly, the water-level in the lake must have fallen at least 23 m. in the 2 weeks prior to 11 December 1973. Whether or not the entire lower series of shorelines could have been cut in such a short space of time is however far less clear. Beach profiles have been produced in experimental situations in a matter of hours (King, 1959, p. 191) but these experiments have simulated marine conditions with regular waves breaking on a gently sloping shore. Wave generation in the Hindle Glacier lake would be by wind or calving from the glacier and would certainly be irregular; ice cover over much of the lake surface would also have a considerable damping effect. However, King's experimental results also showed that beach features submerged below the zone of wave action may be preserved for considerable periods. It is therefore quite possible that some of the lower group of shorelines existed before the lake filled and that the icebergs were stranded on them as the water-level subsequently fell.

The moss cushions growing up to 8 m. a.w.l. would have required subaerial conditions during approximately the last 10 years, although they could certainly withstand short periods of submergence (personal communications from B. G. Bell and N. J. Collins). Thus the recent high water-level in the lake could only have been a temporary phenomenon.

There are two possible interpretations of the evidence relating to the recent history of the lake. A series of shorelines may have been formed prior to 10 years ago, since when the lake level may have been similar to that observed. In this case, the recent filling and draining of the lake would have been an isolated event. Alternatively, filling and draining may have been a regular, possibly seasonal, occurrence with a single shoreline formed each year.

Fig. 4. The eastern side of the lake viewed towards the north. The upper group of shorelines is well developed with the flank of Hindle Glacier in the background.

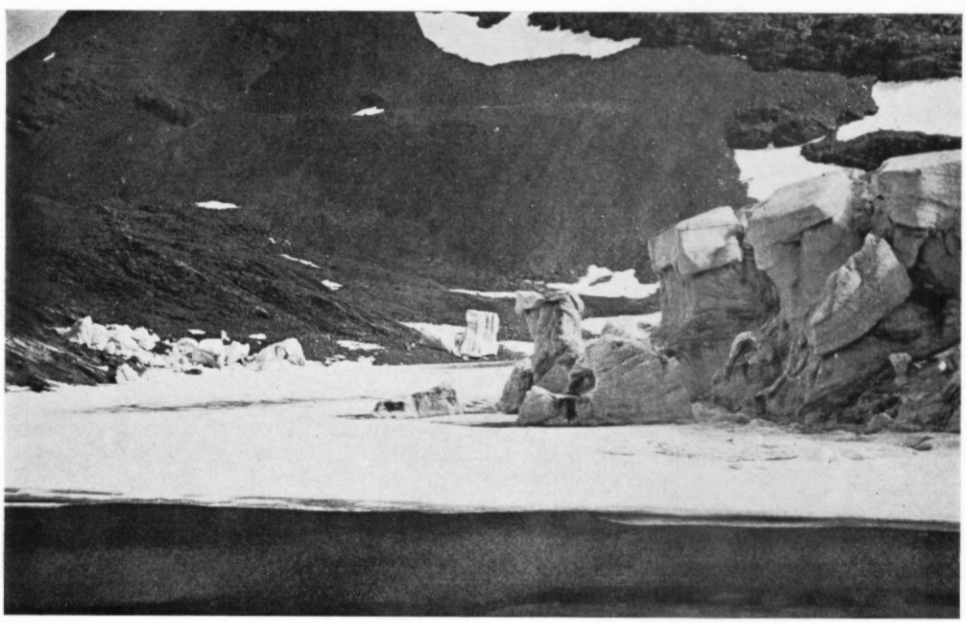

Fig. 5. Icebergs stranded on the lower shorelines on the west side of the lake, viewed from the east. The largest stranded iceberg is 3 m. high.

The sudden drainage of ice-dammed lakes can be initiated either by flotation of the ice barrier (Thorarinsson, 1953) or by ice flow as a result of excess pressure at the bottom of the lake over the corresponding ice pressure (Glen, 1954). The former is perhaps the more likely since the glacier front collapsed into the lake (Fig. 4) probably after initial lifting caused fracturing of the area adjacent to the water. In either case, a critical water-level is reached after which drainage is rapid and it seems unlikely that this critical level would vary sufficiently to produce the range of shorelines observed. Of course, it is possible that the effects of seasonal filling and draining of the lake have been superimposed on an older series of shorelines, but in this case a well-defined shoreline complex coinciding with the critical lake level of the last few years would be expected. No such prominent level was observed. The filling of the lake did however coincide with the spring thaw in South Georgia and this is most certainly a seasonal effect. If the recent rise in water-level was the first event of its kind for some years, there must have been an additional factor in operation, and this probably affected the subglacial drainage pattern. The movement of Hindle and Ross Glaciers is apparently by a succession of surges (Brown, 1956), the last of which caused their combined snouts to advance almost 1 km. between 1955 and 1965, since when there has been little further change (Stone, 1974). Hindle Glacier would therefore seem to be in the after-surge phase of a cycle during which the lower part of the glacier becomes increasingly stagnant (Robin and Weertman, 1973). Under these conditions, a situation is eventually reached when water is dammed at the base of the glacier by a zero water-pressure gradient and the next surge is initiated. A side effect of this may be the disruption of the subglacial drainage pattern. The recent filling and draining of the Hindle Glacier lake could then be an indication that a further surge cycle is about to commence.

Conclusions

The filling and draining of the Hindle Glacier lake during late November and early December 1973 was probably the first event of its kind for approximately 10 years. An existing series of shorelines around the lake was partially drowned as the lake filled and when draining occurred icebergs were stranded on the re-emergent terraces. Shorelines, which may have been formed during the recent filling and draining, could not be distinguished from earlier levels. These events could be associated with the commencement of a further surge cycle in Hindle Glacier.

Acknowledgements

The preparation of this paper has been greatly assisted by discussion with my colleagues, in particular Dr. P. W. G. Tanner, P. D. Clarkson, B. G. Bell, N. J. Collins and I. Hogg. G. A. Holden gave valuable field assistance. Professor F. W. Shotton kindly provided facilities in the Department of Geology, University of Birmingham.

MS. received 25 July 1974

REFERENCES

Brook, D. 1971. Scree benches around ice-dammed lakes in South Georgia. *British Antarctic Survey Bulletin* No. 26, 31–40.

Brown, R. 1956. The Ross Glacier. *Nature, Lond.*, **178**, No. 4526, 192–93.

Clapperton, C. M. 1971. Geomorphology of the Stromness Bay–Cumberland Bay area, South Georgia. *British Antarctic Survey Scientific Reports*, No. 70, 25 pp.

Glen, J. W. 1954. The stability of ice-dammed lakes and other water-filled holes in glaciers. *J. Glaciol.*, **2**, No. 15, 316–18.

King, C. A. M. 1959. *Beaches and coasts*. London, Edward Arnold (Publishers) Ltd.

Robin, G. de Q. *and* J. Weertman. 1973. Cyclic surging of glaciers. *J. Glaciol.*, **12**, No. 64, 3–18.

Stone, P. 1974. Physiography of the north-east coast of South Georgia. *British Antarctic Survey Bulletin*, No. 38, 17–36.

Thorarinsson, S. 1953. Some new aspects of the Grímsvötn problem. *J. Glaciol.*, **2**, No. 14, 267–75.