AN ICE CALDERA NEAR HOPE BAY, TRINITY PENINSULA, GRAHAM LAND

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HOPE BAY is at the north-eastern tip of Trinity Peninsula, and the ice caldera described here formed on the down-glacier side of a nearby small nunatak (Nobby Nunatak) at an altitude of 250 m. a.s.l. This area consists of an ice piedmont which extends from an altitude of about 300 m. a.s.l. and ends in 20 m. ice cliffs bordering Antarctic Sound. The climate of the area is maritime polar with low summer average temperatures ($\sim 0^\circ$ C), and in most years winter averages are above -17° C. However, melt water can form at any time of year during periods of warm westerly to north-westerly winds which descend the east coast as föhn winds.

THE ICE CALDERA

Sometime in November 1957 an ice caldera formed on the seaward side of Nobby Nunatak on a formerly level surface. The depression was saucer-shaped at its periphery with the steepest slope immediately below Nobby Nunatak; its diameter was approximately 300 m. Crevasses 1 m. wide followed the contours, and the slope towards the centre of the caldera steepened until, about 150 m. from the edge of the depression, it became vertical with a crevasse 7 m. long and 2 m. wide of unknown depth at the bottom. From the glacier surface to the crevasse the difference in altitude was about 20 m.

It retained this appearance throughout the summer of 1957–58. In July 1958 the area was invaded by warm dry air which kept the temperature above freezing point for a few days. Large quantities of melt water drained into the ice caldera. At the end of this melt period the caldera was filled with water to a level above the top of the lower crevasse (Fig. 1). This water

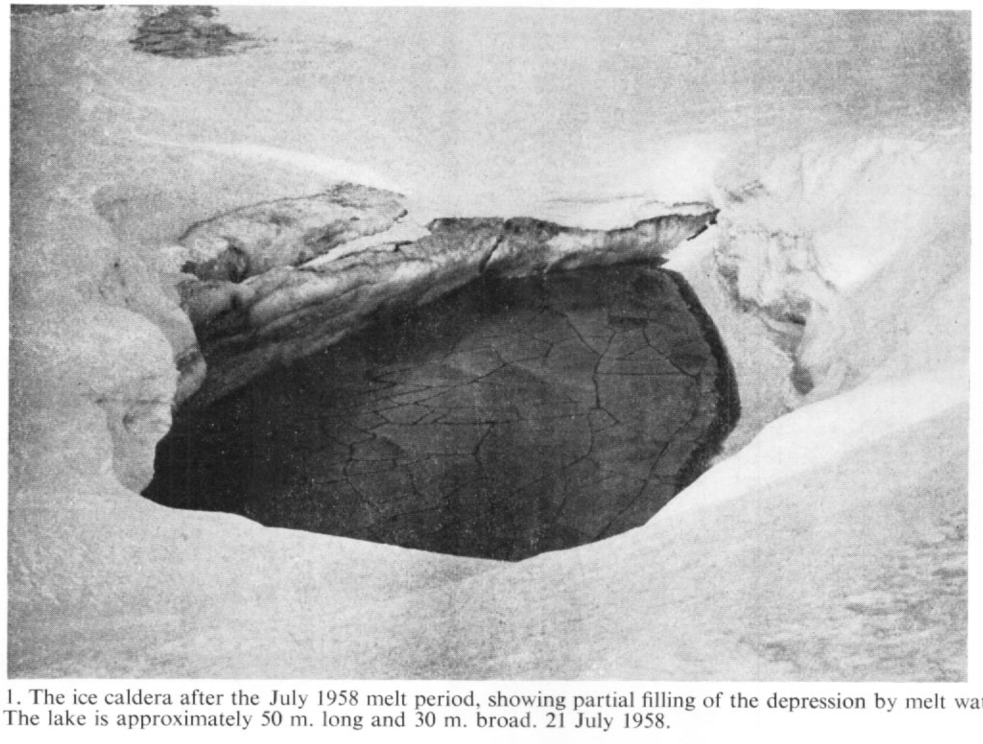

Fig. 1. The ice caldera after the July 1958 melt period, showing partial filling of the depression by melt water. The lake is approximately 50 m. long and 30 m. broad. 21 July 1958.

subsequently froze and the ice caldera remained in this state until the ablation period re-commenced in November 1958. More melt water then accumulated in the caldera and by February 1959 the feature had virtually disappeared. The surface ice was then drilled and found to overlie 2 m. of water. The whole mass eventually froze solid and in early 1960 the feature only betrayed its former existence by the presence of clear, bubble-free ice fringed by relict crevasses filled with blue ice.

Mode of Origin

Similar features have been observed elsewhere and it is pertinent at this point to refer to their locality and the observer's explanation of origin.

i. George VI Sound (Fleming and Stephenson, 1940). The features occur on the ice shelf at lat. 70°45′S. The authors postulated ice movement over hidden islands or, more likely, down-faulting within rift valleys due to lateral pressure.

ii. Amery Ice Shelf (Mellor and McKinnon, 1960). Mellor and McKinnon prefer the term *ice doline*. They have suggested that in the first place lakes form in deep hollows formed by movement of the ice shelf. Collapse of the lake ice on the surface follows catastrophic drainage through cracks created by the ice movement.

iii. North-east Graham Land (Aitkenhead, 1963). The author used the term *ice caldera*. The explanation suggested is the collapse of subglacial caverns after catastrophic drainage when the hydrostatic head is sufficient to lift the ice mass and allow drainage through subglacial and englacial channels.

iv. Iceland (Thorarinsson and Rist, 1955). The ice caldera formed from collapse of a subglacial cavern caused by the release of volcanic heat.

In all these areas considerable amounts of melt water form during the summer. The first two cases cited above are essentially surface features, whereas the third is marginal and where the necessity for including any process other than that of hydrostatic pressure to explain lake drainage is questionable.

Discussion

The movement of the ice immediately above Nobby Nunatak is 0·014–0·028 m./day but below it is only about 0·003 m./day. It is unlikely, therefore, that collapse can have resulted from movement. The thickness of the ice piedmont near Nobby Nunatak has been computed from surface slope and ice movement, and is approximately 50 m. (Koerner, 1964). A bergschrund exists on the down-glacier side of the nunatak and melt water could descend by this to bedrock level in summer. It is therefore necessary to postulate the formation of englacial caverns by this melt water to allow surface collapse, because it is unlikely that sufficient water would collect to provide an adequate hydrostatic head to lift the ice mass and thus allow drainage.

Aitkenhead (1963) has proposed the occurrence of subglacial and englacial melting even after the surface is frozen. Such a process must, however, proceed on only a very small scale, as melt water has an initial temperature which is only fractionally positive. The only other important source of heat is geothermal but it is doubtful whether this is sufficient to prolong the process of subglacial and englacial melting long after the supply of fresh surface melt water ceases. It is for this reason that the formation of an englacial cavern at Nobby Nunatak could be a slow process, taking several years to complete one cycle (if the process is cyclic). It is significant to note that in both the ice caldera near Mount Wild (Aitkenhead, 1963) and the one near Nobby Nunatak collapse coincided with a period of very warm conditions and high melt-water formation. In the caldera near Mount Wild the lake filled up rapidly and drained hydrostatically in a manner similar to that described by Thorarinsson (1939) for the ice-dammed lakes of Iceland.

Below Nobby Nunatak an abundant supply of melt water enlarged the englacial or subglacial cavern to such an extent that collapse of the surface occurred. No surface lake was observed prior to surface collapse and a lake only formed during the next melt period in mid-winter. The occurrence of surface melt at such a time plugged the englacial drainage channels and caused the melt water to collect as a surface lake. Subsequent re-freezing of the lake water levelled the surface depression completely so that another caldera can form only after new englacial or subglacial caverns have been formed.

Ice calderas may therefore be subdivided into two types: those where the subglacial or englacial caverns are formed by melt water and those where they are formed by volcanic heat.

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