

DISRUPTION OF BEDROCK BY THE GROWTH AND COLLAPSE OF ICE LENSES

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ABSTRACT. Hummocks and hollows were found developed in bedrock in the South Shetland Islands, Antarctica. Excavation revealed an ice lens 60 cm thick beneath a hummock. A cycle for the formation of the hummocks and hollows by the growth and collapse of ice lenses is suggested.

RÉSUMÉ. *Rupture du lit rocheux par la croissance et l'effondrement de lentilles de glace.* On a trouvé que des protubérances et des creux s'étaient développés dans le lit rocheux des South Shetland Islands en Antarctique. Un forage a révélé une lentille de glace de 60 cm d'épaisseur sous une protubérance. Un cycle pour la formation de protubérances et de creux par la croissance et l'effondrement de lentilles de glace est suggéré.

ZUSAMMENFASSUNG. *Zertrümmerung des Felsuntergrundes durch Wachsen und Zusammenbrechen von Eislinsen.* Im Felsuntergrund der South Shetland Islands, Antarktika, wurde die Bildung von Buckeln und Hohlräumen festgestellt. Eine Grabung förderte eine Eislinsse von 60 cm Dicke unter einem Buckel zutage. Ein Zyklus für die Bildung der Buckel und Hohlräume infolge des Wachsens und Zusammenbrechens von Eislinsen wird vorgeschlagen.

INTRODUCTION

The purpose of this note is to draw attention to the disruption of bedrock in a periglacial environment by a process which does not appear to have been reported previously at this scale. During the course of field work carried out in the austral summer of 1975–76 in the South Shetland Islands (Figs 1 and 2), it was noted that there were associations of hummocks and hollows developed on the surface of the lapillite-tuff bedrock of Byers Peninsula, Livingston Island (lat. 62° 40' S., long. 61° 00' W.). The hummocks are in some respects similar to pingos incorporating bedrock (Müller, 1959) but they are smaller and consist entirely of bedrock. Pingo collapse produces a mound whereas the end product of the cycle of growth and decay of the hummocks described here is a hollow.

FORM MORPHOLOGY AND LITHOLOGY

The hummocks and hollows were of similar sizes, being approximately 3 m in length, 2.5 m in depth and with a relief amplitude of 0.3 m (Table I). The surface of each hummock had a crack running parallel to the long axis of the form and sometimes another at right-angles to it (Fig. 3). The ground surface was covered by a layer of randomly arranged local bedrock clasts and was underlain by a layer of fines 2–6 cm in depth. Beneath this was fractured bedrock (Fig. 4). Excavation of a hummock revealed an ice lens at 0.45–0.6 m below the surface, with a maximum thickness of 0.6 m. The ice was largely debris-free except for its margins where some bedrock fragments were in part incorporated. Vertically aligned

TABLE I. SIZES OF HUMMOCKS AND HOLLOWES

| | Hummocks | | | Hollows | | |
|--------------------------|----------|---------|--------------------|---------|---------|--------------------|
| | Mean | Maximum | Standard deviation | Mean | Maximum | Standard deviation |
| Length, m | 3.2 | 4.1 | 0.84 | 2.9 | 4.6 | 0.97 |
| Width, m | 2.5 | 3.6 | 0.91 | 2.5 | 4.5 | 1.04 |
| Height/depth, m | 0.33 | 0.57 | 0.15 | 0.28 | 0.35 | 0.06 |
| Slope angle on side, deg | 13 | 24 | 4.8 | 11 | 17 | 3.6 |
| Crack width, m | 0.11 | 0.18 | 0.03 | — | — | — |
| Crack depth, m | 0.31 | 0.47 | 0.09 | — | — | — |

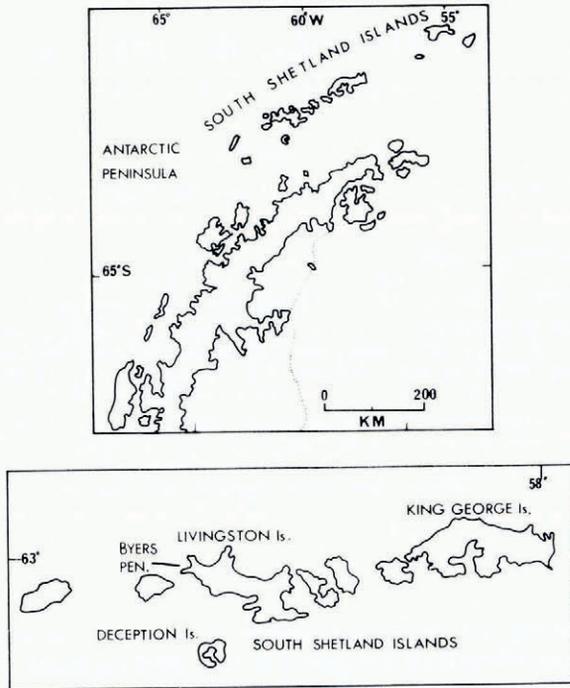


Fig. 1. The Antarctic Peninsula and the South Shetland Islands.



Fig. 2. A typical association of hummocks and hollows. 1 m of tape visible.



Fig. 3. One of the best-developed surface cracks.

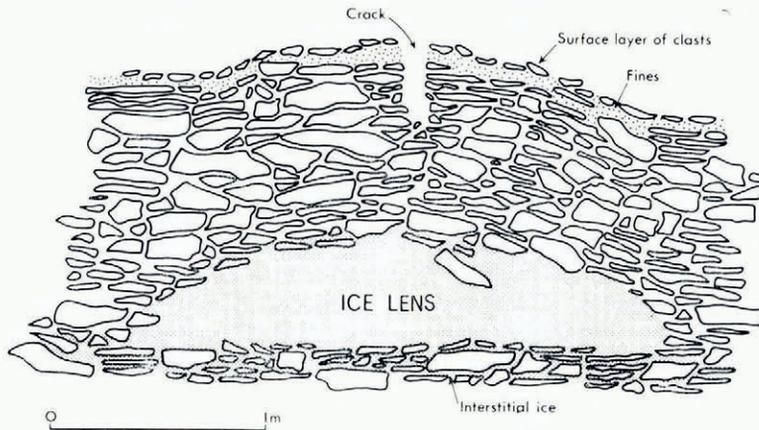


Fig. 4. Section through a hummock, based on photographs and field sketches.

lines of bubbles suggest that it is a lens of segregation origin (Washburn, 1973). Beneath the lens the bedrock was cemented by interstitial ice. The bedrock is a lapillite-tuff with clasts of pumice which are typically between 1 and 10 mm in diameter, though they may be up to 3 cm in size (personal communication from R. E. S. Davies, 1977). The tuff is very friable and breaks along horizontal or sub-horizontal planes to produce platy clasts about 10–15 cm in length, with a maximum of approximately 45 cm.

ENVIRONMENT

The climate of the South Shetland Islands is typical of the maritime Antarctic. Meteorological data are not available for Livingston Island but Pepper (1954) has given data for Admiralty Bay, King George Island (lat. 62° 10' S., long. 58° 30' W.) and Whalers Bay, Deception Island (lat. 63° 00' S., long. 60° 30' W.) (Table II). For most years the mean daily temperature is above freezing from December to March, so that melting of frozen ground is possible during this period. Permafrost was found at all sites investigated during the course of field work on Livingston Island. In January and February, when the work was carried out, the depth of the active layer at low altitudes (less than 30 m) was between 0.3 and 0.7 m, depending on materials.

TABLE II. CLIMATIC STATISTICS FOR WHALERS BAY AND ADMIRALTY BAY

| | <i>Whalers Bay</i> °C | <i>Admiralty Bay</i> °C |
|---------------------------------|--------------------------|----------------------------|
| Mean annual temperature | -2.8 | -2.7 |
| Mean daily temperature, January | +1.4 | +1.3 |
| Mean daily maximum, January | +1.7 | +3.3 |
| Mean daily temperature, July | -8.2 | -8.0 |
| Mean daily minimum, July | -11.5 | -11.4 |

INTERPRETATION

It would seem that the growth of the ice lens is causing the hummock and it is suggested that the hollows result from the collapse of the hummocks following the melting of the ice. A cycle of growth and decay of ice lenses is suggested as follows:

1. An ice lens is initiated at a point in the bedrock and begins to grow, heaving up the bedrock which cracks vertically to accommodate the expansion and deformation.
2. As the ice lens grows, the sides of the hummock steepen, enhancing mass wasting and resulting in the removal of material from the hummock.
3. During the winters the lens increases in size until a threshold is reached when the widening of the crack alters the thermal conductivity of the system to such an extent that the lens is susceptible to melting in subsequent summers.
4. With the melting of the lens the bedrock collapses and, because of the removal of material from the system, a hollow is produced.

No climatic change is necessary for the cyclical growth and collapse of ice lenses in this model so that the development of hummocks and hollows is possible under the present climate of Byers Peninsula. Lapillite is the dominant bedrock type of eastern Byers Peninsula, comprising 70% of the succession, so that this process is at least locally important and may be active in other periglacial environments with a suitable lithology.

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