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ABLATION POLYGONS ON SNOW—FURTHER OBSERVATIONS AND THEORIES

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Abstract. A general description of ablation polygons is given and variations from widely distributed regions are examined. After discussion of the conditions in which they most frequently develop, possible explanations are considered, leading to the conclusion that the polygons result from ablation by turbulence in the surrounding air, and that the dirt fringes to the polygons may be explained by the "normal trajectory" theory.

Zusammenfassung. Es wird eine allgemeine Beschreibung von Ablations-Polygonen gegeben, und Veränderungen nach weithin verbreiteten Regionen werden untersucht. Nach Besprechung der Bedingungen unter welchen sie sich am häufigsten entwickeln, werden mögliche Erklärungen erwogen, die zu der Schlussfolgerung führen, dass die Polygone das Resultat von Ablation, hervorgerufen durch Wirbel in der umgebenden Luft, sind, und dass die schmutzigen Ränder der Polygone durch die „normale Trajektorie" Theorie erklärt werden können.

Introduction

Attention was drawn to the phenomenon of "dirt polygons" in an article[1] in *Weather* by one of the present authors, and the correspondence resulting from this publication has been sufficient to justify a re-statement of the problem. Among the matters needing review is nomenclature, for the term "dirt polygon" is too suggestive of "soil polygon" and "stone polygon"[2,3], which seem to be quite unrelated in all respects other than shape. The phenomenon here described is essentially a feature of the snow surface, and the dirt fringe is so incidental that sometimes it does not even exist. In view of this confusion the revised terminology of "ablation polygon on snow" will be used in place of "dirt polygon".

Ablation polygons may be seen on the surface of partially ablated snowbeds. They consist of an array of shallow depressions in the snow surface, the centres of which are several inches apart. The cusp lines between adjacent depressions are generally, although not always, marked by a concentration of dirt: these lines form a polygonal pattern and will be called "dirt fringes" in this paper.

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Examples have already been cited from the Crossfell area[1], Scotland[4] and Alaska[6], but subsequent observations have been reported from Hampshire, Wales, Italy, Austria, Iceland and Japan, while further data have been assembled from the Crossfell and Alston area of Cumberland. Figs. 1 and 2 (p. 31) show splendid examples of ablation polygons on the upper and lower surfaces respectively of old firn in the Alps, and Figs. 3 and 4 are of the last remains of a snowbed at 5900 ft. (1798 m.) on Mount Kirigamine, in the Nagano prefecture of Japan. Amongst the most significant of these later observations is that of polygons on the vertical face of a snowbed near Black Burn on Crossfell (15 April 1955); something of this type is recorded by photograph (*b*) of P. C. Spink[4].

Conditions for Development

Certain general conditions seem to govern the formation of ablation polygons and of the accompanying dirt fringes, and the factors which appear to affect these two elements of the phenomenon may be considered separately.

In the first place ablation polygons appear to have few obvious controls. Geographical location is unimportant although their development appears to be affected by objects immediately surrounding the snowbed, such as boulders, trees, and even clumps of grass or heather. Nor do the depth or age of the snowbed have any great influence, although the best examples are found on snow initially quite thick and undergoing rapid ablation. North-facing slopes are often more likely to be affected, but polygons have been found on almost all orientations of slope. Further to this the degree of slope is similarly unimportant since they have been found on horizontal, sloping, vertical, and even inverted surfaces. The main influence therefore is likely to be meteorological, for the phenomenon is an aspect of ablation by evaporation. This usually implies moderate or strong warm winds, but excessive sunshine only causes grooves due to run-off of melt-water, and pitting where objects such as dirt and stones absorb more heat than the surrounding snow and melt the snow in contact with them by conduction. Heavy rain tends to diffuse the dirt so that if polygons form, they are without the dirt fringe, e.g. February 1956 at Alston. However, ablation polygons without dirt have also been seen in the Crossfell area during dry, clear, cold, calm weather: these frequently show a series of concentric rings in the depressions, possibly associated with thin strata in the snow.

The dirt fringe is not always present, but its occurrence is so frequent and its appearance so distinctive that it warrants special consideration. Clearly defined fringes may be very sharp indeed, in which case the dirt is usually atmospheric soot and locally introduced particles of soil and vegetation. Heavier objects, like gravel, do not tend to become concentrated along the lines. The dirt fringes can appear around any ablation polygon system irrespective of orientation or inclination of slope.

Discussion of Theories

The secondary nature of the dirt fringe, suggested by its occasional absence, means that its cause is likely to be independent of factors controlling the formation of ablation polygons. Consequently a separate approach must be made to each of these two features.

The cuspate surfaces characteristic of ablation polygons have been accounted for in a variety of ways and a summary is listed in the early work of Richardson[1]. In this significance was given to theories involving convection cells, both in the air above and in the snowbed. Upon closer examination convection cells do not appear to explain all the observations assembled and a new approach has been considered necessary. Strong or moderate winds would give rise to a stream of eddies in the lee of obstacles. These eddies can be regarded as rotating discs or cylinders of air with diameters comparable with the size of the obstacle, e.g. the diameter of a boulder, or the thickness of a tree trunk. In the relatively slow-moving boundary layer above the snow surface, these eddies could conform to a depression in the surface for a few seconds or less, causing a minute amount of ablation and maintaining or accentuating the shape of the depression before

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breaking down and being carried away. This suggestion fits the association observed between patches of cuspate surfaces and adjacent obstacles. It does not seem entirely consistent with this theory that dirtless polygons were found near Crossfell's summit in March 1953 during calm, dry, cold conditions. However, although the weather at Alston was calm, the mountain summit undoubtedly had some air movement, and ablation in the dry air of that month would have been by evaporation from the solid state. The concentric rings showing stratification sometimes revealed in these polygons also suggests evaporation, for melting in warm air would destroy the effect.

Having developed a theory for the ablation polygon it is necessary to explain the frequent association of the dirt fringe—a feature of remarkable clarity when the phenomenon reaches its best development. To explain this the process described by Ball[5] seems to be entirely convincing and satisfactory. This may be called the "normal-trajectory" theory. It suggests that by assuming that the trajectory of dirt particles is normal to the surface as ablation continues, dirt which is initially uniformly distributed tends to become concentrated along the ridges. The theory is largely confirmed by the observation that leaves of grass and heather, originally lying at random on the surface, tend to move to the adjacent ridge by being twisted to lie along it.

Conclusion

After a reconsideration of all the observations and theories assembled it is suggested that turbulence in the lee of surrounding obstacles accounts for ablation polygons, and that the "normal trajectory" theory of dirt motion on an ablating snowbed explains the dirt fringes. The "turbulence" theory concerning polygon development is especially suspect but both aspects of the phenomenon require verification by further observation or experiment. Up to date experimental approaches using smoke to observe air currents, and hair-dryers applied to sooty snow surfaces to synthesis polygons, have failed to show any results. There is still a need for careful observations from this country and abroad if the complexities of these fascinating features are to be completely solved.

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NOTES ON THE FORMATION OF OGIVES AS PRESSURE WAVES

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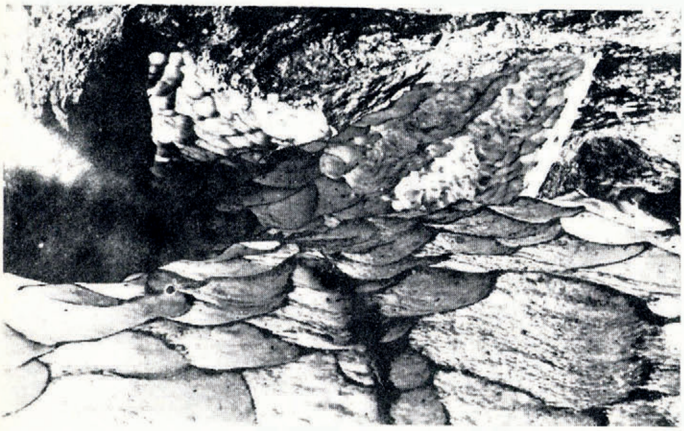
Based on the observations and velocity measurements on the Mt. Collon glacier, it was shown that during the time of ablation large local increases in velocity can arise, which were taken to be the cause for the formation of pressure waves[1]. In the report quoted below, the reason for the astonishing local acceleration of the movement in July, i.e., at the time of strongest ablation, was thought to lie in the increased amount of melt water and in the resulting reduction of friction on the glacier face[2].



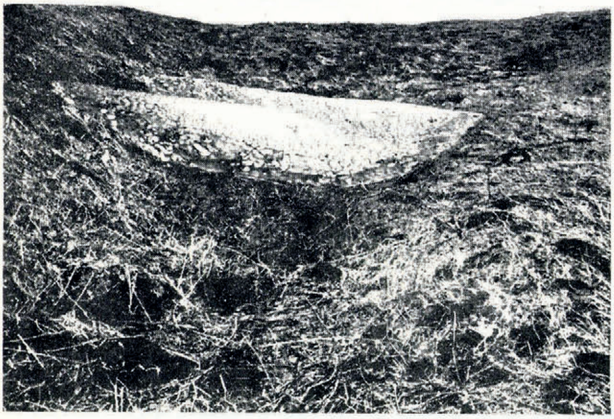


Fig. 1 (*above, left*). *Upper surface polygons on old* névé. *Fig. 2* (*above, right*). *Inverted dirt polygons under old* névé. (*Photographs, Dept. of Geography, Leeds University.*) *Fig. 3* (*below, left*). *Snow-bed with polygons. Mt. Kirigamine, Japan, 1 May, 1954. Fig. 4* (*below, right*). *Details of Fig. 3*. (*Photographs by H. Suzuki.*) (*See W. E. Richardssn* and *R. D. M. Harper, p. 25.*)

BENDING OF BLUE-BANDS BENEATH HEAVY BOULDERS

Cambridge Austerdalsbre Expedition 1955, Paper No. 3

By G. de Boer

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A neat demonstration of the plasticity of ice under pressure was seen on Austerdalsbreen, Norway, during the summer of 1955. The camp of the Cambridge Expedition was situated on a patch of moraine, the largest boulders of which must have weighed some hundreds of tons. Ablation of the