R. Bruce King *
Esher, Surrey

LOBES IN THE CAIRNGORM MOUNTAINS, SCOTLAND

Abstract

Measurements of sizes and orientations of boulders in the centre and exterior of lobes suggest that they are produced by viscous flowage but controlled by bedrock jointing. Two different lobe types are recognized: stone-banked and vegetation-covered. The latter, which is a less active version of the former probably date from Zone IV and most of the former from the Little Ice Age.

INTRODUCTION

The Cairngorm Mountains, which straddle the borders of the counties of Inverness, Banff and Aberdeen and reach a maximal height of 4,300 ft. (1,300 m), are extensively covered by lobes and are, therefore, a suitable area for studying the processes governing these features. The mountains possess a periglacial climate, as defined by Sharp (1942), i.e. „characterized by low temperatures, strong winds, and many fluctuations across the freezing-point at certain seasons". It should also be noted that they consist of well-jointed granite, which weathers (by granular disintegration) into well-rounded boulders, which comprise the coarse fraction of lobes.

As a first approach to an understanding of the processes governing lobes, they were mapped and particular attention was paid to their variability, if any, with respect to lithology, angle of slope, altitude and aspect. A week was also spent in the Kebnekaise region of northern Sweden. Here, the more severe climate, lack of vegetation and different rock types (mostly phyllites) provided an interesting comparison with the Cairngorm Mountains.

GENERAL DESCRIPTION

There are two common lobe types in the Cairngorm Mountains: stone-banked and vegetation-covered. The former is differentiated from the latter by the presence of a stone garland. Stone-banked lobes are found at higher

* Kerry Stables, Lammas Lane, Esher, Surrey. Great Britain.

altitudes and on steeper slopes than vegetation-covered ones. Where stone-banked and vegetation-covered lobes are present on the same constant-angle slope, stone-banked lobes occupy the higher part. Nevertheless, angle of slope is more important in determining the presence of stone-banked lobes than altitude, since where the lower part of a slope is steeper than its upper part, stone-banked lobes are found on the former and vegetation-covered lobes on the latter.

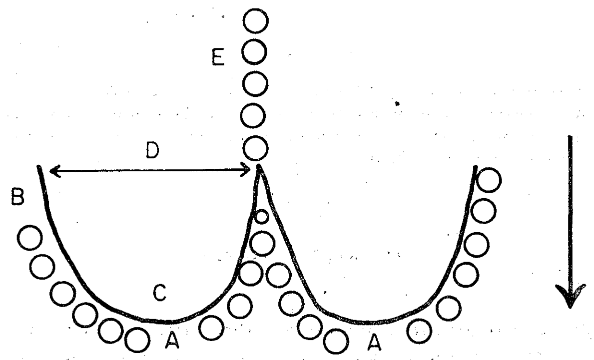


Fig. 1. Theoretical diagram showing the plan of two lobes of a series

Arrow indicates downslope direction. Small circles represent a stone garland. A–A is a lobe front. E is a boulder stream

Lobes occur in series. Figure 1 shows two lobes of a series. The other lobes of the series extend both sides of these lobes such that the line AA, here defined as the lobe front is approximately tangential to all the lobes of the series. Examples can be seen in Plate 1. A lobe series usually but not

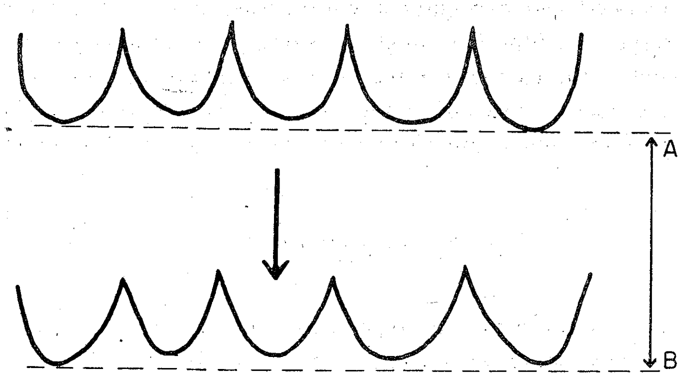


Fig. 2. Plan of two lobe series

Arrow indicates downslope direction. Broken lines are lobe fronts necessarily relates to the series upslope and downslope. Lobe fronts usually parallel contours and the distance between them (AB in Figure 2) varies from 10 to 200 yards (9 to 180 m).

STONE-BANKED LOBES

Stone-banked lobes occur over a wide range of altitude: from just below the highest mountain summits to 1,750 ft. (550 m). They generally occur on slopes between 20° and 35° but can also be found on slopes as low as 10°. These figures can be compared with those of Spitsbergen described by Klatka (1961) who found 'garlands' (stone-banked lobes) on slopes between 11° or 12° and 28° to 30°.

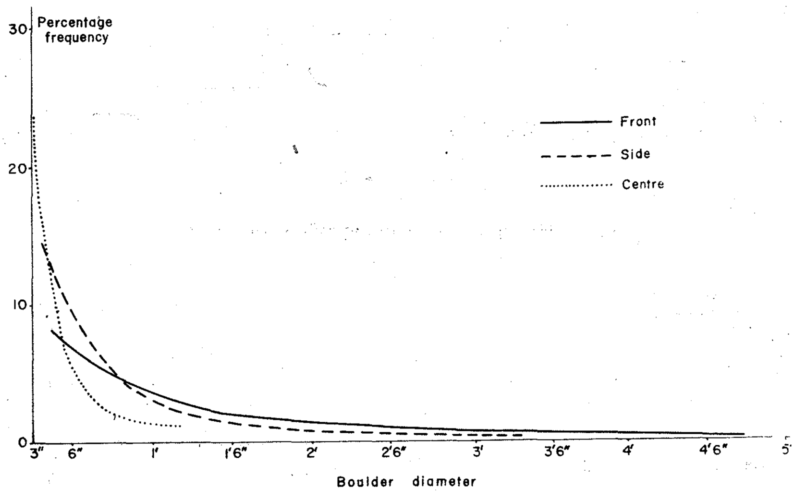


Fig. 3. Frequency curves of the boulder sizes of the front, side and centre of stone-banked lobes

The interior of stone-banked lobes consists of boulders, soils, and vegetation. The exterior consists of larger boulders and no soil or vegetation (Pl. 2). Figure 3 shows the distribution of boulder sizes for the front, side and centre (A, B and C respectively in Figure 1) of four randomly selected stone-banked lobes. Samples of twenty-five were taken from the front, side and centre of each lobe. The length of the longest axis of each boulder was measured to the nearest inch. Any stone below 3 in. (7.5 cm), which is the usual smallest stone diameter of the exterior, was disregarded. Since the distribution showed curvature when plotted on semi-logarithmic paper, a second degree curve fitted to logarithms was tested and found to fit the distribution within the level of accuracy of the original measurement. The equations of the curves are:

$$\text{Front: } \log y = 1.01 - 0.0566\,x + 0.000484\,x^2 \qquad (1)$$

$$\text{Side: } \log y = 1.25 - 0.0952\,x + 0.00126\,x^2 \qquad (2)$$

$$\text{Centre: } \log y = 1.42 - 0.252\,x + 0.0119\,x^2 \qquad (3)$$

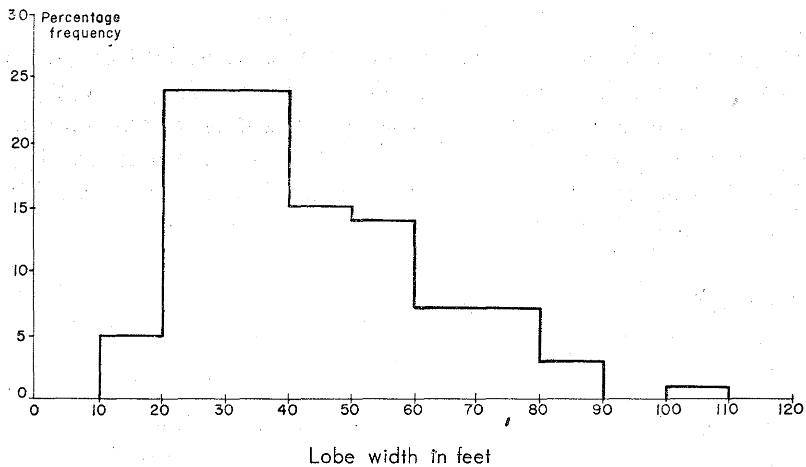


Fig. 4. Histogram of stone-banked lobe widths

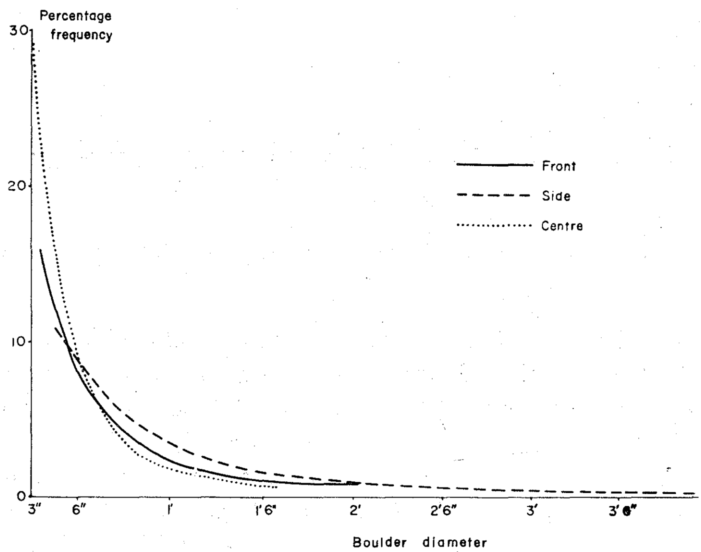


Fig. 5. Frequency curves of the boulder sizes of the front, side and centre of vegetation-covered lobes

The mean boulder diameters of the front, side and centre are 12.78 in. (32.5 cm), 9.28 in. (23.5 cm) and 4.98 in. (12.6 cm) respectively. The mean boulder diameter of the entire lobe, as indicated by the samples, is 9.02 in. (23.0 cm). Boulder size also appears to increase with depth.

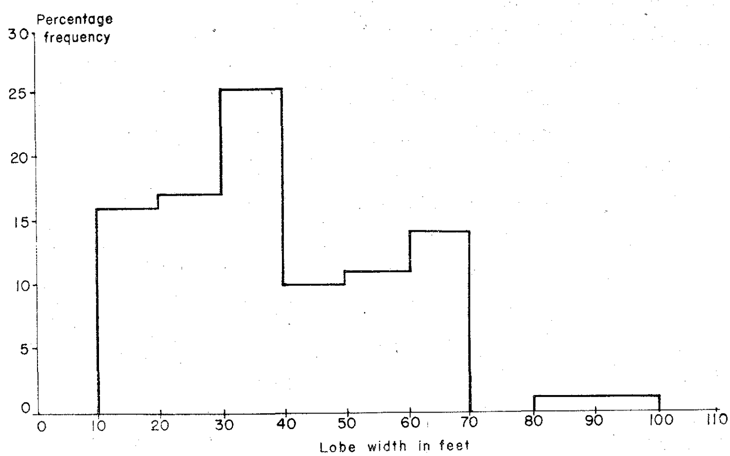


Fig. 6. Histogram of vegetation-covered lobe widths

The sizes of a hundred stone-banked lobes were measured from areas scattered throughout the Cairngorm Mountains. Maximal lobe widths (i.e. D in Figure 1) to the nearest foot were measured for each lobe. In Figure 4, the distribution is plotted in frequency groups of ten feet. A curve was not calculated because even a logarithmic normal curve was found to depart greatly from observed values. The distribution appears logarithmic but with a lower limit which presumably represents the smallest width a lobe can attain without losing its form. The limit, is, however, gradual which may be due to a relationship between lobe width and boulder size or variations in joint density.

VEGETATION-COVERED LOBES

Vegetation-covered lobes occupy a much greater area than stone-banked ones. They occur over a similar altitude range to stone-banked lobes (viz. 4.000 ft. (1.200 m) to 1.750 ft., 550 m); but as mentioned earlier, they usually occupy the lower part of a constant-angle slope where stone-banked occupy the upper part. They generally develop on slopes between 10° and 20° but they do also rarely occur on slopes as steep as 30° and as gentle as 5°. These figures can be compared with those for Spitsbergen described by Dutkiewicz (1961) who found lobes occurring on slopes between 3° and 20°. Sharp

(1942) described lobes in the Yukon on slopes between 5° and 15°. Neither of these authors differentiated, in their slope measurements, between vegetation-covered and stone-banked lobes.

Plate 3 shows vegetation-covered lobes. As defined, they do not possess a stone garland but excavation into the border of some lobes did reveal large boulders (Pl. 4). Figure 5 shows the distribution of boulder sizes for the front, side and centre (A, B and C respectively in Figure 1) of four randomly selected vegetation-covered lobes. The same methods of sampling, measurement and curve fitting were used as for stone-banked lobes. The equations of the boulder sizes of vegetation-covered lobes are:

$$\text{Front: } \log y = 1.24 - 0.122\ x + 0.00266\ x^2 \tag{4}$$

$$\text{Side: } \log y = 1.15 - 0.075\ x + 0.000800\ x^2 \tag{5}$$

$$\text{Centre: } \log y = 1.48 - 0.190\ x + 0.00595\ x^2 \tag{6}$$

The mean boulder diameters of the front, side and centre are 8.62 in. (21.9 cm), 11.14 in. (28.2 cm) and 6.08 in. (15.4 cm) respectively. The mean boulder diameter of the entire lobe, as indicated by the samples, is 8.61 in. (21.9 cm).

A hundred vegetation-covered lobes' widths were also measured from samples scattered throughout the area studied. Their size distribution is shown in Figure 6. Method of measurement and plotting were the same as for stone-banked lobes. The mean width was found to be 42.0 ft. (12.8 m) with a standard deviation of 24.6 ft. (7.6 m). The distribution is also further removed from a logarithmic normal curve than that of stone-banked lobes. The geomorphic significance of these factors will be discussed later.

DISCUSSION OF HYPOTHESES

Peach *et al.* (1912, p. 160) put forward earth creep as a hypothesis to explain lobes but they did not go into any details. Most of the other hypotheses, which have been proposed, can be considered different types of creep. Williams (1959) (amongst other hypotheses) proposed that the weight of a snow patch could initiate movement. However, snow patches in the Cairngorm Mountains occurred between lobes rather than on them. On the other hand, if a lobe of one series occurs downslope from the re-entrant of the series above as at A in Pl. 3, and if the lobe fronts are sufficiently close together, the weight of the snow patch could possibly affect the lobe downslope. But, mostly, lobes follow each other downslope (Fig. 2) and, in any case, lobes probably govern the position of snow patches, not the reverse.

Williams (1959) also suggested that meltwater, either by its weight or because it decreases soil strength, might cause lobe movement. He showed that when meltwater was added to the soil, pressures measured to a depth of 56 cm only recorded pressure equivalent to that of 25 cm. Meltwater would cause maximal movement in the spring which was found to be true of Victoria Island, Arctic Canada (Washburn, 1947, p. 92). Most authors (Williams, 1957a and b; Rudberg, 1958; Smith, 1960, and Jahn, 1961), however, found maximal movement in both spring and autumn.

In equations (1)–(6), the constant term is the logarithm of the intersection of the curve with the y–axis, i.e. it gives the logarithm of the percentage of stones of 3 in. (7.5 cm) diameter. The coefficient of x is an average logarithmic gradient, i.e. a generalisation of the distribution, and is the most important coefficient to consider. The coefficient of x in equation (3) is much less than that of equations (1) and (2). The hypothesis, to which a χ^2 test was applied ,was therefore considered whether the population represented by equation (3) could belong to that represented by equation (1). Because of the second degree logarithmic nature of the distribution, the lower class intervals were taken at every inch, but the higher ones were grouped together and every measurement greater than 1 ft. was grouped together. This was done because the distribution of observed frequency values around computed frequency values does not properly correspond to the expected distribution when the expected frequency is small (Cochran, 1942). The value of χ^2 was found to be 170. If this figure is compared with a probability criterion of 0.005 (Thompson, 1941), the populations represented by equations (1) and (3) are found to be different. Applying a similar test and using the same probability criterion, it was also shown that the population represented by equation (2) is also unlikely to belong to that represented by equation (1). Lobes thus appear to be sorted in much the same way as polygons and stripes. It would be reasonable to suggest a genetic connection, evidence of which can be seen on a slope in the Cairngorm Mountains where stripes can be traced downslope into lobes and at Kebnekaise, where the overspilling of a polygon was seen to produce a lobe (Pl. 5). The sorting can be maintained by viscous flowage, which Jahn (1961) proposed as a hypothesis for lobe development. Dżułynski and Walton (1963) have shown that viscous flowage produces sorting and also a lobe border as the coarse material "immediately ahead ... is pushed forward and aside" and "piles up between neighbouring convexities to form a ridge", which conforms with the boulder stream which extends upslope from lobes (Fig. 1 and A in Pl. 2) and which Lundqvist (1949) has suggested is the border of the lobes as they move downslope. Other evidence in support of viscous flowage was shown by Jahn (1961) who found that stakes in a lobe centre moved further than those at the side. On Victoria Island, Arctic Canada, Washburn (1947, p. 92) found a similar convex downslope curvature of movement.

Thus viscous flowage seems to explain both the internal sorting and external appearance of stone-banked lobes. However stone orientation mea-

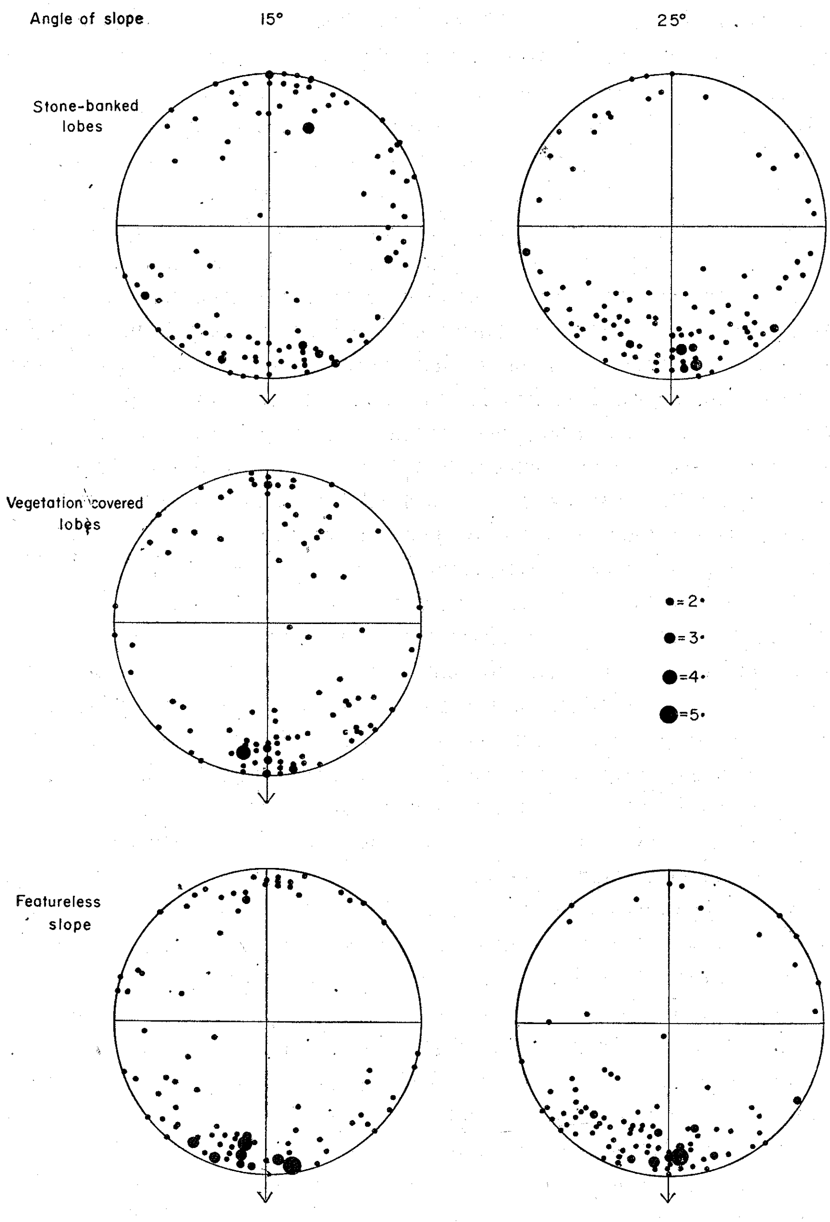
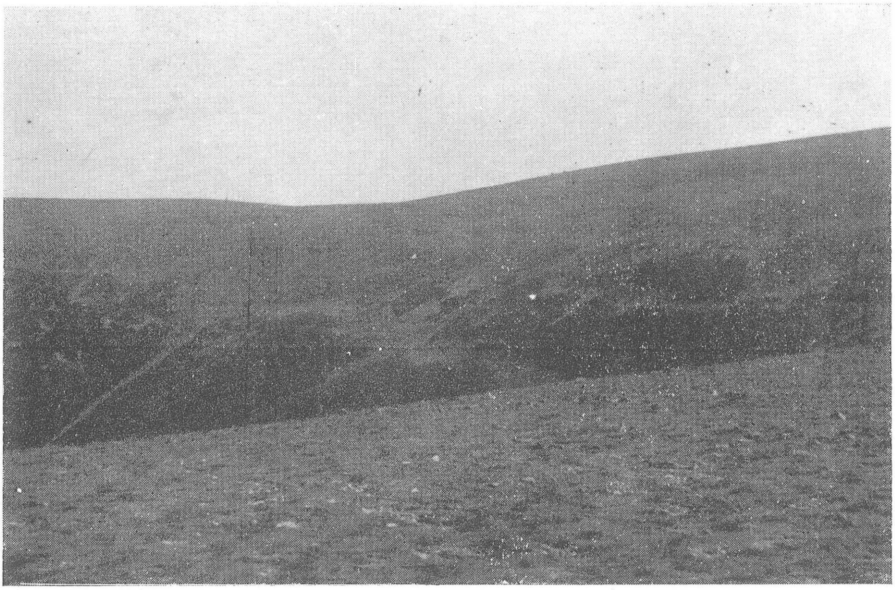


Fig. 7. Stone orientation diagrams of the centres of stone-banked and vegetation-covered lobes on 15° and 25° slopes compared with stone orientation diagrams of featureless slopes of the same angles

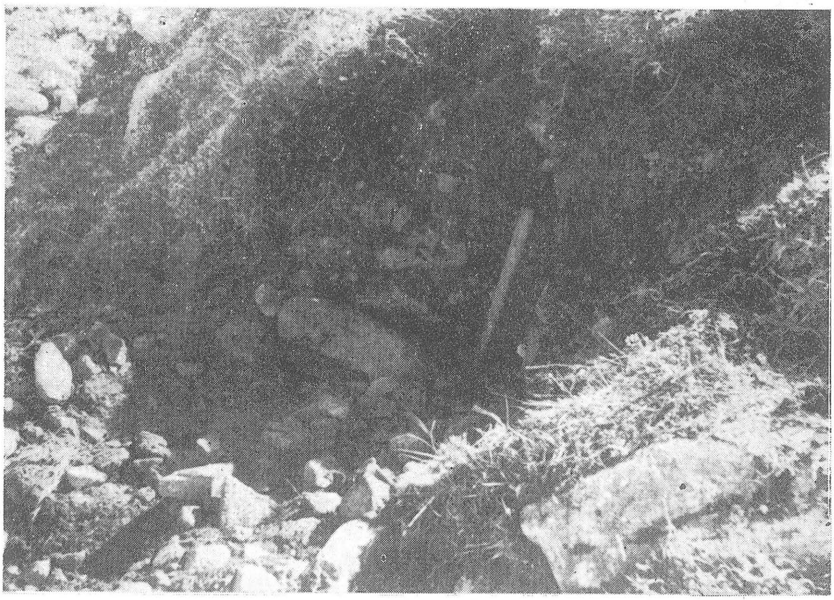


Pl. 1. Lobe series on Carn Ban Mor at 3,000–3,500 ft. (900–1,100 m)

Pl. 2. Stone-banked lobes at 3,250 ft. (1,000 m) in Coire an t-Sneachda

Note the boulder stream at 'A'

Pl. 3. Vegetation-covered lobes at 3,500–3,750 ft. (1,100–1,150 m) on the slope between Coire Bogha-cloiche and Coire an Lochain



Pl. 4. Excavation into the border of a vegetation-covered lobe at 2,500 ft. (750 m) on the northern slope of Fiacaill a'Coire Chais

Pl. 5. Avalanching of stones over boulders to form a lobe at about 4,000 ft. (1,250 m) in the Kebnekaise district

Pl. 6. Stone-banked lobes at about 4,000 ft. (1,250 m) in the Kebnekaise district

surements of lobes compared with a featureless slope, in the immediate environment of the lobes and with the same lithology, angle of slope, altitude and aspect, appear to introduce a contradiction. Four randomly selected sites of twenty-five stones from position C in Figure 1 were taken to make up each diagram in Figure 7. Orientations were measured to the nearest 5° and the angle of inclination to the nearest degree. Orientations were measured of stones with a minimal elongation ratio of 3 : 2 for long to intermediate axis respectively. The smallest long axis measured was 2.5 in. (6.25 cm). The diagrams show a preferred orientation downslope, as to be expected. The apparent slight right-hand preference is probably an experimental error due to inaccuracies in measuring deviations from the downslope direction. Orientation percentage strengths are shown in Table I. The only value which is not statistically significant (Curray, 1956) is that of stone-banked lobes on a slope of 15°. The table shows, as expected, that strengths increase with angle of slope but it also shows that orientations on a featureless slope have a greater strength than in lobes. Hypotheses were therefore considered whether lobe populations could belong to those of the featureless slope and χ^2 tests were applied. Considering the argument raised in the test of equations (1) and (3), class intervals were taken

Table I

Percentage strengths of stone orientations of lobes compared with a featureless slope for 15° and 25° slopes

	15°	25°
Stone-banked lobes	16.6	56.6
Vegetation-covered lobes	28.7	
Featureless slope	39.4	70.3

as 5° for low downslope deviations, 10° in most of the others and as much as 30° for low upslope deviations. χ^2 values are shown in Table II. Using a probability criterion of 0.05, stone orientations of stone-banked lobes are found to belong to a different population to those of a featureless slope. In fact, a probability criterion of 0.005 in the case of the 15° slope and 0.025 for the

Table II

χ^2 values of stone orientations of lobes compared with a featureless slope for 15° and 25° slopes

	15°	25°
Stone-banked	77.79	38.77
Vegetation-covered	32.97	

25° slope also suggest different populations (Thompson, 1941). However, even a probability criterion of 0.1 does not prove any difference in the case of vegetation-covered lobes. It should be noted, however, that the same criterion value also does not prove any similarity.

A discussion of stone orientations in lobes cannot avoid reference to Lundqvist (1949, Figure 8), who claimed that lobes have a radial orientation in the centre and a tangential orientation in the circumference. There is no obvious sign of circumferential orientation in the chaotic assemblage of well rounded boulders which form stone garlands in the Cairngorm Mountains but it was observed by the present author in the platy phyllite boulders of Kebnekaise, especially in areas of high lobe density. The orientation in the sides in areas of high lobe density at Kebnekaise is presumably due to interaction with neighbours; the orientation in the front and sides where there is a lower density is probably due to interaction with large boulders (Pl. 6) and/or rock outcrops in the lobe's path. Similar interactions with the well rounded boulders of the Cairngorm Mountains would probably have a more dynamic effect than with platy boulders: well rounded boulders are more likely to be squeezed out. This might explain the large accumulation of boulders found immediately downslope from many lobes in the Cairngorm Mountains.

Despite the evidence suggestive of viscous flowage, there seems to be a resisting force in stone-banked lobes in the Cairngorm Mountains preventing high downslope orientation strength. A consideration of lobe fronts could explain this dilemma. They were mentioned earlier as being mostly parallel to the contours but, in many places, they are aligned across the slope although the axes of the lobes themselves are still downslope. Skew lobe fronts have also been observed in Norway (Williams, 1957b, p. 42). In one particular place in the Cairngorm Mountains, two lobe fronts could be traced perpendicular to each other and in a rock outcrop nearby, the dominant jointing direction was found to coincide exactly with the dominant lobe front direction. Coincidence of jointing and lobe front directions seemed to hold true in other areas but the multiplicity of joint directions made proof inconclusive. It would seem, therefore, that structure is an important factor in positioning a lobe front. Frost action is known to be very selective: weak bands are easily eroded and stepped slopes are common in periglacial climates. As lobes approach the edge of a resistant band, they would be decelerated. In areas of dense structural control and strong bedrock influence, where the distance between resistant bands is small and the lobate form has not the distance or thickness of materials to develop, altiplanation terraces would be found. Evidence to support this can be found in the Cairngorm Mountains, since altiplanation terraces occur near summits and on arêtes where the bedrock influence is strongest. Although no direct evidence of resistant bands preventing lobe movement was observed in the Cairngorm Mountains, lobes were seen resting on resistant bands in the Kebnekaise region. In the Cairngorm Mountains, a small 12 ft. (3.5 m) wide stone-banked lobe contained two 10 ft. (3 m) diameter boulders in its stone garland which appeared effectively to be preventing further downslope movement. Similar evidence was frequently seen at Kebnekaise; here the large boulders appeared to have disintegrated *in situ* from rock outcrops.

DIFFERENCES BETWEEN STONE-BANKED AND VEGETATION-COVERED LOBES

It remains to be explained why vegetation-covered lobes have stronger downslope orientation than stone-banked ones. After lobes have become inactive, normal surficial solifluction (here used in the strict sense to mean downslope movement without the necessity of permafrost) would take place and is presumably responsible for the stone orientation of the featureless slope. Vegetation-covered lobes have probably therefore been inactive for a longer period of time than stone-banked ones.

Another difference between the two lobe types is provided by a comparison of Figure 4 and 6, which suggests that the widths of stone-banked lobes more closely approach a logarithmic normal curve than the widths of vegetation--covered ones, although statistical analysis can neither prove or disprove that they belong to the same population. Lobes may be initially and on low angle slopes, strongly influenced by structural control. Further development, however, would tend to negate these structural controls and size distributions would approach logarithmic normality. It would appear therefore, that vegetation-covered lobes are not as developed or as active as stone-banked ones. The secondary peak between 60 and 70 ft. may be due to resistant bands of this spacing in the localities sampled. Evidence of structural control of lobe width was seen in the Kebnekaise region: lobes are bifurcated by resistant outcrops. The difference in frequency of 10–20 ft. between Figures 4 and 6 may be due to the incorporation of small lobes by large ones in the more active stone-banked lobes. Evidence suggestive of this was found very occasionally; Figure 8 shows a stone-banked lobe which seems to have overrun a smaller one which has since become partly vegetated.

There is also a difference in sorting between the two lobe types. When a χ^2 test, using the same class intervals as for the comparison between equations (1) and (3), is used to see if the population represented by equation (6) could belong to that of equation (3) and a probability criterion of 0.01 is applied, the distributions are found to be different. The difference is seen in Figures

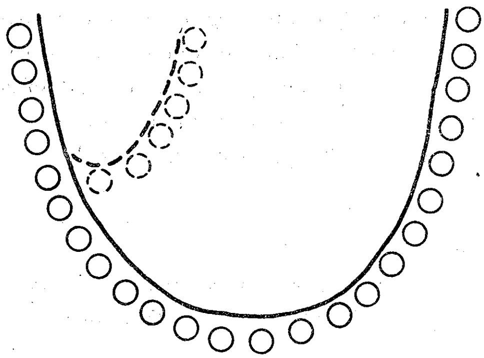


Fig. 8. Incorporation of a partly vegetation-covered lobe (broken line) in a larger stone--banked lobe

Full circles: stone garland; broken circles: buried stone garland

3 and 5 by the greater area under the curve of equation (6) than that of equation (3), i.e. in the centre of a vegetation-covered lobe, there is a significantly greater proportion of coarse boulders than in a stone-banked one, which in turn, suggests that vegetation-covered lobes are less developed than stone-banked ones. Thus there appears to be further evidence that stone-banked lobes are active for a longer period than vegetation-covered ones and are presumably therefore active in milder climates than those necessary for vegetation-covered lobe development. Most probably, vegetation-covered lobes were stone--banked during their active period but have since become vegetated (Pl. 4).

AGE

Very occasionally, at high altitudes and on steep slopes, the stone garlands of stone-banked lobes are bounded by a turf bank, about 1 ft. (30 cm) high. Galloway (1958) suggested that these turf banks indicate present-day activity. He envisaged the lobes burrowing into the soil. Evidence in support of this hypothesis was found above 2.900 ft. (900 m) on a west-facing slope in the Cairngorm Mountains where a correlation between turf banks and lack of lichen on boulders forming the stone garland was seen and vice versa. A few hundred feet downslope (2.600–2.750 ft., 800–840 m), some measurements were made of lichen diameters. Every facet of every boulder in a stone garland was examined and the sixty largest diameters of *Rhizocarpon geographicum* thalli were recorded to the nearest 0.25 in. (6 mm). Where the thalli were elliptical, the shorter diameter was measured. Following Stork (1963), a mean diameter was calcutated from the five largest thalli. As suggested by

Sugden (1965), diameters were compared with those of the Jostedalsbreen region in southern Norway, since this is the climate approximating closest to that of the Cairngorm Mountains, where growth rates have been measured. In the former region, Bornfeldt and Osterborg (1958) measured a growth rate of 46 mm per century. Since the measured lobes occur only a few hundred feet downslope from the active ones (those with a turf bank), it is likely that the lichen are first generation. The measurements indicate dates from 1610 to 1730 A.D., which agrees with travellers' accounts (e.g. Taylor, 1618) of a colder climate at about this time, which roughly corresponds with the period which has been called the Little Ice Age.

Most stone-banked lobes in the Cairngorm Mountains, are probably only activated by climatic catastrophies, such as a sudden and large snow melt or a severe storm producing supersaturated ground. Intense frost heave and/or permafrost, which would also produce supersaturation, may have existed in the Cairngorm Mountains in the seventeenth and eighteenth centuries and may account for the lichenometric measurements.

Vegetation-covered lobes are found on glacial deposits in valleys extending into the Cairngorm Mountains. These deposits can be tentatively dated as Zone III, if the glacial history of the Cairngorm Mountains is considered similar to that of the rest of highland Scotland. The most likely period of activity of vegetation-covered lobes is during the initial rapid amelioration of climate in Zone IV when there was excess meltwater, possibly permafrost and before they could be stabilised by vegetation.

SUMMARY

Stone-banked lobes are found at higher altitudes and on greater angles of slope, are more sorted but are not so strongly oriented as vegetation-covered ones. The sorting of both lobe types is similar to that found in polygons and stripes and on one slope, stripes merge into lobes downslope. The experiments of Dżułynski and Walton (1963) show that viscous f ow ıge maintains the sorting and accounts for the boulder streams extending upslope from the lobes. However, stone orientation measurements indicate a weaker orientation in lobes that that found on a featureless slope of the same angle, suggesting that there is a resisting force in lobes preventing downslope movement. It was also found that lobes occur in series in such a way that a straight tangent can be drawn, here called a lobe front. Since lobe fronts seem to coincide with the dominant jointing direction of the granite, it seems reasonable to conclude that joint-controlled ledges decelerate lobes so that they tend to come to rest on these ledges, which are subsequently obliterated by weathering. The stronger

orientation and less-developed sorting of vegetation-covered lobes together with the other factors which differentiate them from stone-banked ones, all suggest that they are stone-banked lobes which have ceased activity, probably since Zone IV. Most stone-banked lobes were probably active in the Little Ice Age, while some at high altitudes (above about 3.000 ft., 900 m) are active to-day.

ACKNOWLEDGEMENTS

I would especially like to thank Dr. J. B. Sissons for providing me with invaluable advice throughout my research. I also owe a debt of deep gratitude to the Natural Environment Research Council of Britain for giving me a grant and paying my travelling expenses both to the Cairngorm Mountains and the Kebnekaise region of northern Sweden. I would further like to thank the Department of Physical Geography of Stockholm University for allowing me to stay at a reduced rate and for making my sojourn so enjoyable at the Tarfala Research Station. My gratitude is also expressed to Mr. M. J. Burke for organising the expedition to Kebnekaise. My thanks are also extended to the Aviemore Police (Scotland) for concerning themselves about my welfare when I was camping in the Cairngorm Mountains.

References

Bornfeldt, F. & Österborg, H., 1958 – Lavarter som hjlpmedel for datering av ändmoräner vid norska glaciärer. Unpub. report. Dept. Geogr. Stockholm.

Cochran, W. G., 1942 – The χ^2 correction for continuity. *Iowa State College Jour. Sci.*, 16: 4.

Curray, J. R., 1956 – The analysis of two dimensional orientation data. *Jour. Geol.*, 64.

Dutkiewicz, L., 1961 – Congelifluction lobes on the Southern Hornsund coast in Spitsbergen. *Biuletyn Peryglacjalny*, no. 10.

Dżułyński, S. & Walton, E. K., 1963 – Experimental production of sole markings. *Trans. Edinb. Geol. Soc.*, 19.

Galloway, R. W., 1958 – Periglacial phenomena in Scotland. Thesis presented at the Univ. of Edinburgh.

Jahn, A., 1961 – Quntitative analysis of some periglacial processes in Spitzbergen. *Zeszyty Nauk. Uniw. Wrocł.* Nauka o Ziemi 2, ser. B: 5.

Klatka, T., 1961 – Problèmes des sols striés de la partie septentrionale de la presqu'île de Sörkapp (Spitzbergen). *Biuletyn Peryglacjalny*, no. 10.

Lundqvist, G., 1949 – The orientation of the block material in certain species of flow earth. Points of view on method. *Geogr. Ann.*, vol. 31.

Peach, B. N., Horne, J., Gunn, W., Clough, C. T., Hinxman, L. W., Crampton, C. B. & Anderson, E. M., 1912 – The geology of Ben Wyvis, Carn Ghuinneag, Inchbae and the surrounding country, including Garve, Evanton, Alness and Kincardine. *Mem. Geol. Surv. Scot.*

Rudberg, S., 1958 – Some observations concerning mass movement on slopes in Sweden. *Geol. För. Förh.*, Bd. 80:1.

Sharp, R. P., 1942 – Soil structures in the St. Elias Range, Yukon Territory. *Jour. Geomorph.*, vol. 5.

Smith, J., 1960 – Cryoturbation data from South Georgia. *Biuletyn Peryglacjalny*, no. 8.

Stork, A., 1963 – Plant immigration in front of retreating glaciers, with examples from Kebnekaise area, northern Sweden. *Geogr. Ann.*, vol. 45.

Sugden D. E., 1965 – Aspects of the glaciation of the Cairngorm Mountains. Thesis presented at the Univ. of Oxford.

Taylor, J., 1618 – The pennyless pilgrimage. London.

Thompson, C. M., 1941 – Table of percentage points of the χ^2 distribution calculated by Catharine Anne Thompson. *Biometrika*, 32.

Washburn, A. L., 1947 – Reconnaissance geology of portions of Victoria Island and adja cent regions. Arctic Canada. *Geol. Soc. America, Mem.* 22.

Williams, P. J., 1957a – The direct recording of solifluction movements. *Amer. Jour. Sci.*, vol. 255.

Williams, P. J., 1957b – Some investigations into solifluction features in Norway. *Geog. Jour.*, vol. 123.

Williams, P. J., 1959 – Solifluction and patterned ground in Rondane. *Norsk. Vidensk Akad. i Oslo, 1, Mat.-Naturv. Klasse*, No. 2.