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ASPECT AND LANDFORMS IN NORTH EAST YORKSHIRE

The variation of slope angle according to aspect, the distribution of fossil mass movement phenomena and the results of snow patch erosion have been examined in the drainage basin of the Esk in north east Yorkshire, England.

Throughout this area there are many small terraces or benches, sometimes boulder-strewn, which cannot be related on the basis of height. They occur most frequently on slopes facing north east and north west (fig. 1) although they are present, less well-developed, on slopes facing in other directions. These benches are especially well-developed on two outcrops of coarse, resistant gritstone. Similar features may exist on other outcrops but they cannot be identified with certainty. The benches are small in size; the flats are usually about 30 yards wide (30 metres), they possess steep, well defined backs (up to 20 degrees) and the slope angle of the terrace flat itself is usually quite high and sometimes as great as 7 degrees. In some cases the features occur in groups distributed either laterally or vertically on a valley side and they are most frequent between 800 and 1100 feet O.D. (240—330 metres).

Similar but larger features identified in southern England (Te Punga 1956; Waters 1962) have been termed altiplanation terraces; periglacial features in Quebec possessing similar characteristics have been described as nivation hollows (Henderson 1956), and golets terraces have been described in the Mongolian People's Republic (Richter 1963). Eakin (1916, p. 78) originally described altiplanation terraces as "essentially accumulations of loose rock materials" but these Eskdale features are erosional in origin. They are bench-like in form and are therefore termed *nivation benches*.

Sections were taken through several of the benches. On each terrace, below a podzol soil profile, there is a deposit of blue or yellow sandy clay.

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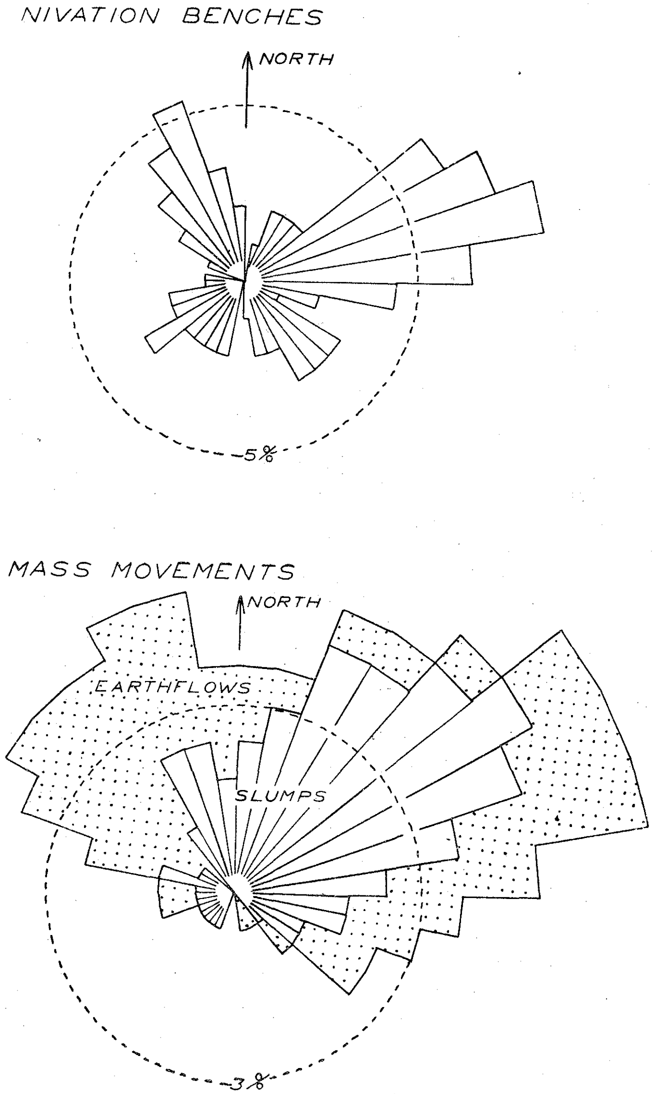

Fig. 1. The number of nivation benches, slumps and earthflows in the Esk drainage basin, Yorkshire, plotted for 10 degree groups according to aspect

On some terraces there is a slight sill at the outer edge of the flat and this appears to be in bedrock and not the result of deposition. The morphology and distribution of the benches indicates that they were probably developed by freeze—thaw processes activated by snow patch erosion (Lewis 1939; Nichols 1963). Finely comminuted material found beneath snow patches in Spitsbergen (Lewis 1939) may correspond to the sandy clay found resting on the terrace flats in Eskdale. The occurrence of well-developed benches on the two resistant outcrops shows that specific rock types are most suitable for the maximum development and preservation of the landform. The development of a nivation bench depended upon the previous existence of a flat facing north east or north west on which a snow patch could accumulate. The duration of the snow patch, especially as affected by aspect, seems to have been important in determining the extent to which nivation occurred. The angles of slope at the back of the nivation benches are higher than those at similar levels on the same outcrops where the features are not developed. Therefore snow patch erosion led to an increase in slope angle on slopes facing north west and north east.

The nivation benches occur above the level of the main free face in the area. In some cases large rotational slumps occur below this free face. These slumps are now stable — they are much larger than present mass movements, they have been eroded slightly by smaller mass movements (principally earthflows and debris slides), they are now vegetated and in some cases peat has accumulated behind the slumped masses. These slumped masses occur most frequently on slopes facing north east but also, to a lesser degree, on those facing north and north west (fig. 1). They are restricted to outcrops of a finely laminated shale overlain by a heavy resistant sandstone which forms the free face in the slope profile. In some of the slumped masses the bedding of the shale is still preserved and blocks of sandstone are also included. The presence of these blocks indicates that the slumps incorporated material detached from the free face. In one case the free face is cambered (Danby Dale) although this is also a fossil feature. In some cases the slumps occur in three groups and this may reflect three distinct phases of slumping.

The development of these features is primarily a reflection of lithology and when the finely laminated paper shale was saturated during periglaciation the overlying free face must have been cambered. The effect of this cambering, combined with freeze—thaw processes, led to the detachment of masses from the slope and these slumped along the line of a shear plane. The several generations of landslipping record successive positions of the free face.

Earthflow tongues are most frequently found on slopes facing north west and at levels below the free face on slopes facing north east (fig. 1). These flowage features are much larger than present day earthflows. Again confined to the outcrop of finely laminated shale, their development was probably conditioned by the saturation of the Alum shale.

The angle of slope of all erosional facets was analysed in several constituent drainage basins in Eskdale (Gregory & Brown, in press). Throughout this area there is a uniform pattern of geological outcrops. The slope angle of each facet was measured in the field and then the facets were arranged in 10 degree groups according to aspect. Inspection of the 10 degree groups showed that slopes facing north east, east, south, west and north west tend to have slope angles greater than others. This diversity is also shown by the weighted mean values calculated for each orientation group when slopes facing west and north west, east and south show angles of slope steeper than the average. Therefore the slopes facing north west, north and north east on which mass movements and nivation benches tend to be best developed are steeper than the average and in addition slopes facing south and west are also significantly steeper than the average.

The possibility that the effect of aspect varies according to height was examined by analysis in which facets in three height groups were considered; below 700 feet (210 metres), 700—1000 feet (210—300 metres) and over 1 000 feet (300 metres). South facing slopes are steeper only below 700 feet (and above 400 feet) while west facing slopes are significantly steeper above 1 000 feet. West and north west and north east facing slopes are steeper than average between 700 and 1 000 feet, and this is the main zone of influence.

Three groups of reasons have been advanced to explain slope angle variations with aspect; tectonic, structural and climatic (von Engeln 1942, p. 142). The first two explanations are not applicable to this area and so the climatic explanation must be considered. Climatic control may be reflected through differences in insolation, in exposure to winds or differences in the depth and persistence of permafrost (Melton 1960).

In Eskdale the occurrence of steeper angles on slopes facing north east, north west, south and west could be the result of different and distinct processes during the last period of periglaciation or alternatively the result of different periods of periglaciation. Particular directions seem to be significant at specific heights and therefore it is likely that these variations in slope angle are contemporaneous. Slopes facing north east, north and north west would receive less insolation than the others and would thus tend to be wetter and subject to more prolonged periglacial erosion, and this may account for their higher slope angles including those developed on nivation benches by snowpatch erosion and those consequent upon slumping below free faces. On other slopes removal of material and modification by solifluction would lead to lower slope angles. The west-facing group cannot be ascribed solely to differences in insolation. Prevailing westerly winds have been cited by other workers (e.g., Büdel 1944) to explain this characteristic. This is possible in Eskdale because the west facing slopes are steeper in the most exposed situations above 1 000 feet. South-facing slopes are steepest only below 700 feet and this seems to be the indirect consequence of the development of the opposite slopes. Material accumulating at the foot of the slope facing north west, north or north east would tend to shift the stream at its base, thus undercutting the south-facing slope and leading to steepening of the facets on the lower parts of that slope.

Aspect therefore does exert an influence on landforms developed under periglacial conditions but this influence is complicated by the possibility of several periods of periglaciation, by the balance of erosion and deposition which can cause an increase or decrease in slope angle and by recent processes which may perpetuate or modify the variations in slope angle. In the case of the Eskdale drainage basin, the paucity of insolation on slopes facing north west, north and north east was responsible for the development of steeper slope angles produced by nivation under snow patches, and by mass movement phenomena. Similar features must formerly have characterised slopes facing in other directions but these effects were either less well-developed or, in the case of slumps, removed by solifluction. These slopes facing south east, south and south west are smoother and have lower slope angles and they would be subjected to less freeze—thaw and wet conditions. West facing slopes are steeper at higher levels on exposed sites, and this can be attributed to exposure to winds which would facilitate increase of slope angles by freeze—thaw on west facing slopes. The south facing slopes are steeper than average only where undercut by streams as a result of accumulation at the foot of the opposite slopes.

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