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THE RANGE OF PERIGLACIAL PHENOMENA IN NORTHERN ENGLAND

Résumé de l'auteur

La variété des phénomènes périglaciaires actuels et fossiles en Angleterre du nord est considérable. Une interprétation exacte de la géomorphologie de cette région est impossible avant que ces phénomènes soient complètement recherchés et que leur importance soit correctement évaluée.

INTRODUCTION

In the British Isles the study of periglacial phenomena has had few devotees. Progress within the last decade has, it is true, been somewhat greater than in any earlier ten-year period, but it is still of only minor importance when measured against achievements in certain other countries. Hence, the exact role of periglacial processes in the shaping of the British landscape continues to be largely unknown.

Because of this general situation it is not surprising that the published literature contains only infrequent references to the periglacial features of northern England [1]. Among the more significant are those in papers by Thomas H a y (1936, 1937, 1942, 1943, 1944), who was one of the first people to recognise that a variety of periglacial features exists in the Lake District. More recently, valuable quantitative investigations have been made by T. N. C a i n e, (1963a, 1963b), who has examined the present-day movement of screes and sorted stripes in part of the north-western Lake District. However, the only other published literature which contributes at all significantly to an understanding of periglacial phenomena in

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[1] In this paper the term „northern England" refers to the area between the Anglo-Scottish border in the north and the cities of Lancaster and York in the south.

northern England is that by S. E. Hollingworth (1934), G. W. Dimbleby (1952), J. T. Andrews (1961), and K. J. Gregory (1966).

Since little has been written about cryergic activity in northern England, one might easily imagine that its significance is very limited. However, during recent investigations the present author has discovered that the effects of frost action can be seen at many widely-separated localities within the area. Indeed, such is the variety of periglacial forms in northern England that it would appear necessary to re-examine certain of the more traditional views on landscape origins in this area.

A simple division of Great Britain into major periglacial regions might recognise three distinct areas. First, there is an upland zone which lies north and west of a line running approximately from the estuary of the Severn to that of the Tees. Although glaciers have been the chief agents of landscape evolution in this area during the Quaternary [2], active and relic periglacial features are more widespread than is usually acknowledged. On the other hand, in many parts of non-glaciated southern England it is the relic periglacial forms which tend to dominate the landscape, though under present conditions morphologically-significant frost action is usually lacking. Finally, there is between upland Britain and southern England an area in which periglacial phenomena are again chiefly of the fossil variety. However, since this zone was glaciated more than once during the Pleistocene, its periglacial forms are generally of less importance in relation to the total landscape than are those of southern England. In summary, then, a general change occurs from north-west to south-east across Great Britain. The change is from a landscape where there are numerous glacier-moulded forms to an area in which the imprints of Pleistocene frost action are everywhere apparent.

According to the above divisions, northern England mainly belongs to recently-glaciated upland Britain. As such, it was largely behind the ice margin in Vistulian * times and therefore possesses numerous glacial features dating from that period. No doubt, it is partly because of this that studies relating to the area's periglacial phenomena are so few. Yet, within any region the frequent occur-

[2] Quaternary nomenclature in this paper follows that used by R. G. West (1963).

* The term *Weichselian* used by the author is changed to *Vistulian* by the Editors (Editor's note).

rence of a particular group of climato-morphological features does not, of course, mean the total exclusion of phenomena attributable to other sets of conditions. Thus, while it is true that Pleistocene glaciations have dominated Quaternary landscape evolution in northern England, it is equally true that an accurate evaluation of the region's geomorphology will only be possible after a thorough investigation of periglacial landforms and processes. Therefore, in one sense at least, all climato-morphological types which have affected the area during Tertiary and Quaternary times become of equal importance. Obviously, a story can never be fully understood if one of its chapters is left incomplete.

The following notes discuss the variety of periglacial forms occurring in northern England and attempt to fill in some of the missing pages in our understanding of that area's geomorphological evolution.

FROST-SHATTERED BEDROCK

Frost action has brought about the disruption of bedrock in many parts of northern England. Because of the area's geological diversity, a variety of rock types therefore shows evidence of congelifraction. This point can be illustrated by reference to the Moor House National Nature Reserve (north-east Westmorland) and its surrounding areas[3]. It is here that work has been concentrated during the present survey. The Reserve's solid geology is made up of Carboniferous-age rocks, though these are in many places obscured by superficial deposits. Where, however, bedrock is exposed the results of congelifraction are often visible. Such is the case, for example, with sandstone outcrops found in various parts of the Reserve (eg. in Rough Sike: G. A. L. Johnson and K. C. Dunham, 1963). Moreover, the disruption of this rock by frost has not only produced congelifracted bedrock, but has also given rise to the widespread development in this area of block fields. Another significant result of congelifraction on the Reserve has been the formation in the upper Knock Ore Gill valley of impressive frost-riven cliffs, below which are extensive scree slopes. Both types of landform have resulted essentially from the weathering of limestone. At other places within the area (eg. at the head of Middle Tongue Beck) congelifraction has brought about the

[3] The location of places mentioned in the text is shown on fig. 1.

distintegration of shales. However, unlike the limestones and sandstones, these rocks have not weathered to give significant landscape features.

Just beyond the western edge of the Reserve is a series of Lower Palaeozoic rocks forming what is generally known as the Cross Fell inlier. At many localities these too show evidence of having been disrupted by congelifraction. For example, at the entrance to Knock Pike quarry frost-shattered rhyolite bedrock (Ordovician) can be seen passing upwards into a congelifluction deposit. Nearby, on Flagdaw and on Burney Hill, members of the Skiddaw slate group (Ordovician) have clearly been disrupted by the same type of weathering.

The instances of congelifraction mentioned above demonstrate that in northern England frost shattering has affected a variety of rock types. However, in referring solely to localities where Palaeozoics outcrop, these examples do not give a complete picture of the different age groups to which the frost-disturbed rocks of this area belong. Thus, congelifraction has occurred not only in the Palaeozoics, but has also disrupted bedrock of Mesozoic age (eg. the Jurassic sandstones of the North York Moors).

In such a tentative stage of investigations it is obviously very difficult to establish a chronology of periglacial events in northern England. There is, nevertheless, some indication that all the examples of bedrock congelifraction in this area may not date from the same period. Indeed, on present evidence it seems reasonable to distinguish at least three periods of frost shattering. One of these is now affecting the highest parts of the region, though its importance appears to be quite small: periglacial processes other than frost shattering are, in fact, of greater significance. This weak present-day phase of congelifraction is separated from the more important late Pleistocene/early Holocene one by the Flandrian climatic optimum, during which frost is unlikely to have been morphologically effective in any part of northern England. Cryergic dormancy thus followed what appears to have been the fairly intense cryergic activity of the Vistulian deglaciation phases in this area. Finally, the work of D. F. W. Baden-Powell (1950) suggests that a third, even older period of congelifraction may be recognised in northern England. This occurred immediately prior to the last glaciation of the area, and often manifests itself in the form of an angular congelifluction deposit which now lies beneath glacial till. Examples of this have been found at Robin Hood's Bay (Yorkshire) and in the Cheviots (D. F. W. Baden-Powell: personal communication). These and other sections provide evidence that cryergic activity is a precursor to glacial action. Moreover, they are a welcome reminder of the part which frost plays in facilitating the work of a glacier.

BLOCK FIELDS

Throughout the nineteenth century there were writers who believed that earthquakes have played an important, if not dominant role in the formation of block fields. One of those who subscribed to this view was J. C. Ward (1876). Thus, in his memoir on "The geology of the northern part of the English Lake District", Ward wrote of "a certain blocky structure common to several of the mountain tops, and notably Scafell Pikes". He considered that these block fields were formed partly by earthquakes which occurred in Flandrian times! Fortunately, such views were not held by all nineteenth-century writers. J. Yates (1830—1), for example, was of the opinion that frost is a more powerful agent of rock disruption than earthquakes, while J. Geikie (1894) claimed that "As the mountain-tops became uncovered [4] enormous quantities of rock-débris together with great blocks would be detached by frost". Only slowly, however, did the idea gain momentum that frost has played an important role in the formation of many block fields. J. E. Marr (1916) was one of the first people who used it to explain the origins of Lake District block fields.

There is little reason to question the general validity of Marr's suggestion, although the exact role of frost in block field development is not as yet properly understood. It would, however, seem from the available evidence that at least two theories may be needed to account for the block fields of northern England. The first proposes that such features can originate and develop entirely under periglacial conditions. As is well known, congelifraction of bedrock occurs widely in certain types of frost climate. In addition, transportation of the fractured material from an *in situ* position may be possible due to frost heaving and congeliflaction. The operation of such processes can therefore give rise to large areas strewn

[4] i. e. due to the melting of glaciers.

with angular, blocky debris. Fine material is also produced, though only in comparatively small amounts, and is often largely removed, especially on steeper ground, by processes of slope wash. Block fields in northern England which appear to have been formed in the manner just outlined include those in and around the Moor House Reserve (i.e. those on Cross Fell (pl. 1), Little Dun Fell, Knock Fell, in the upper Knock Ore Gill valley, etc.).

A second theory may be necessary in order to explain adequately block spreads of the type that occurs, for example, on the summit of Nethermost Pike in the central Lake District. Here individual blocks may be either angular or they may exhibit a significant degree of rounding. The discovery that some of these possess grooves, all aligned in roughly the same direction, suggests that they have been glacially abraded. Thus, although present information is not sufficient to elucidate the chronological development of such blocks fields, it does seem that they are the result of both glacial and periglacial conditions. This kind of situation has already been discussed by T. Hay (1942), who examined block spreads near Ennerdale Water in the western Lake District.

NIVATION BENCHES

The majority of studies relating to altiplanation terraces in the British Isles have been made in south-west England. However, a recent paper by K. J. Gregory (1966) describes similar, though smaller features occurring most frequently between 800 and 1100 ft. O. D. (240—330 m.) in the Esk drainage basin, north-east Yorkshire. To these he applies the term *nivation benches*. They are best developed in coarse, resistant gritstone on slopes facing north-east and north-west. Although sometimes debris-strewn, these features are essentially erosional in origin and have probably resulted from the operation of processes associated with snow patches.

CONGELIFLUCTION DEPOSITS

Although thirty years have elapsed since the publication of C. F. S. Sharpe's (1938) classic work on mass movement, there have been few attempts to discover the cotribution which this

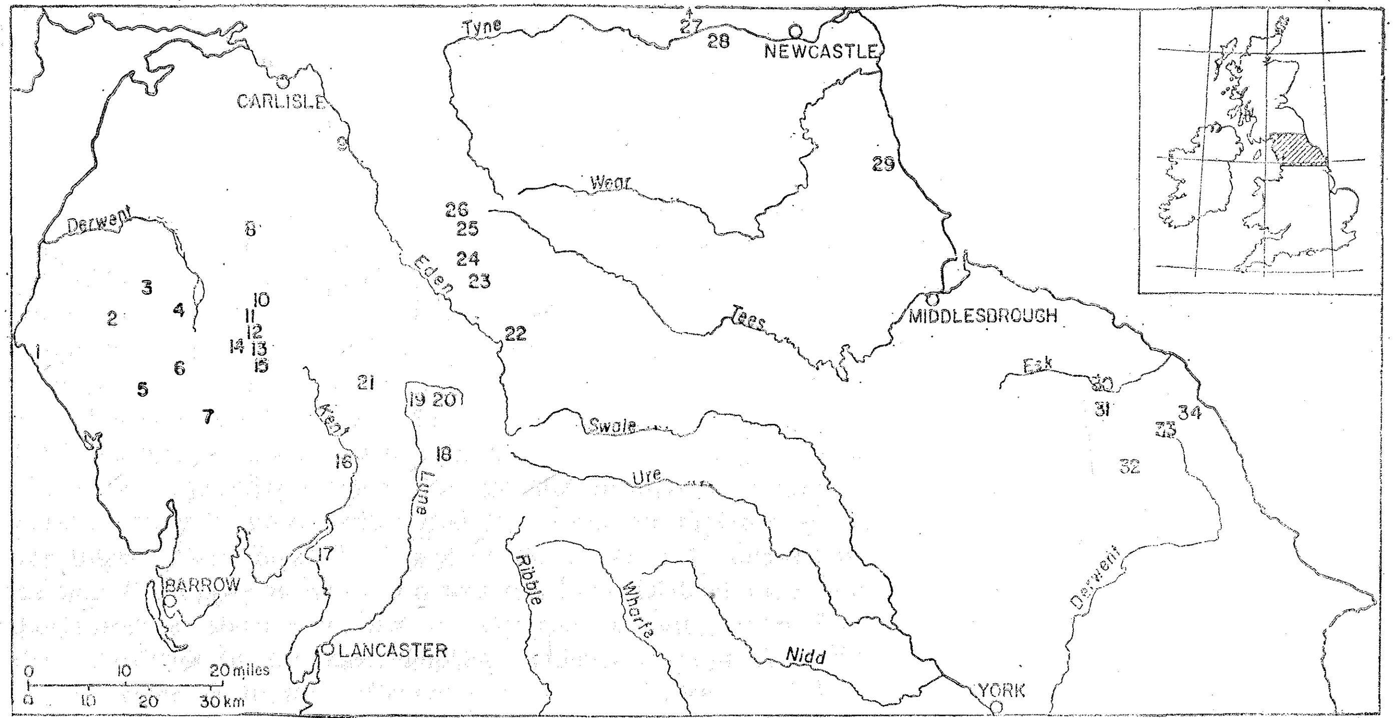


Fig. 1. Location of places in northern England mentioned in the text

Lake District and surroundings: 1. St. Bees, Ehenside Tarn; 2. Ennerdale Water; 3. Grasmoor Fells; 4 Hindscarth; 5. Wasdale screes; 6. Scafell Pikes; 7. Swirl How; 8. Bowscale Fell; 9. Moorthwaite Moss, Abbot Moss; 10. Watson's Dod, Hart-side, Stybarrow Dod, Raise; 11. Helvellyn; 12. Nethermost Pike, Dollywaggon Pike; 13. Seat Sandal, Fairfield, Rydal Head, Great-rigg Man; 14. Steel Fell; 15 Greenhead valley, Heron Pike; 16. Kendal, Underbarrow Scar; 17. Lowland Lonsdale, Arnside

Howgill and Shap Fells: 18. Sedbergh area: Winder, valleys of Settlebeck Gill and Crosdale Beck; 19. Tebay area: Carlin Gill, High Carlingill Farm, Low Borrowbridge; 20. Great Swindale, Weasdale, Langdale, West Grain, Churn Gill; 21. Whatshaw Common

Pennines: 22. Brough; 23. High Cup Gill, Great Rundale Beck, Backstone Edge, High Scald Fell; 24. Cross Fell inlier: Dufton Pike, Knock Pike, Flagdaw, Burney Hill; 25. Moor House Reserve: Knock Ore Gill valley, Middle Tongue Beck, Knock Fell, Great Dun Fell, Little Dun Fell, Rough Sike, House Hill; 26. Cross Fell

Cheviots: 27. Beanley area

County Durham: 28 Greenside; 29. Warren-House Gill

North York Moors and surroundings: 30. Esk drainage basin; 31. Murk Mire Moor; 32. Levisham Moor, Lockton Low Moor; 33. Eastern Tabular Hills; 34. Robin Hood's Bay group of processes has made towards the evolution of landscapes in northern England. Yet, as a comparatively small amount of research will often show, mass movement has been and still is quite active in many parts of the region. Thus, the morphological features to which it is at present giving rise include the landslides, terracettes and creeping boulders of temperate areas, and the terraces and ploughing blocks of periglacial environments. Phenomena such as congelifluction deposits, screes, and block streams also occur in northern England, but these are an expression of former, rather than of current mass movement processes. It seems logical that a discussion of the periglacial features just mentioned should begin with congelifluction (or head) deposits, and that notes on related phenomena should follow in later sections.

An early reference to fossil congelifluction deposits in northern England was made by J. E. Marr and W. G. Fearnsides (1909). Working in the Howgill Fells they noted that angular head is fairly widespread on the higher ground in that area (tab. I). Moreover, they correctly attributed its formation to frost action. Over thirty years later T. Hay (1942, 1944) put forward the idea that the upper parts of the western Lake District may have experienced a shorter period of cryergic activity than have upland localities further east. Quoting evidence in support of this view, he referred to the different extent and thickness of fossil congelifluction deposits in various parts of north-western England. For example, he pointed out that such deposits occur more widely in the Howgill Fells than they do in the Lake District (T. Hay, 1942). Unfortunately, these ideas have not received the credit they deserve, largely because academic opinion was until recently entrenched in the belief that areas north of the Vistulian ice margin have suffered little from Pleistocene frost action. While E. A. Fitz Patrick (1958) and R. W. Galloway (1961a, b, c) have done much to rectify this situation with regard to Scotland, no comparable work has been undertaken in northern England. As a result, during the last twenty or so years references to the fossil congelifluction deposits of this region have been comparatively few in number and always brief (G. W. Dimbleby, 1952; R. Common, 1954; D. Walker, 1956; W. W. Anson and J. I. Sharp, 1960; F. Oldfield, 1960; E. Derbyshire, 1961; G. A. L. Johnson and K. C. Dunham, 1963; K. J. Gregory, 1965; D. Walker, 1966). However, this does not mean that there is a paucity of such

Table I

Localities in northern England where congelifluction deposits have been recorded

Localities mentioned in the published literature	Localities noted during the present survey
LAKE DISTRICT AND SURROUNDINGS	CENTRAL LAKE DISTRICT
Watson's Dod (T. Hay, 1942) St. Bees (D. Walker, 1956) Lowland Lonsdale (F. Oldfield, 1960) Ehenside Tarn, Moorthwaite Moss, Abbot Moss (D. Walker, 1966)	Steel Fell Heron Pike Greenhead valley Nethermost Pike Stybarrow Dod, etc.
HOWGILL FELLS	
at many localities in the upper parts of the region — at the head of the following valleys: Great Swindale, Weasdale, Langdale, West Grain, Churn Gill (J. E. Marr and W. G. Fearnsides, 1909)	Sedbergh area (Winder, valleys of Settlebeck Gill and Crosdale Beck) Tebay area (several impressive exposures: a) in a tributary valley of Carling Gill, b) in a recent landslide near High Carlingill Farm, c) at the head of a stream valley which enters the Lune near Low Borrow-bridge)
PENNINES	
Moor House Reserve (G. A. L. Johnson and K. C. Dunham, 1963)	at many places on the Moor House Reserve on several hills of the Cross Fell inlier (Flagdaw, Knock Pike, Dufton Pike, etc.) on Cross Feell, High Scald Fell, Backstone Edge
NORTH YORK MOORS	
eastern Tabular Hills (G. W. Dimbleby, 1952) Esk drainage basin (K. J. Gregory, 1965)	Murk Mire Moor Levisham Moor Lockton Low Moor
OTHER LOCALITIES	
in the upper parts of most valleys in the east Cheviot area (R. Common, 1954) much 'prismatic' clay of earlier geological literature thought to be a congelifluction deposit (W. W. Anson and J. I. Sharp, 1960) near Beanley in the Cheviots (E. Derbyshire, 1961)	Shap Fells (beside the A6 (T) near Whatshaw Common, south of Shap)

deposits in northern England. On the contrary, they appear to be quite widespread. An attempt to substantiate this view has been made in table I, which lists the places in northern England where congelifluction deposits have been found by the present writer, together with localities mentioned in the published literature.

It should be noted that Hay's ideas on the duration of periglacial conditions in various parts of north-western England refer only to the situation in the higher parts of the region. At lower levels the thickness of head is usually quite small and does not appear to vary significantly in different parts of that area. From this, one assumes that most of the periglacial phenomena on the lower ground in northern England were formed during a relatively short period in late Pleistocene/early Holocene times, whereas frost was morphologically significant a good deal earlier than this in certain higher parts of the region.

Although congelifluction deposits in northern England are essentially a product of former cryergic activity, they are nevertheless being quite vigorously reworked at many localities within the region. The processes responsible for this are of two main kinds. First, there are those operating under humid, temperate conditions in the lower parts of the area. By reworking head deposits these are giving rise to new features, such as landslides, terracettes, and creeping boulders. Secondly, as a result of climatic deterioration over the last few millennia, periglacial conditions have returned to the higher ground in northern England and are therefore reactivating many frost phenomena. Thus, one may find that congelifluction is remoulding the uppermost parts of an existing head deposit into various kinds of small-scale terrace. In addition, it is often possible to measure with ease the annual rate of high-altitude block movement. Reactivation by frost of congelifluction material in northern England also leads during winter to the formation of needle ice (pipkrake) and frozen-out stones. These have both been recorded in the Lake District by T. Hay (1936, 1937, 1943), and have been studied by the present writer on the Moor House Reserve. Less frequently, they have been noted during cold spells at low altitudes.

Though the congelifluction deposits of northern England have been discussed only in brief terms, the present contribution has perhaps shown that they merit greater attention than they have so far received. It is indeed more than likely that some of the deposits previously considered to be of glacial origin will have to be reinterpreted as the products of congelifluction.

SCREES

Screes are of common occurrence in the upland areas of northern England. Consequently, references to them have been appearing in the literature at quite frequent intervals over the last hundred years. In fact, rather more than a century has passed since D. Mackintosh (1865) proposed a twofold classification of Lake District "screes" [5]. In the first of his categories are those debris accumulations which consist largely of boulders and whose formation he wrongly attributed to marine action. No doubt, terms such as *block field, boulder spread,* etc. would be used by modern research workers for many of these features. On the other hand, the word *scree* continues to be employed for many of the landforms in the second group which Mackintosh distinguished. Having noted that these consist of "small fragments, sand, or mud", he correctly suggested that "atmospheric action" is responsible for their formation. Over twenty years after Mackintosh put forward these ideas the results were published of C. Davison's investigations into scree movement (C. Davison, 1888a, 1888b). Derived largely by experimental means, these showed that temperature changes play an important role in the movement of scree fragments. In the first paper he wrote on this topic Davison (1888a) stated that conditions favouring such movement occur, for example, near the top of Hindscarth in Cumberland. He also made the interesting observation that scree fragments at this locality usually have their long axes pointing downslope. Further investigations prompted Davison to write another paper (1888b). His aim on this occasion was principally to compare the rate of scree movement in winter with that in the summer half of the year. By doing this, he came to the conclusion that the descent of scree is most rapid in summer, as this is the time of year when the diurnal temperature range

[5] As used by Mackintosh, the word *scree* applies to a feature "composed of loose materials which lie scattered between the crest of a declivity and the bottom of a valley". The term is therefore given a rather wider meaning than some authors would assign to it.

is greatest. However, in addition, he did not fail to notice that the average daily movement recorded during winter months was higher than one would expect if it were simply proportional to the temperature range. He therefore decided that snow must be largely responsible for this.

During the twentieth century there has been an increase in the frequency with which screes have been examined in northern England. Thus, J. E. Marr's book "The geology of the Lake District" (1916) contains a summary of the more important facts relating to the landform, while a paper by W. Leach (1930) describes the vegetation growing on certain non-calcareous screes in Wales and the Lake District. Unfortunately, however, many of the references published in the first half of this century discuss the feature as no more than incidental to a main theme (eg. J. J. Hartley, 1941). Indeed, it was not until 1961 that there appeared a fairly detailed geomorphological study of screes in northern England (J. T. Andrews, 1961). This compared the famous Wasdale screes of the Lake District with similar features in the Schefferville region of Central Québec—Labrador. In doing so, it examined two main problems. First, it considered in detail the nature of these screes and, secondly, it attempted to evaluate their significance as indicators of climatic change. According to Andrews, the screes in both areas were formed under periglacial conditions in the recent geological past. Further work on Lake District screes, this time of a quantitative nature, has been carried out on the Grasmoor Fells in the north-west of the area (T. N. Caine, 1962, 1963b). Among the more important results of this study was the discovery that surface stones in this locality can move distances greater than one foot (about 30 cm.) per annum.

Undoubtedly, screes are one of the most widespread periglacial features in the uplands of northern England. However, as the foregoing paragraphs suggest, almost all examples of the feature mentioned in the published literature occur in the Lake District. While it is true that screes are numerous in this region and often form one of the most conspicuous elements of its landscape (eg. at Rydal Head, below Fairfield), they are by no means absent from other parts of northern England. Thus, they have been examined by the present author in several of the valleys which dissect the Pennine escarpment near Appleby (Westmorland) and which contain streams such as the Knock Ore Gill, Great Rundale Beck, and High

Cup Gill. Similarly, investigations west of Kendal on the southern margins of the Lake District have been partly concerned with elucidating the nature and formation of the limestone screes in that area. Further work on screes has been carried out in the Howgill Fells (eg. on the slopes of Winder, overlooking Sedbergh in Yorkshire). Reference must also be made to a paper by M. M. Sweeting (1966), who has recently examined calcareous screes in north-west Yorkshire and has mentioned others near Kendal and Arnside (Westmorland). In conclusion, one can say that screes are not only widespread in parts of northern England, but have also developed over a wide altitudinal range. For example, limestone screes can be found above the 2000 ft. (609 m.) contour (eg. at the head of the Knock Ore Gill valley), or they may occur fairly near to sea level (eg. below Underbarrow Scar, west of Kendal).

The origins of most screes in northern England can reasonably be attributed to late Pleistocene/early Holocene frost shattering and congelifluction. Although the effects of frost action on rock outcrops, even at the highest levels, are now fairly small, there is much to suggest that scree movement continues at many localities. Evidence for this is of two main kinds. First, there are the results of quantitative investigations by T. N. Caine (1962, 1963b), M. M. Sweeting (1966), and the present writer (since 1965). In all cases, easily-detectable amounts of movement have been recorded over comparatively short periods of time. Secondly, there is the observational evidence indicative of such movement. Features which provide this include brake blocks (L. Tufnell, 1966), avalanche tracks (eg. on the Heron Pike screes in the Lake District), and the lack of a continuous vegetation cover. In addition, it is well known that man and animals make their own, often appreciable contribution to scree movement. Clearly, the term *scree* is an appropriate name for such an unstable landform, as it comes from an old Norse word meaning debris which moves when one stands on it (A. Holmes, 1965).

BLOCK STREAMS

Of the block streams investigated during the present survey, those which occur on Knock Fell are among the best preserved. Although under present-day conditions these features appear to be virtually immobile, they once provided an important means whereby debris from the mountain's block field area was transported to somewhat lower ground. This debris consisted principally of large, angular blocks of sandstone and it was moved over fairly gentle slopes.

CONGELIFLUCTION TERRACES

In addition to the Pleistocene congelifluction phenomena just described, there are mass movement features in northern England whose formation is usually the result of current periglacial activity. One of the most important of these is the congelifluction terrace. Since deposits of glacial origin are rare at higher levels in northern England, the formation of these terraces very often involves a reworking of fossil head deposits.

An examination of active congelifluction terraces in various parts of northern England has shown that these can be of at least two basic morphological types. The first may be called a *garland terrace* because of its arcuate-shaped riser. Differences in the extent to which vegetation covers such terraces make it possible to subdivide this category. Hence, arcuate-fronted terraces having a complete mantle of vegetation on both tread and riser may be called *vegetation-covered garland terraces*. On the other hand, where only the riser is vegetation-covered, then the phrase *vegetation-banked garland terrace* would seem appropriate. A third possibility is that the riser will be bare, and that vegetation will cover only the tread. If this is the case, the term *earth-banked garland terrace* might be used. Examples of all three varieties of garland terrace have been found by the writer in northern England (eg. on the Moor House Reserve, and at places in the central and western Lake District). However, the only type yet described in the published literature is the vegetation-banked garland terrace, a feature examined and photographed by T. Hay (1937) in the Helvellyn area of the central Lake District. To date, all garland terraces investigated by the present writer have been small-scale features whose development can be attributed to present-day cryergic activity. Thus, on both Great Dun Fell and Little Dun Fell, for example, individual terraces are rarely more than 2 ft. (about 60 cm.) in any dimension.

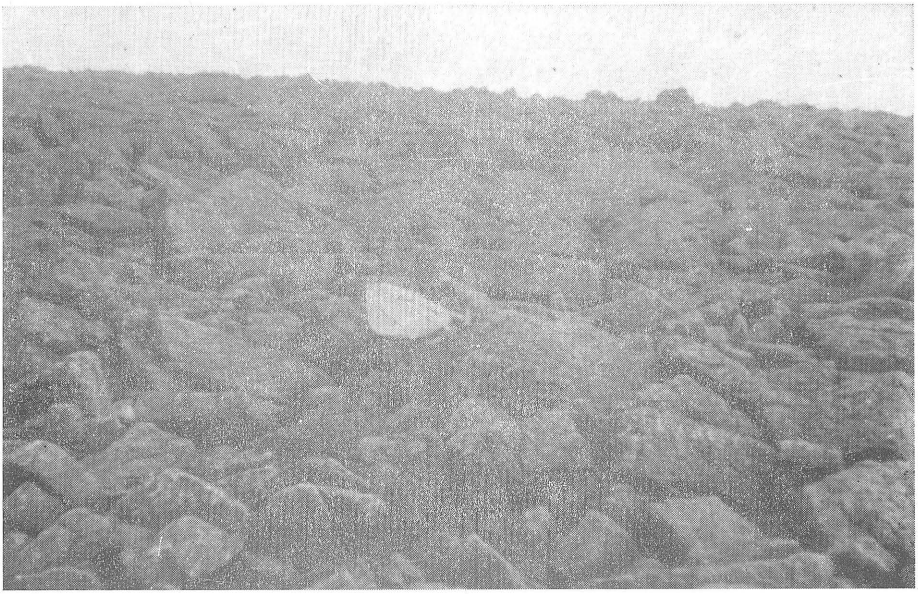
A second, morphologically distinct group of congelifluction terraces occurring in northern England are those whose fronts lie roughly parallel to each other and approximately at right angles to the line of maximum slope. These may be called *parallel terraces*, and again it is possible to distinguish vegetation-covered, vegetation-banked, and earth-banked varieties. Well-developed examples of the first sub-type have been investigated in both the northern Pennines (eg. on the Moor House Reserve), and in the Lake District (eg. on Stybarrow Dod). Parallel terraces of the vegetation-banked kind have also been found on the Moor House Reserve (eg. at the head of Middle Tongue Beck), and in the Lake District (eg. on Fairfield). However, no earth-banked parallel terraces have so far been discovered in the areas examined. In all the cases just mentioned, terraces are essentially small-scale features, although their treads are often much longer than those of garland terraces.

As one might expect, there are variants on these two basic congelifluction terrace forms. For example, mass movement on some high-altitude slopes in our region gives rise to a kind of parallel terrace similar in appearance to the terracettes of humid temperate areas. In other words, despite the tendency for terrace fronts to exhibit a general parallelism, some bifurcation of individual members occurs. Evidence from northern England, in fact, suggests that parallelism of terrace fronts is not necessarily any less pronounced in a humid temperate area than it is in periglacial environments. Hence, it is often difficult to evaluate the precise role of frost in the development of terraces by mass movement.

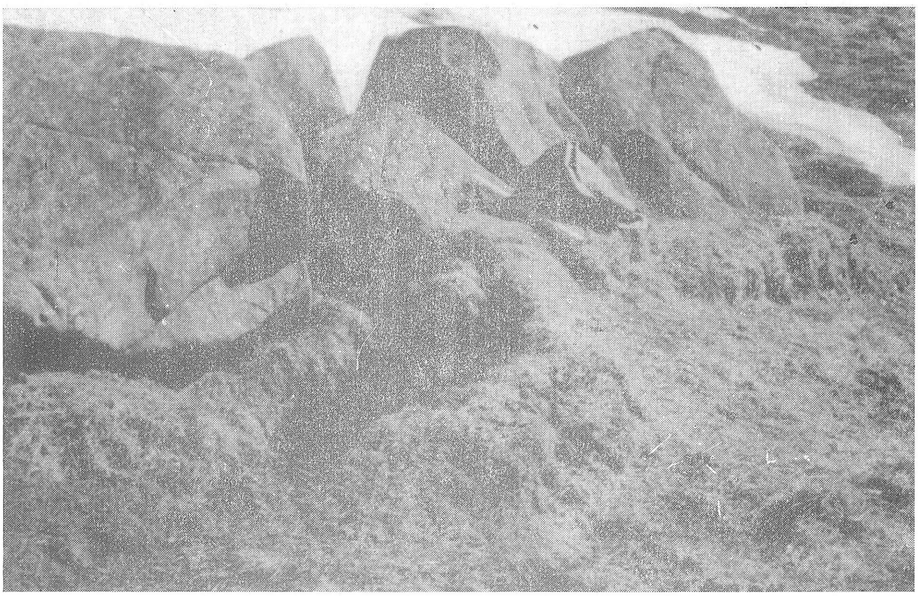
Observations also indicate that in certain parts of northern England congelifluction terraces may be found which are larger than those described above. Such is the case on Nethermost Pike, where terraces have developed whose treads are between 1 and 2 ft. (30—60 cm.) high and which have a length of several yards. Although congelifluction is active in this region, these features appear to be a manifestation of former, rather than of current periglacial conditions.

PLOUGHING BLOCKS

At the present time, congelifluction on the higher ground in northern England often gives rise to the formation of ploughing blocks (pl. 2). These are individual fragments of rock which move

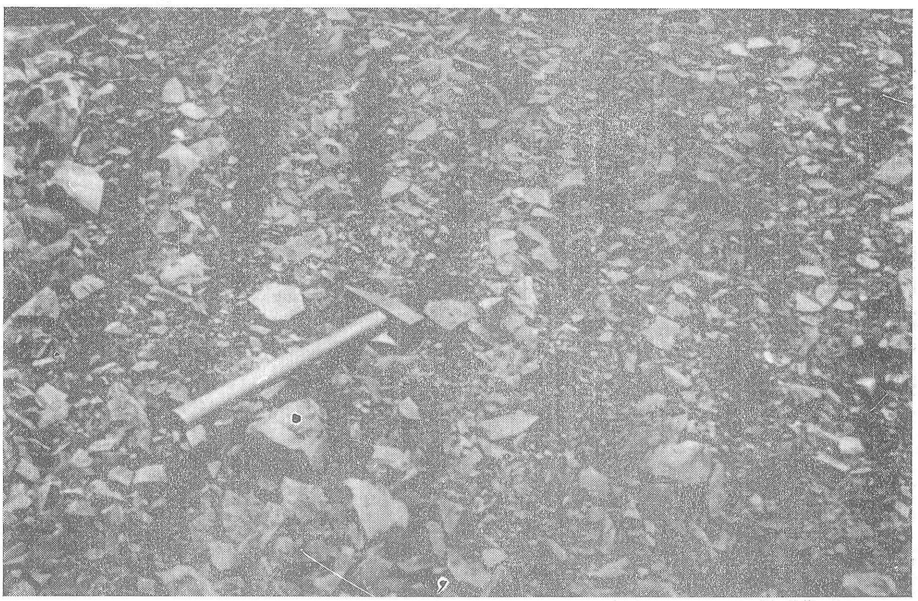


Pl. 1. Sandstone block field near the summit of Cross Fell (northern Pennines)

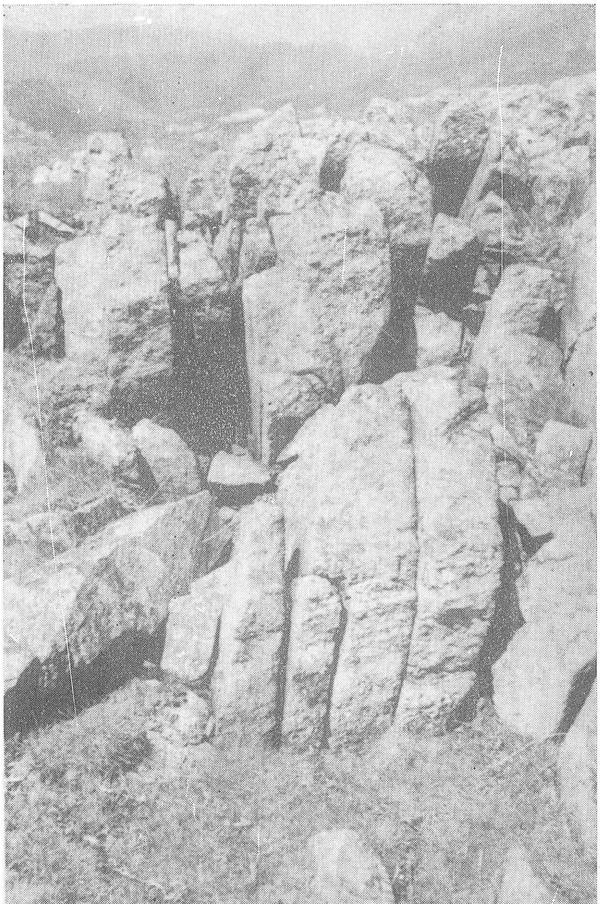


Pl. 2. Group of ploughing blocks, west-facing slope of Little Dun Fell (Moor House Reserve)

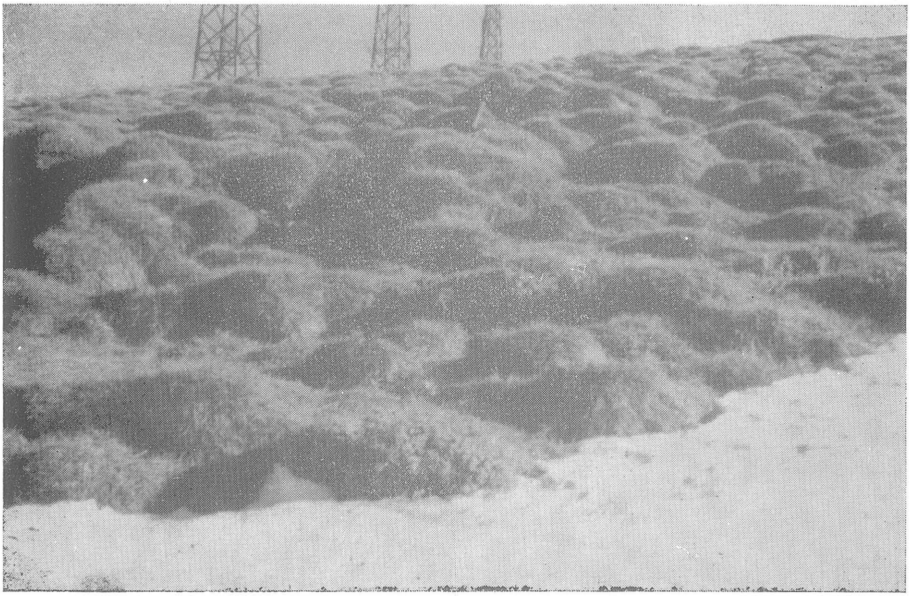
Pl. 3. Large-scale fossil stone polygon, Backstone Edge (northern Pennines)



Pl. 4. Small-scale active stone stripes near the summit of Fairfield (central Lake District)



Pl. 5. Erected stones on the top of Seat Sandal (central Lake District)



Pl. 6. Thufur „field" west-facing slope of Great Dun Tell (Moor House Reserve)

Pl. 7. Frost-degraded turf near the top of Helvellyn (central Lake District)

downslope faster than does the ground surrounding them. In doing so, they push soil and vegetation before them and leave a depression in their rear.

Although this type of block movement was being noted more than fifty years ago, particularly by Scandinavian writers (eg. J. Rekstad, 1909; B. Högbom, 1914), it has rarely been studied in any detail. Hence, little has been written about ploughing blocks in the British Isles, though such features have admittedly been recorded on three occasions in northern England. The first of these was in 1937 when a paper appeared containing a few details of ploughing blocks in the central Lake District (T. Hay, 1937). Five years later a second brief reference was made to such features by Hay (1942). Finally, in more recent years, ploughing blocks have been recorded on the Moor House Reserve (G. A. L. Johnson and K. C. Dunham, 1963). Unfortunately, when put together these references afford no more than a bare outline of ploughing block characteristics, and for this reason a detailed account of the feature is now being prepared. As a result, only its main attributes are here considered.

In the absence of any detailed studies of ploughing blocks in northern England, one might imagine that such features are of little importance within the region. However, this would be an erroneous supposition for there are, in fact, many upland localities in the area where this kind of block movement is taking place. Indeed, on present information it would seem that ploughing blocks are among the most widespread of the currently-developing periglacial phenomena in northern England. No doubt this is at least partly accounted for by their ability to form at comparatively low altitudes. Thus, while it is now uncommon for most other periglacial features to develop below the 2000 ft. (609 m.) contour in northern England, it is by no means unusual to find ploughing blocks at altitudes of between 1500 and 2000 ft. (457—609 m.). They occur, for example, on Steel Fell (central Lake District) where the highest point is only 1811 ft. (552 m.) O. D. This type of low level occurrence does not, however, appear to be confined to northern England, since it has been recorded in the central Alps. P. W. Höllermann, 1964) and elsewhere. Naturally, the best examples of the landform tend to occur not at relatively low altitudes but at much greater heights. Thus, some of the finest ploughing blocks which the writer has yet discovered are those at around 2700 ft. (823 m.) on Little Dun Fell.

The fully-developed ploughing block has three main components. First, there is the block itself, which in northern England can be derived from any one of several rock types (sandstone, limestone, andesite, rhyolite, etc.). Then, immediately downslope from this is a mound whose exact form is dependent upon such variables as internal composition, extent of vegetation cover, and size. Finally, a depression occurs upslope from the block. Observations in northern England suggest that this has less variable characteristics than does the mound. Hence, only two basic types have so far been identified. These are, first, the elongate variety whose length may exceed 20 ft. (about 6 m.), as on Little Dun Fell, and, secondly, the half-bowl or niche-shaped depression. On the basis of variations in the nature of mounds and depressions, C. F. Capello (1955) has made a "classification" of ploughing block types. Although several of these types have been identified in northern England, the majority of ploughing blocks examined there do not fall into the categories distinguished by Capello. Hence, a great deal more work appears to be necessary before a comprehensive list of ploughing block types has been formulated.

As already suggested, ploughing blocks are a congelifluction phenomenon formed by differential slope movements. In fact, the creation and positioning of their mound and depression is the result of an ability to move faster than the surrounding ground. Often, ploughing blocks are associated with small, active congelifluction terraces, as on Swirl How in the western Lake District. Such occurrences clearly indicate that, although an entire slope is in motion, it is the blocks which travel fastest. Unfortunately, little quantitative information is yet available to substantiate these remarks, though work on the Moor House Reserve does suggest that a fair number of ploughing blocks in this area have a mean annual rate of movement of between 1/2" and 2" (about 1—5 cm.). No doubt, the greater part of this movement is accomplished during spring, for this is the time of year most favourable to congelifluction in the uplands of northern England. The exact details of how block movement occurs are not yet clear, but it would seem that the main agent producing it is frost, assisted by temperature fluctuations, water and gravity.

STONE POLYGONS

Frost action in the British Isles has given rise to several types of polygon. The most widely occurring of these appear to be the ice-wedge polygon and the stone polygon, both of which can be found in northern England. It is also possible that a third variety of polygon may exist in the south-east of our region, where bedrock is of chalk. However, as R. B. G. Williams (1964) has shown, this type of pattern is common only on those parts of the chalk outcrop in or near East Anglia. Because of this, and because ice wedges in northern England are discussed later, the present section is concerned only with the area's stone polygons. These appear to be of two main kinds. First, there is the currently-forming variety, which in northern England occurs most frequently above the 2000 ft. (609 m.) contour. Individual polygons of this type are usually no more than a few inches in diameter and are characteristic of flattish, stony ground where vegetation is sparse or absent. Among the first to describe such features in northern England was S. E. Hollingworth (1934), who found them in the northern part of the Lake District. More recently, they have been studied by T. N. Caine (1961), who has established that such patterns develop less frequently in the Lake District than do stone stripes. A comparable situation appears to exist in the northern Pennines. Thus, despite a lengthy search in this area, undoubted examples of active stone polygons have been found at only one locality (south-facing slope of Great Dun Fell). By contrast, the other basic type of stone polygon occurring in northern England (the large-scale, fossil variety) is widespread on the higher parts of the Moor House Reserve, on Cross Fell, High Scald Fell, and at several other localities in the northern Pennines (pl. 3). It does not, however, appear to be so well developed in the Lake District. The diameter of this kind of polygon may be only a few feet, as on Little Dun Fell: alternatively, it can exceed 50 ft. (15 m.), as do examples on Knock Fell. Usually, the fine material in the centre of such features is now vegetation-covered, while the coarser debris which forms the polygon borders may stand "on edge".

Associated with the fossil stone polygons of the northern Pennines are features sometimes known as "debris islands". These are circular-shaped areas of relatively fine material which have formed within a block field. The diameter of individual circles has been found to vary quite markedly and can be up to 50 ft. (15 m.), as on Knock Fell.

It seems likely that the fossil stone polygons and debris islands just mentioned were formed over permafrost at some time during the Vistulian period. Their resemblance to currently-developing forms in high altitudes (eg. in Spitzbergen) is very striking.

STONE STRIPES

Several attempts have been made to explain the origins of stripes found in northern England. Among the earliest is a suggestion by J. C. Ward (1876) that in the Lake District heavy rain is responsible for the "strange appearance upon many of the fell-tops, or sides, as if stones had been sown along regular lines close together". Unfortunately, these remarks seem to have tempted no one into making a fuller investigation of such patterns. Indeed, they were hardly mentioned again in the published literature until 1934 when S. E. Hollingworth recorded their existence in the northern Lake District and correctly attributed their formation to periglacial activity. Soon after this, T. Hay (1936, 1943) focussed attention on a new aspect of the problem by claiming that needle ice has an important role in the present-day formation of stone stripes. However, this idea has recently been questioned by T. N. Caine, who has attempted, like Hay, to elucidate the details of stone stripe development. Working at altitudes of over 2000 ft. (609 m.) on the Grasmoor Fells, Caine has found that several consecutive days of sub-zero temperatures are more important for the present-day development of stripes than are diurnal freeze—thaw cycles. In addition, he claims that these stripes are basically the result of differential frost heave, aided by small-scale mass movements and rill wash. His observations also revealed that surface stones at these altitudes are moving at easily-detectable rates (T. N. Caine, 1962, 1963a, 1963b). Thanks to work by Hay and Caine, miniature stone stripes are probably the best understood of all periglacial features in northern England.

Like their polygonal counterparts, the stone stripes of northern England have two main forms. These are, first, the small-scale variety indicative of present-day frost sorting, and second, the large, fossil kind, which probably originated when permafrost existed in the area. Differences between these two types are illustrated by the following examples. The first occurs near the summit of Fairfield. Here currently-forming stripes have been discovered with individual bands 3 to 4″ (7—10 cm) across (pl. 4). This type of feature occurs on ground where vegetation is usually lacking and where debris is of at least two contrasting sizes. On the other hand, stripes of the large-scale, fossil variety which were found on Great Dun Fell have individual bands whose average width is around 4 ft (over 1 m.): as elsewhere in northern England, the fine stripes have an arched cross-profile and are now vegetation-covered, while the coarse bands are of platy fragments, many of which are "on edge". Not surprisingly, the individual bands of the currently-forming stripes examined were rarely more than 20 ft. (6 m.) long: by contrast, localities are known (eg. at the northern end of Nethermost Pike, and on the west-facing slope of Little Dun Fell) where fossil stripes exceed 100 ft. (30 m.) in length.

As already noted, T. N. Caine has discovered that in the Lake District stone stripes are forming more often than stone polygons. Thus, over 50 examples of the former were known to him, but only 14 of the latter. Rill work, which facilitates striping but not polygon formation, is probably a highly significant factor in explaining this difference (T. N. Caine, 1962, 1963a). Although it is no doubt true that stone stripes are developing more frequently in northern England than their polygonal counterparts, it will always be difficult to give the precise number of localities where both are forming. This is largely due to the ephemeral nature of such features, and, consequent upon this, their frequent destruction by man and animals. For various reasons, places where large-scale sorting once occurred may also be difficult to identify. Nevertheless, fossil stripes have been discovered at a fair number of localities in northern England (eg. on Little Dun Fell, Great Dun Fell, and Knock Fell in the northern Pennines: on Greatrigg Man, and Nethermost Pike in the Lake District). It may be significant that fossil polygons have been recorded in northern England about as often as have their striped counterparts, though further research is necessary before this can be regarded as a fact of widespread application.

Under present conditions, stone stripe formation usually takes place above about 2000 ft. (609 m.) in northern England, providing that material suitable for sorting is available. Because such material appears to be rather scarce in the northern Pennines (large parts of the area are peat covered), most of the active stone stripes recorded in northern England have been found in the Lake District. At a small number of favoured localities in that area (eg. below Heron Pike) currently-forming stone stripes have been noted below the 2000 ft. (609 m.) contour. On the other hand, fossil stone stripes have been discovered rather more frequently in the northern Pennines than in the Lake District. Like their polygonal counterparts, these strongly resemble currently-developing forms in high latitudes.

ERECTED STONES

In several upland areas of northern England rocks have been found in an erected position due to past frost action. Such features are, for example, widely developed on the Moor House Reserve where they are of sandstone. By contrast, erected stones investigated in the central Lake District (eg. on Seat Sandal: pl. 5) have been formed from volcanic rocks of Ordovician age, while those of the North York Moors (eg. on Murk Mire Moor) are of Jurassic material. Similar features have been noted by the writer in other upland areas of the British Isles (eg. on Dartmoor, where they are of granite).

By reference to the Moor House Reserve, it can be demonstrated that erected stones may form a part of several periglacial landforms. Thus, on Little Dun Fell there are numerous cases of where stones in the borders of fossil polygons are in an erected position. Investigations on neighbouring Great Dun Fell and elsewhere have proved that stones in the coarse bands of fossil stripes may also be erected. In addition, various non-patterned forms may have erected stones in them. For example, a survey of fossil congelifluction deposits on House Hill, near the Moor House field station, revealed that about 66% of the stones there are in an erected position. Finally, instances have been recorded (eg. on Knock Fell) of where platy, erected stones occur on the edge of a block field.

The processes whereby frost can give rise to the formation of erected stones are as yet imperfectly understood. However, from evidence collected in various parts of northern England it appears that such features can be produced in at least two very different ways. The first of these consists essentially of the mechanical weathering of rock which has protruded for some time above the general level of the ground. Thus, where congelifraction has been most pronounced along planes lying at an angle to the ground surface, rocks may be sectioned and give the appearance of having been cut with a knife (pl. 5). Clearly, by processes of reduction and removal the portions of a sectioned mass will gradually be destroyed, so that in time perhaps only one isolated, platy fragment lying in an erected position will remain.

However, the formation of some erected stones is best explained by a theory which has already been discussed by a number of authors (eg. A. Cailleux and G. Taylor, 1954). Briefly, this maintains that platy fragments occurring below ground level may be turned and placed on edge by cryoturbation processes. The slow upward movement of such fragments may lead to their eventual appearance above ground level. On several occasions during the present survey, pits dug to reveal the subsurface nature of various deposits (eg. the fossil congelifluction deposits on House Hill) have uncovered stones in different states of erection. There is much to suggest that this theory is particularly suited to explain erected stones in polygonal and striated ground. No doubt it also accounts for many of the erected fragments in congelifluction deposits.

Clearly, to understand the formation of erected stones is to go a long way towards explaining the origins and development of several periglacial landforms. It is, therefore, imperative that geomorphologists pay more attention to the study of this phenomenon than they have in the past.

STONE FLATS

So far as is known, all the published literature on stone flats in the British Isles is contained in a paper by T. Hay (1942). It would appear that the main concern of this short reference was to describe the feature's principal characteristics, using as an illustration a stone flat from near the top of Hartside in the central Lake District. Particular mention was therefore made of the inverted soil profile which is typically associated with this kind of frost phenomenon. As was shown by Hay, this profile consists of a stony surface layer which is underlain first by a zone of smaller fragments and then by a fine black soil. Finally, at the base of the profile is solid rock.

In more recent years, T. N. Caine (1961) has undertaken a further examination of stone flats in the Lake District. His work, which has not, unfortunately, been published, shows the feature to be quite widespread in the area. Thus, he recorded some 45 examples of it, most of which were found above the 2200 ft. (671 m.) contour. Like Hay, Caine regards the Lake District stone flats as currently-developing periglacial phenomena and believes that their inverted profile is the result of frost pushing the larger material upwards to the surface. He has also found that frost sorting of this material can give rise to stone polygons and stripes.

THUFURS

The published literature appears to contain only one reference to the existence of active thufurs in the British Isles. This was made by the present writer who has noted such features on Great Dun Fell (L. Tufnell, 1966: pl. 6). Although found at several places near the top of this mountain, vegetation-covered frost hummocks are best developed on its exposed west-facing slope at an altitude of around 2700 ft. (823 m.). The individual hummocks examined were on average 8″ (20 cm.) high and were usually juxtaposed, thus giving rise to thufur "fields". Sometimes, they have developed in association with small congelifluction terraces on slopes of up to 17°.

Available evidence suggests that thufurs are rare in northern England. Their occurrence on Great Dun Fell can be largelly attributed to the mountain's severe climatic regime, which in many ways is similar to that in parts of Iceland — a country where thufurs are well developed.

ICE WEDGES AND INVOLUTIONS

Maps have already appeared showing the known distribution of fossil ice wedges in Scotland (R. W. Galloway, 1961a) and in England south of the Vistulian ice margin (R. B. G. Williams, 1964). Unfortunately, no comparable map exists for the area being covered in the present paper, although a few of the localities plotted by Williams do fall within this region. Of these, all are in that part of north-east Yorkshire which escaped glaciation during the Vistulian. According to G. W. Dimbleby (1952), ice-wedge polygons in this area were formed before the last interglacial and may have diameters of more than 40 yards. Evidence that similar features occur in the more recently glaciated areas immediately to the north has been put forward by R. G. Carruthers and W. Anderson (1941). In a short letter to the editor of *Nature* they claimed to have found many examples of fossil ice wedges in north-east England: unfortunately, they gave no details of how such features are distributed within the area, though they did mention that wedge structures were examined in a pit at Greenside, County Durham.

Rather less is known about periglacial involutions in northern England. Thus, while they have been recorded in the area (W. W. Anson and J. I. Sharp, 1960), no information is so far available on their nature and distribution. It is clearly imperative that the work of Galloway (1961a) should be extended to cover the most recently glaciated areas to the south of the Anglo-Scottish border.

FROST-PATTERNED VEGETATION

Frost, assisted by moving water, gravity, wind, animals, and man, often gives rise to features which may conveniently be grouped under the heading "frost-patterned vegetation". Many such features result essentially from the disruption and degradation of a turf cover, and thus provide yet another indication that frost is actively modifying the upland landscapes of northern England. On the other hand, at some localities the nature of the existing vegetation pattern may have been at least partly determined by past cryergic events. For example, on Ben Wyvis in Scotland patterned vegetation has developed over fossil polygons and stripes (R. W. Galloway, 1961c).

A variety of patterns can be formed through the degradation of a turf cover by frost action. Some of these have already been discussed by S. E. Hollingworth (1934), T. Hay (1937), and T. N. Caine (1961), all of whom recorded examples of such features in northern England. Thus, observations by Hay show that on areas of bare ground small rings of vegetation may occur, as near Raise in the central Lake District (T. Hay, 1937). Then there are the patterns discussed by Hollingworth (1934) and Caine (1961). On gentle slopes, these consist of turf patches at roughly equal distances apart and set in an area of otherwise bare debris. However, with increasing steepness there is a tendency for various kinds of terrace to develop, as on Bowscale Fell in the northern Lake District (S. E. Hollingworth, 1934). This connection between vegetation patches on otherwise bare ground and certain terrace forms was examined a number of times during the present survey. For example, at around 2800 ft. (854 m.) on Fairfield vegetation clumps, vegetation arcs, vegetation-banked garland/parallel terraces, etc. were all found in close proximity. Even more striking is the area of frost-patterned vegetation at 3100 ft. (945 m.) near the summit of Helvellyn (pl.7). These and other examples of patterned vegetation in the uplands of northern England are no doubt largely produced by frost. Sometimes, however, wind may be the chief factor responsible for the development of a vegetation pattern in a periglacial environment: this kind of situation is described in the next section.

Perhaps the most noteworthy examples in the British Isles of where past cryergic activity has influenced the present vegetation pattern are those involving the chalk polygons and stripes described by R. B. G. Williams (1964) and others. On a more modest scale, Pleistocene frost action has been an important factor in determining the present vegetation pattern at certain localities in northern England. For example, curious patterns occur in the vegetation on the summit of Cross Fell: it seems likely that these are an expression of former periglacial sorting. Again, in the North York Moors the borders of fossil ice-wedge polygons are now marked by the relatively light colour of their vegetation (G. W. Dimbleby, 1952).

From the preceding remarks it should be obvious that the term *frost-patterned vegetation* has been used to include features which might just as easily be described under headings such as *congelifluction terraces, polygons and stripes,* etc. On the other hand, it is clearly useful to have in one place all known facts concerning those vegetation patterns which originate largely through frost action.

WIND ACTION

No detailed study has yet been made of periglacial wind action in the British Isles and very little has been written about its effects in northern England. However, A. Cailleux (1942) has noted the occurrence of a few periglacial ventifacts north of the York—Escrick (i. e. Vistulian) moraines, while C. T. Trechmann (1919) has described what he regarded as a loess deposit occurring at Warren-House Gill on the Durham coast. It has a maximum thickness of 12 ft. (nearly 4 m.) and is in many respects similar to loess found in other parts of Europe. Despite the fissured and cracked nature of the Magnesian Limestone (Permian) below it, the author considered the deposit to be interglacial rather than periglacial. By doing so, he was of course merely following what was then accepted opinion.

At the present time, wind appears to be of restricted geomorphological significance in northern England. However, one must admit that its erosional importance is often difficult to evaluate, since aeolian action does not necessarily lead to the formation of distinct and easily-recognisable geomorphological features. Thus, it is certain that wind, together with needle ice, moving water, gravity, animals, and man, assists in the erosion of peat at high levels in northern England, though in doing so it frequently produces no definite, lasting shapes. Hence, in view of these difficulties, one must always be careful not to underestimate the erosional ability of periglacial wind action.

During the present survey, only one type of periglacial feature has been identified for which an aeolian origin seems likely. This has been studied, for example, at altitudes of between 2700 and 2900 ft. (823—884 m.) on Nethermost Pike and on Dollywaggon Pike. Basically, it consists of a groove, usually less than 2″ (5 cm.) deep and with a stony floor, which interrupts the vegetation cover and has its long axis aligned in the direction of the prevailing winds. Often, such features are grouped in quite large numbers with individual members only a short distance from each other. Where this is so, the ground may have a striped appearance. However, the detailed form of these grooves, their position on exposed areas of slope, and their alignment strongly favours the idea that wind is the chief agent in their formation. If this idea is correct, then wind is obviously of importance in the degradation of turf at high levels in northern England. In this context it may be significant that just below one set of grooves on Dollywaggon Pike vegetation-banked garland terraces were noted: this suggests that wind is also assisting the degradation of vegetation on their treads. Hence, it appears unwise to dismiss wind as being geomorphologically insignificant at the present time in the uplands of northern England: detailed investigations may attribute to it greater importance than would a cursory examination.

PSEUDO-PERIGLACIAL PHENOMENA

When attempting to identify the geomorphological effects of cryergic activity, the field worker must always reckon with the existence of features whose appearance is very like that of certain periglacial phenomena but whose origins are not the result of frost action. It is therefore vital that the periglacial geomorphologist should at all times exercise the utmost caution if he is to avoid misinterpretation.

Pseudo-periglacial features may be grouped into two principal classes. First, there are those which contribute to the shape of the ground. Included in this category are various types of pattern and certain features due to mass movement. Thus, polygons, usually between 3 and 7 ft. (about 1—2 m.) across, are well developed in outcrops of Carboniferous limestone near Brough (Westmorland). However, the furrows which give rise to these polygonal shapes are not due to cryergic activity, but form the grykes in a limestone pavement. Especially where overlain by a thin vegetation cover, these can form patterns deceptively like some of those resulting from periglaciation. At other localities in northern England pseudo-periglacial hummocks have been noted. They occur, for example, above Underbarrow Scar, west of Kendal. Hummocks in this area are vegetation-covered and usually have dimensions similar to those of thufurs. However, a number of factors indicate that they are not periglacial features: among these are the irregular and sometimes appreciable distances between individual hummocks, the presence of ants in virtually all of the examples studied, and the comparatively low altitude at which such features occur. Other types of pseudo-periglacial hummock include those produced by cattle stamping their feet on the ground or by moles. In both cases, forms similar to thufurs may result. The interpretation of some mass movement features is also liable to cause difficulties. Thus, it is not always easy to differentiate either a creeping or sinking boulder from a ploughing block, especially in those parts of northern England at altitudes of between 1000 and 2000 ft. (305—609 m.). Again, brake blocks whose formation is controlled by periglacial action often look very similar to those characteristic of humid, temperate areas (L. Tufnell, 1966). Finally, another brief reference can be made to certain of the terrace features which result from mass movement. Here again there is the difficulty of suggesting exactly how two different climato-morphological regions permit the development of landforms whose appearance is at least superficially identical.

The other major group of pseudo-periglacial features comprises those which usually give rise to no surface expression. Although these have been little studied by the present writer, it is clear from the literature that they occur in many parts of Europe. Hence, research on ice wedges, involutions, etc. in northern England would have to take into account the existence of their many pseudoforms.

These brief remarks on pseudo-periglacial features make no attempt to be comprehensive. They are simply intended as a warning against overemphasizing the geomorphological importance of frost in northern England.

CONCLUSIONS

The present survey has been mainly concerned with the identification of periglacial phenomena in selected areas of northern England. However, by combining information gathered through field work with a reading of the available literature, it has been possible to consider periglaciation effects over the whole region. Since this is the first attempt of its kind, various difficulties have naturally been encountered and as a result a number of errors have doubtless been made. Even so, it can be affirmed with certainty that a wide range of periglacial phenomena exists in northern England and that there are many cryergic features awaiting detailed investigation. If, therefore, the present notes help to stimulate interest in what is essentially an uncharted area of knowledge, their publication will have been worthwhile. Furthermore, valuable work can be done not only by the professional geomorphologist, but also by the amateur enthusiast: basic details concerning the nature and distribution of periglacial features in northern England are, after all, still very few.

Present knowledge allows one to draw several conclusions about the effects of frost action on landscape evolution in northern England. Although some of these are tentative and contain an element of speculation, others cannot reasonably be questioned. Above all, they provide a basis for further research and discussion.

(1) About 20 different kinds of periglacial phenomena have so far been identified in northern England.

(2) If we are to understand fully landscape evolution in northern England, the role of cryergic activity must be properly evaluated. This necessitates a much greater interest in frost phenomena than has hitherto existed. On the other hand, enthusiasm for periglacial research must be tempered by the knowledge that a fair number of pseudoforms occur within the region. Hence, only after an exhaustive study should a feature be assigned to the periglacial category.

(3) To date, several periods of cryergic activity have been recognised in northern England. One of these is currently affecting the higher parts of the region. According to T. N. Caine (1961), it is morphologically significant in the Lake District above 2200 ft. (671 m.). Secondly, there is a great number of periglacial features whose origins date from Vistulian times. Some (eg. various head deposits and screes) can reasonably be attributed to frost action which occurred during the latter stages of that period. Others (eg. congelifracted bedrock below glacial drift) would appear to represent a very early Vistulian phase of cryergic activity. In most parts of northern England these must be regarded as two separate periods of morphologically significant frost action, broken by a longer period of ice cover. Finally, in north-east Yorkshire there are ice-wedge polygons considered by G. W. Dimbleby (1952) to represent an even earlier, pre-Vistulian (? Gipping) cryergic phase.

In a number of localities superposition of periglacial phenomena of different ages has been found. Thus, on Great Dun Fell small congelifluction terraces are developing over large-scale fossil stripes.

(4) There are significant differences between the present climato-morphological regime in upland northern England and the

Vistulian periglacial environment(s). Today, frost does little more than re-sort and move existing debris. The phenomena it produces are almost invariably small-scale (polygons, stripes, terraces, etc.) and they develop under conditions of temporarily-frozen ground. On the other hand, Vistulian frost action gave rise to the preparation of debris (i. e. congelifraction), as well as to its subsequent sorting and movement. In addition, the periglacial landforms which resulted were on an altogether grander scale than those being currently formed and they almost certainly developed when the ground was permanently frozen.

(5) Evidence suggests that the assemblage of periglacial features within a major subregion of northern England tends to differ from that in other parts of the area. As investigations into this problem are just beginning, the summary which follows is only tentative: it lists the main periglacial features so far discovered in the various subregions of northern England.

(a) Lake District: fossil screes, block fields, congeliflucion deposits, and erected stones. Present-day stripes, congeliflucion terraces, ploughing blocks, stone flats, and frost-patterned vegetation.

A subdivision of this area into eastern and western parts will almost certainly be possible when more information has been collected.

(b) Howgill Fells: fossil congelifluction deposits, and screes.

(c) Northern Pennines: in those parts of the area where periglaciation has been strongest, the main features examined have been: fossil congelifluction deposits, polygons, stripes, block fields, erected stones, and screes. Present-day congelifluction terraces, and ploughing blocks.

(d) North York Moors: fossil congelifluction deposits, and ice-wedge polygons.

(e) Cheviots: fossil congelifluction deposits.

(f) Lowland areas of northern England: fossil congelifuction deposits, and ice wedges.

(6) There are contrasts in the extent to which frost has modified the landscapes in different parts of northern England. For example, the duration of Vistulian cryergic activity may have been greater in upper parts of the eastern Lake Dictrict than at com-

parable altitudes further west. On the other hand, no area of the Lake Dictrict endured Vistulian periglacial conditions for as long as did parts of the Howgill Fells or the northern Pennines. It would, in fact, seem that nunataks existed in northern England for at least part of the Vistulian. In addition, large areas of the North York Moors appear to have been ice-free and subjected to periglaciation for the entire Vistulian period.

At lower altitudes in northern England cryergic activity was probably restricted to the transition phases at the beginning and end of the Vistulian (and of other glacial periods). Surviving evidence for these events includes frost-shattered bedrock, congelifluction deposits, and screes. However, man has probably destroyed much evidence relating to late Vistulian periglacial events, while glaciers have largely obliterated frost phenomena of the early Vistulian. Hence, there is always the danger of under estimating the influence of cryergic activity at low altitudes during such transition phases. Despite this, Pleistocene frost action seems to have modified the upper parts of northern England more than its lower areas. Moreover, this situation is being perpetuated under present conditions, as frost is now morphologically significant only in the higher parts of our region. In other words, those areas which in the past underwent the greatest periglacial metamorphosis are once again those parts of northern England experiencing the most intense frost action.

Clearly, the foregoing evidence suggests that while glaciers have been the main agents of Quaternary landscape evolution in the lower parts of northern England, the dominant processes on higher ground away from the western coast have been those attributable to frost action. This kind of situation may be fairly widespread in those parts of the British Isles which lay behind the Vistulian ice margin.

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