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FOSSIL PATTERNED GROUND IN EASTERN ENGLAND

Abstract

Fossil polygons and stripes of a distinctive type are found widely in eastern England. They are notable for their large size, and for the striking rendering by present vegetation. Representative sections were dug to expose the underground structures. Polygons are composed of superficial cover materials (aeolian sands or solifluction debris) lying in flat-bottomed troughs formed in chalky materials. Stripes are very similar. The origins of the structures are discussed. The forms are found to be essentialy different from stone polygons etc. and cannot be matched with any present Arctic patterns. Some 500 localities are known and all are restricted to chalky materials and the eastern half of the country. Possible reasons for this are suggested. A general Last Glaciation age for the patterns is indicated: some however may have survived from the Gipping (Saale) retreat.

INTRODUCTION

Large-scale patterned ground of several types occurs in lowland Britain as a relic of periglacial conditions, and two kinds have gained particular attention. First, there are the ice-wedge polygons or fracture nets familiar from many present-day tundras. Search of air photo coverage has made it clear that they are much more widespread and important than the literature would indicate (fig. 1). The second type is the subject of this paper and is an apparently unique class of pattern which is strongly represented in eastern England. Examples of it were first discovered by Watt in 1955 on certain heaths in the Breckland of East Anglia. Since then little more has been written on the topic and the following paper is offered as a brief introduction.

GENERAL CHARACTERISTICS

The main forms are polygons of cellular type which are replaced by stripe patterns on slopes of greater than one to two degrees. Transitional forms occur frequently (plate 1), but sometimes, apparently when the break of slope is more abrupt, the conversion to stripes is very sharp (plate 2).

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The size of the patterns is remarkably large; the distance between the mid--lines of matching stripes is on average about 25 feet (7.5 metres), whilst the diameter of polygons measured from the centre of their partitions is commonly 35 feet (10.5 metres). It is usually believed for polygons and stripes in general that these two measures are the same because of the relation of the forms on a slope. However, for the patterns in question, there can be no doubt that the values differ substantially. There is little variation in size between individual examples.

It would be wrong to think of the stripes as only simple parallel bands, for there are many special features besides chance irregularities. On slopes which are convex in plan, so that the area which the stripes have to cover increases downhill, approximate constancy of spacing is still preserved. New stripes are inserted either by the forking of a single stripe in a down-slope direction or by the sudden splaying out of a pair between which the extra band begins. On some photographs of bare fields it can be seen that the stripes are not continuous but arranged *en échelon*. Cross partitions are sometimes so frequent as to create a peculiar boxwork pattern. Plate 2 shows the herringbone effect produced by stripes intersecting from opposed slopes and turning together along the floor of a shallow valley.

The patterns appear as contrasting arrangements of chalky and dark soil on ploughed fields, as differences in the growth or maturity of cereal crops, and, by far the most clearly, as contrasts in heathland vegetation between calcicole and calcifuge communities. But fundamentally they consist of a „soil" structure concealed by a shallow later cover of topsoil, hill creep or blown sand. The plant pattern is only a secondary representation of this and may be imperfect but is often much more emphatic than the soil markings on a bare field. The patterns are often difficult to appreciate on the ground and are far better revealed on air photographs.

Heathland vegetation varies in its responsiveness. Polygons and stripes defined by heather (*Calluna*) growing in otherwise open grassland are usually the most striking. Gorse (*Ulex europaeus*) sometimes supplements the heather, and occasionally dominates — as has happened at the Drove, Brettenham, since plate 1 was taken. Faint plant patterns are often seen which are composed of grass alone, but their nature is difficult to discover. Locally there may be a segregation of particular species of fescue and bent (*Festuca* and *Agrostis*), but in general the markings seem to be due merely to the habit of the plants, such as their spacing and leafiness. Since most species of grass are indifferent to soil acidity, it rather looks as if the important factor is the varying exposure to drought, which is greatest on the non-chalky part of the pattern. There are other plants which play a minor role. Since the vegetational aspects of the patterns have been the subject of a much fuller investigation by D. E. Coombe (unpublished) they are not discussed any further here.

THE UNDERGROUND STRUCTURE AND DEPOSITS

The key to an understanding of the patterns is clearly the underlying soil structure. Published information adds little to the observations of Watt. Stripes of heather at Thetford Heath could be traced to a bare area where the topsoil had been stripped off. Watt found that the heather corresponded to stripes of sand with scattered flints, whilst the intervening grass bands overlay ribs of chalky boulder clay with numerous flints aggregated towards the middle line. This division between sandy and chalky parts has proved to be a usual and a distinctive feature of this pattern. Sections and exploratory borings were made at various places to discover the nature of the structure underlying this pattern.

A 15 metre trench was constructed across a representative area of polygons on Thetford Heath, and revealed a basically simple structure (fig. 2 A). Deep sand underlies the heather of the partitions and fills a flaring trough, like a moat in plan, formed in extremely chalky till. The sand becomes very shallow over the centre of the polygons. Complexity is introduced by numerous irregular gullies and pipes caused by solution at the base of the sand, but it will be noted that the unaffected parts conform to a smooth surface (broken line in section).

The chalky material varies with the locality. It may consist of the Chalk itself, but in the Breckland it is probably more usually composed of intensely chalky till of Gipping (Saale) age. Sometimes it appears to be a solifluction deposit.

The derivation of the sand has important implications for the origin of the pattern as a whole, and special attention was paid to this problem. At Thetford Heath, the sand was evidently aeolian. It had the high sorting and grade size of a typical dune sand, with 75 per cent of the grains lying between 0.1 and 0.3 mm diameter. Moreover the grains in the relatively small fraction of coarse sand showed conspicuous rounding and often frosting. Further confirmation was obtained nearby at a second section (described later), where brilliantly polished fractured flints were found in the sand. The high gloss strongly suggests an origin from sand blast. Significantly, flints partly embedded in the till were polished on their projecting surfaces, demonstrating that even the lower layers of the sand were wind-derived. Flints now lying on the surface have lost all trace of polish and have only a dull white patina.

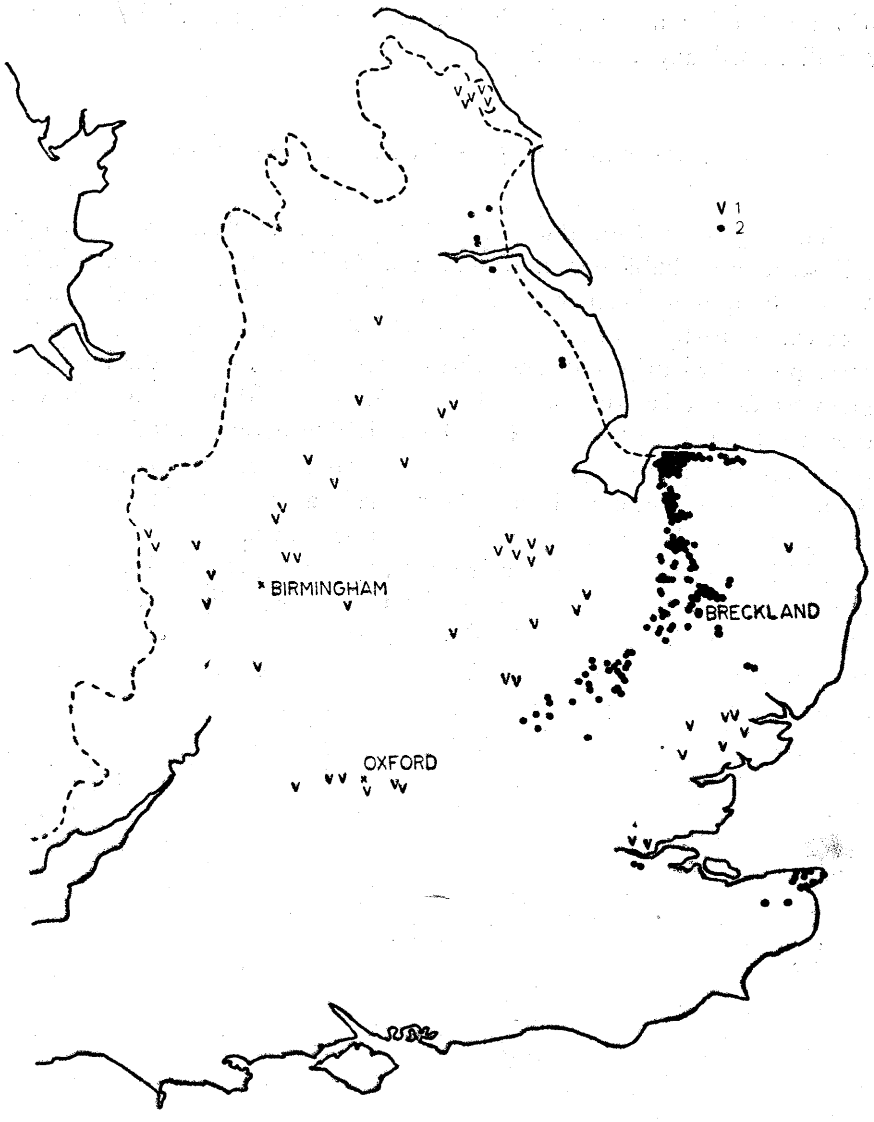

Fig. 1. Map of localities for polygons and stripes

1. ice-wedge polygons; 2. trough patterns. The ice margin of the Last Glaciation is shown as a broken line. The map is compiled from air photographs taken by the Royal Air Force and J. K. St. Joseph and from information published by Dimbleby (1952) and Shotton (1960 and 1962)

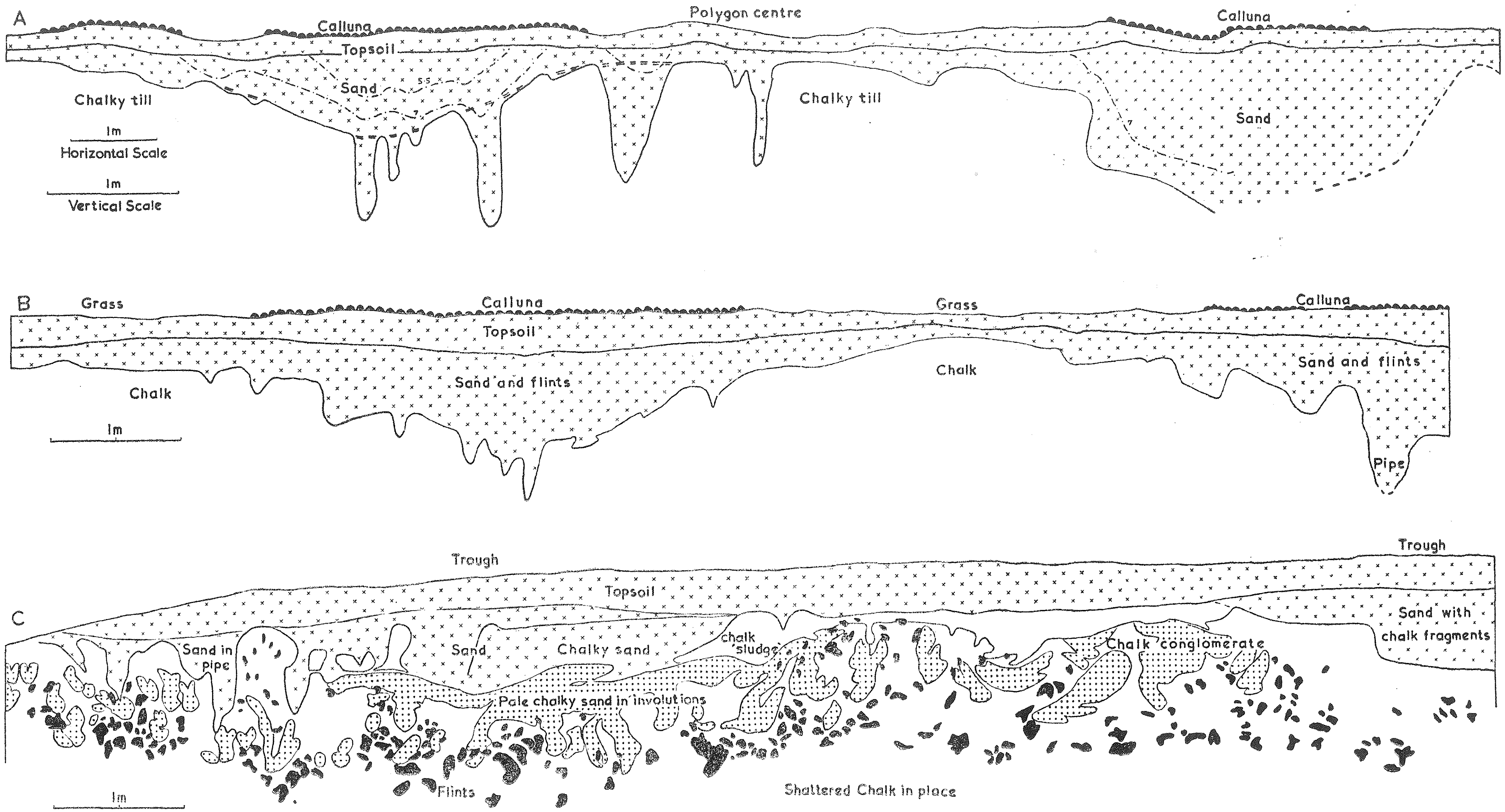

Fig. 2. Cross-sections to illustrate the underground structure

Top (A): section through a polygon: Thetford Heath, Norfolk. Figures refer to pH readings — these are not complete for the right hand partition. Centre (B) — section through stripes: Grime's Graves, Norfolk. The right hand trough is excavated to the mid-line. Bottom (C) — stripes in section: small pit, Risby Poor's Heath, near Cavenham, Suffolk (grid. Ref. TL/777678). Flints in black

In both sections the abundance of fractured flints found within the sand presents some difficulty, since the larger pieces could not possibly have been moved to their position by the wind. It seems likely that the stones have been expelled by frost action from the adjacent till. Presumably this would be before the sand was deposited on top, since the polished stones projecting from the till have not been ejected and yet could not have received their polish after the sand was in place. Immediately before burial, therefore, the surface of the till can be imagined covered by a loose litter of flints, some of which, sufficiently exposed to sand blast, would become polished. A defect of the hypothesis is that no trace of this layer survives between the sand and the till in the sections. If the sand was directly wind-accumulated in the moats the total dispersal of such a stone layer after burial is difficult to conceive even with the help of later frost action or the burrowing of animals. The possibility is not precluded however that the polygon moats were filled by microsolifluction from off the central domes, the sand having been evenly deposited before the patterns started to form. This, together with the other processes mentioned, might explain the disappearance of the stone layer and the complete intermixing of the flints in the sand. Nevertheless the story is far from clear.

It is seldom easy to decide whether the sandy material filling a particular example of pattern is dominantly wind derived or solifluctional in origin. Besides flints, the sand often contains innumerable small chips of white Chalk. These are light enough to be brought by the wind, but solifluction might be capable of shaving off similar fragments of the underlying bedrock during its passage. On the slope of the Chalk escarpment in eastern Cambridgeshire a site was found where, if correctly interpreted, the patterns were infilled by intensely chalky sand. This was identical in appearance with the Taele ,,Gravel'', a local solifluction deposit, which is exposed in sections only a short distance away.

Cross-sections of stripes reveal a structure that much resembles a polygon partition. Since there is little variation in the important features, only two sections will be quoted although others have been investigated.

At Thetford Heath a trench through a stripe showed that it was roofed over by a tightly packed layer of stones. This presumably was an erosion pavement of aeolian origin, but it might not be periglacial since it lay near the surface, and wind erosion has continued intermittently to the present day in the Breckland. Deep in the trough, the sand contained a more limited number of flints: as mentioned, many of these were polished. Perhaps because the stripes act as channels for subsurface water, the chalky till was so decalcified in parts that the outline of the trough was indistinct.

At Grime's Graves (fig. 2 B) the troughs were more stony but still much larger than would be necessary to accommodate the stones. It is the sand rather than the flints which seems to be the fundamental material. A definite stone layer was not found, but again many polished flints were encountered.

AFFINITIES AND THE PROBLEM OF ORIGIN

Watt and later writers have used the expression „stone" stripes (and likewise „stone" polygons) for the East Anglian patterns. This however is misleading. To justify the title „stone" stripes it would be essential, according to common understanding, that the alternating bands be textural opposites, differentiated by size of material as fine and coarse zones. Furthermore, each stripe should be the complement of its neighbour so that the pair, if mixed together, would reconstitute the original texture of the material.

The East Anglian patterns observe neither of these basic conditions. In the first place, it is doubtful if the trough fillings are systematically any stonier than the intervening chalky portions. These are often still very stony and unsorted. Secondly, the aeolian or solifluction materials filling the troughs could hardly be derived at first hand from the surrounding till. They are allogenic deposits that have somehow become incorporated in the pattern. The adjacent chalky parts are not the residue of the till from which the sand has been separated but the little-altered till itself.

Perhaps Watt was misled by the stone lines he observed in the centre of the till bands at Thetford Heath. I have not noticed these elsewhere, and these may be accessory rather than essential features. Moreover the stone rows are in the wrong position in the pattern to relate to stone stripes. In the Canadian Arctic, Drury (1962) reports how with vegetation stripes the bare ground between the bands of vegetation may develop a longitudinal crack down the centre line. Stones might collect in such a fissure and the flint rows in the Breckland might be explained in this way.

Even when allowance has been made for any resemblance, the East Anglian forms differ fundamentally from stone polygons and stripes. The question is not merely a technical matter of names because affinities with Arctic forms and the problem of formation are involved. These trough patterns were not created by a sorting process and a different origin must be found for them. They evidently belong to the general, if artificial, category of non-sorted polygons and stripes.

It has not yet proved possible to match the details of these patterns with any found in Arctic areas. Vegetational stripes are figured by Washburn from Victoria Island, North West Territories, Canada. These are non-sorted, 10—13 feet (3—4 metres) apart, and are represented upslope by polygons marked out by vegetation growing in boundary depressions. The very patchy nature of the pattern and its relatively small size contrast with the Breckland examples. The great depth and flat trough form of the latter is a further barrier to matching with Arctic forms.

Partly because of this, the mechanism of formation in the Breckland types is uncertain. The patterns have not been produced by ice wedges as stated by Shotton (1962). The cross-sections of Breckland polygons and stripes are totally unlike fossil wedges, since the trough floors are gently rounded or even flat and usually as wide as they are deep. Moreover there seems to be general acceptance of the view that stripes are never associated with ice-wedge patterns, in which polygons can occur on quite steep slopes.

An attractive explanation is that actual heaving of the till set up the pattern by producing a surface microrelief of troughs and swells. The depressed portions of such a pattern would become infilled with blown sand and soliflucted material and form the partitions now seen. Clearly we must look to the structure of the till itself for any evidence of such heaving. Practical difficulties arise. In the first place, any trench should be dug at least 8 feet deep so as to penetrate the till below the partitions — a considerable undertaking for any distance. Secondly, the till is almost as hard as concrete.

A section through both stripes and underlying material is seen however in a quarry face at Risby Poor's Heath as mentioned by Baden Powell and West (1960). Since figure 2 C was drawn, the section has become less well exposed. The structures though beautifully clear, unfortunately throw little light on the mechanism of stripe formation. Unmoved Chalk, exceedingly frost shattered and lying in loose tablets, grades insensibly upwards into a tightly bound conglomeratic material consisting of disordered chalk pebbles set in chalky matrix. This may have sludged down from the plateau above or been disordered *in situ*. The disturbance in this zone is picked out in colour by swirls or involutions of sand and included flints, many of which stand vertically. The flints all appear to derive from one layer which is partly preserved intact. The stripes take the familiar form of wide flaring troughs, sand-filled and quite sharply defined from the underlying contorted materials.

The problem is whether the stripe formation is causally connected with the underlying contortions or purely incidental. The contortions are complicated and irregular, with the individual folds only a foot or so (0.3 metres) across. By contrast the stripes are relatively simple in structure and very much larger, being 16 feet wide (5 metres). The contortions give the impression of occupying a definite zone which dips below the troughs and rises towards the surface in between them. Yet the level of unmoved shattered chalk is reached at much the same depth all along the exposure. Stripes and involutions occur together in this fashion at a number of places. Nevertheless both can occur separately and the relationship may be purely coincidental save in one respect. The evidence of involutions and bedrock shattering shows that the Chalk of eastern England thawed out in summer to depths of 5 to 6 feet (1.5—1.8 metres) and the Breckland patterns were evidently developed within this zone.

A number of authors especially Troll consider that giant stone stripes (but not miniature ones) were once individual polygons or lines of polygons which have been drawn on to sloping ground by solifluction and have in the process been transformed into linear shape. The alternative, also widely held, is an essentially static transformation in which stripes are as much primary forms as polygons. The different shapes are the result of the changed action of the component forces according to the angle of slope.

Troll based his opinion partly on the fact that Arctic stone stripes frequently follow a zig zag or sinuous course. The same feature is sometimes shown by the Breckland patterns, but the balance of evidence supports the alternative view that the stripes have formed independently of polygons. The chief point is the immediacy with which polygons replace stripes as these reach level terrain. No case is known of stripes being continued from a slope on to flat ground, yet a solifluction sheet would hardly be checked immediately on reaching the base of a hill slope. Many solifluction sheets on the Chalk seem to have travelled great distances on slopes as low as two degrees. The patterns are too deeply embedded for the whole structure to be affected by any but especially massive solifluction, of which there is no indication. If flow rather than sliding was involved the surface layers would inevitably move faster than the lower zones and this would drag out forms like cross-partitions by dispersing the upper part of the filling downslope. Unless the solifluction was remarkably uniform over the whole area of the patterns it would disrupt and destroy them. The detailed form of the transition does not seem appropriate to the conversion of polygons to stripes by actual motion. All this suggests therefore that at sites where stripes of the East Anglian type occur slope solifluction has been no more than slight since their inception. This inference, although it can only be tentative, may provide a clue to their peculiar distribution.

THE PROBLEM OF DISTRIBUTION

The distribution of the patterns (fig. 1) presents two major issues. In the first place, the patterns appear to be confined to chalky areas, for prolonged search of air photo coverage has failed to reveal similar examples elsewhere. The question arises whether this is mere appearance. The detection of the patterns depends on the existence of a perceptible contrast between the component materials. For the vegetation this contrast is supplied by the acid and alkaline portions of the pattern. On bare fields the necessary contrast is created by the light and dark markings. In both situations, chalk with a superficial cover of sand provides near optimum conditions for the recognition of patterns. Such conditions may not be found on other soils.

These facts could explain a greater frequency of the patterns on chalkland, if such were the case, but they cannot account for their complete absence from other soils. Similar contrasts of surface material and underlying rock are met with off the Chalk (for instance the sand deposits on the Lias in Lincolnshire) though perhaps not as commonly. But the distinctive Breckland patterns are never seen in these localities. Moreover it is implied in the foregoing hypothesis that other types of patterned ground if similarly recognized through soil contrasts would also be necessarily confined to the Chalk. This is not so. For instance, air photographs of gravel areas throughout England fairly frequently show ice wedge polygons (fig. 1).

Failing other explanations, it must be supposed that the chalky materials are themselves in some way responsible. They may have special qualities which render only them liable to the development of structures of this sort. Clearly any firm conclusion must await more evidence. The general susceptibility of Chalk to frost is already known. In England it is more seriously affected by present-day heaving than any other type of ground (Ward 1948 a & b). The plasticity of chalk solifluction deposits and tills during a thaw following a long frost is very noticeable. The same materials for the rest of the year can be extremely hard and seemingly far too strong to be rhythmically disturbed in large patterns.

The form and size of many types of Arctic pattern are known to depend on the depth of the seasonally thawed „active layer". This in turn is partly controlled by the nature of the material and the mode by which ground-ice is formed in it. This may be the link which explains the restriction of the East Anglian patterns to chalky ground.

A second striking feature of the distribution of these patterns is that they are found only in the east. They are most abundant in Norfolk but become progressively scarcer as the chalk outcrop is followed into southern

Cambridgeshire. No sites have yet been found west of Hitchin. Patterns are very scarce in Lincolnshire and Yorkshire and this can hardly be due to incomplete data. They are common in the Isle of Thanet; farther west there are only isolated examples near Gravesend and Canterbury. Nearly five hundred localities are known; in the areas of heavy concentration (Norfolk and Thanet) the map can show only a proportion. Elsewhere most sites are represented individually. More detailed maps at scales of one inch to a mile and greater have been prepared but are not shown here. Despite the inspection of numerous air photos, the search for patterns in western Chalk areas has been unavailing. A complete coverage of Salisbury Plain for instance produced no definite examples. Although a few localities will probably be discovered in the west, the overwhelming superiority of eastern districts is already clear. It would be interesting to know if there are any occurrences in France.

Such a distribution does not reflect any known position of the ice margin during the Last Glaciation. There is insufficient difference in the rainfall figures for the eastern and western halves of the country to justify the belief that the patterns have been destroyed by greater post-glacial surface lowering in the west. The preservation of the structures to a depth of four to six feet (1—1,8 metres) in the Breckland must be remembered in this respect.

The easterly distribution may depend on a continental climate in these parts at some stage in the periglacial. Whether the control was coldness or merely dryness is unknown. Connected with this problem is the possibility already mentioned that stripes indicate a lack of major slope solifluction. If this inference is correct, greater solifluction in the west may have prevented the formation of stripes or destroyed them. Loess localities are also dominantly eastern but the correlation with the map of patterns is poor.

Climatic control as an explanation meets with certain difficulties however, and can lay no claim to finality. Although permafrost was doubtless a factor in the formation of the patterns it can hardly have determined their distribution since it was not restricted to the eastern half of the country. Ice wedge polygons and giant stone stripes occur in the Midlands and the west: both are generally regarded as evidence for permanently frozen ground. Furthermore, the diffuse distribution of the wedge patterns contrasts strikingly with the concentrated and restricted occurrence of the chalkland forms. The discrepancy is difficult to explain. With the latter type, it is also odd that if climate governed the distribution at a national level its influence should be so little seen on a local scale. The slope aspect under periglacial conditions can markedly affect the climate at a site and with it the rate and type of erosion. In spite of this, the patterns show no consistent preference for a slope with a particular orientation.

THE AGE OF THE PATTERNS

The widespread conformity of the patterns with the shape of the present land surface suggests as Shotton (1962) has mentioned that the majority of examples do not predate the Last Glaciation. Local instances bear this out. Along the front of the Chalk escarpment in eastern Cambridgeshire there are old solifluction deposits (Taele Gravel) correlated with the end of the Gipping (Saale) glaciation which are now dissected by shallow valleys and so outcrop on the tops of spurs and low foothills. In sharp contrast, patterns are found not only on the higher ground but also along the valley sides and floors. The time of their formation, when the relief must have been very little different from the present, is most easily assigned to the Last Glaciation. Patterns also occur on the extensive valley plain of the Cam between Cambridge and its source at Ashwell, where this surface cuts the Chalk Marl. The downstream continuation of this part of the plain surface is formed by the gravels of the Barnwell or High terrace (Sparks 1957) which have yielded a Last Interglacial flora (Sparks & West 1959). Again a Last Glaciation age is implied.

It is however just possible that on level ground patterns from an earlier period might be preserved. Destruction is made likely by the relative shallowness of the troughs and the solutional lowering which may well proceed on Chalk surfaces at a rate as great as 1 inch (2.5 cm) in 1000 years according to the analysis of drainage waters. Yet where the patterns occur they may actually benefit from solution. If the troughs receive the greater part they may be deepened faster than the general ground surface is lowered, and become even further embedded. Such a process, if it exists, is clearly only at early stage at Thetford Heath, since the original trough structure is preserved but solution does seem most active under the partitions. Only one pattern has been so far discovered with features that might make it of Gipping age. This locality, in eastern Cambridgeshire, has already been mentioned as showing a polygon trough infilled by Taele Gravel. The depth of the overlying soil is seemingly too great to have formed entirely since the Last Glaciation. The chalk sand beneath is more or less unweathered, whereas if the patterns are really of Hunstanton age and the sand had lain on the surface throughout an interglacial one would expect the troughs to be filled by a complex mixture of soil and decalcified sand. Finally, the patterns cease where they flank the break of slope at the edge of a dry valley. No transition to stripes occurs, which suggests their removal by the later development of the valley side. But the age of these patterns is a matter for conjecture at present.

CONCLUSION

The Chalk landscape of Britain has suggested to many the heavy imprint of periglacial processes. It might be thought that in the east the extensive occurrence of patterned ground was clear proof of such sculpture. Yet all that can be safely concluded is that where the structures are well preserved post-periglacial changes have been slight. The question whether the landforms are periglacial can only be decided with other evidence, although as mentioned the presence of stripes may indicate the unimportance of slope solifluction. Much of the shallow sand covering the Breckland has long been supposed to be of periglacial origin. The patterns provide interesting confirmation of this.

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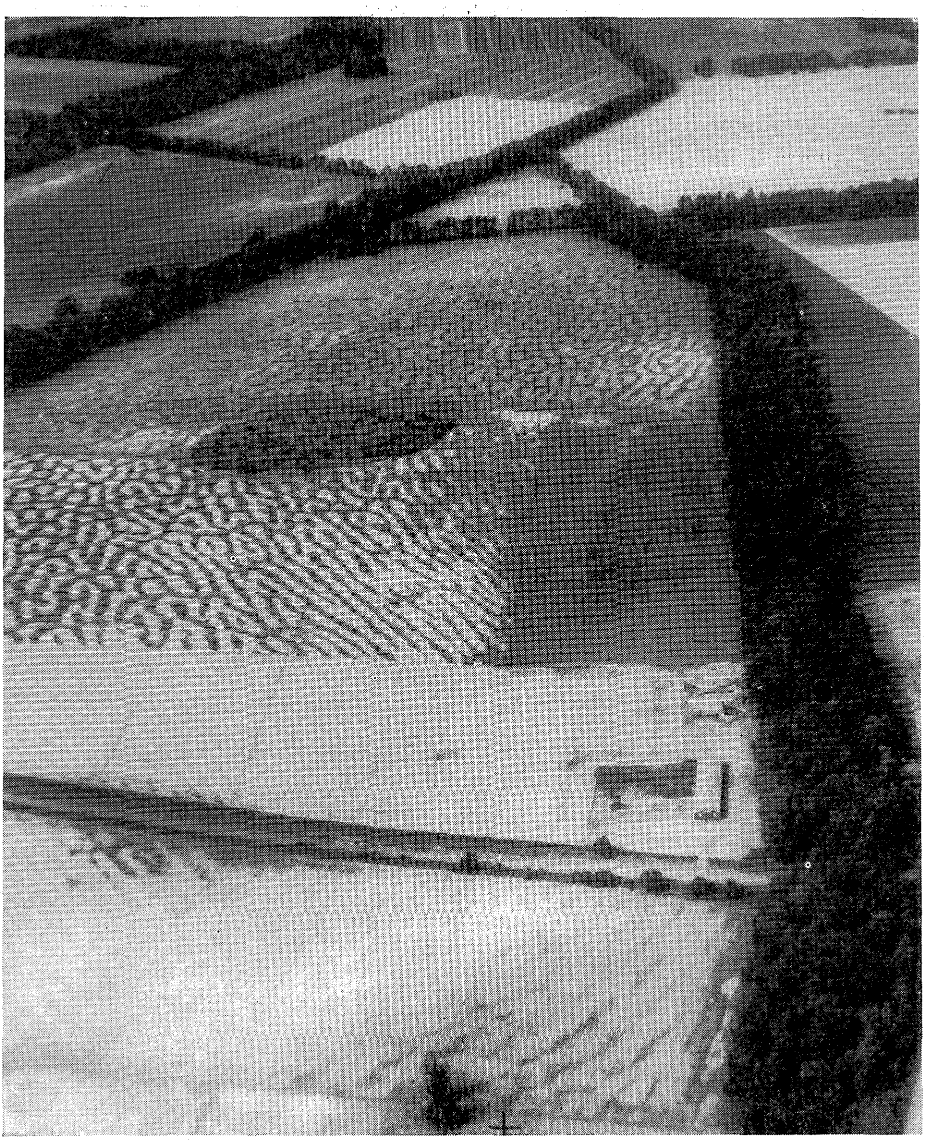

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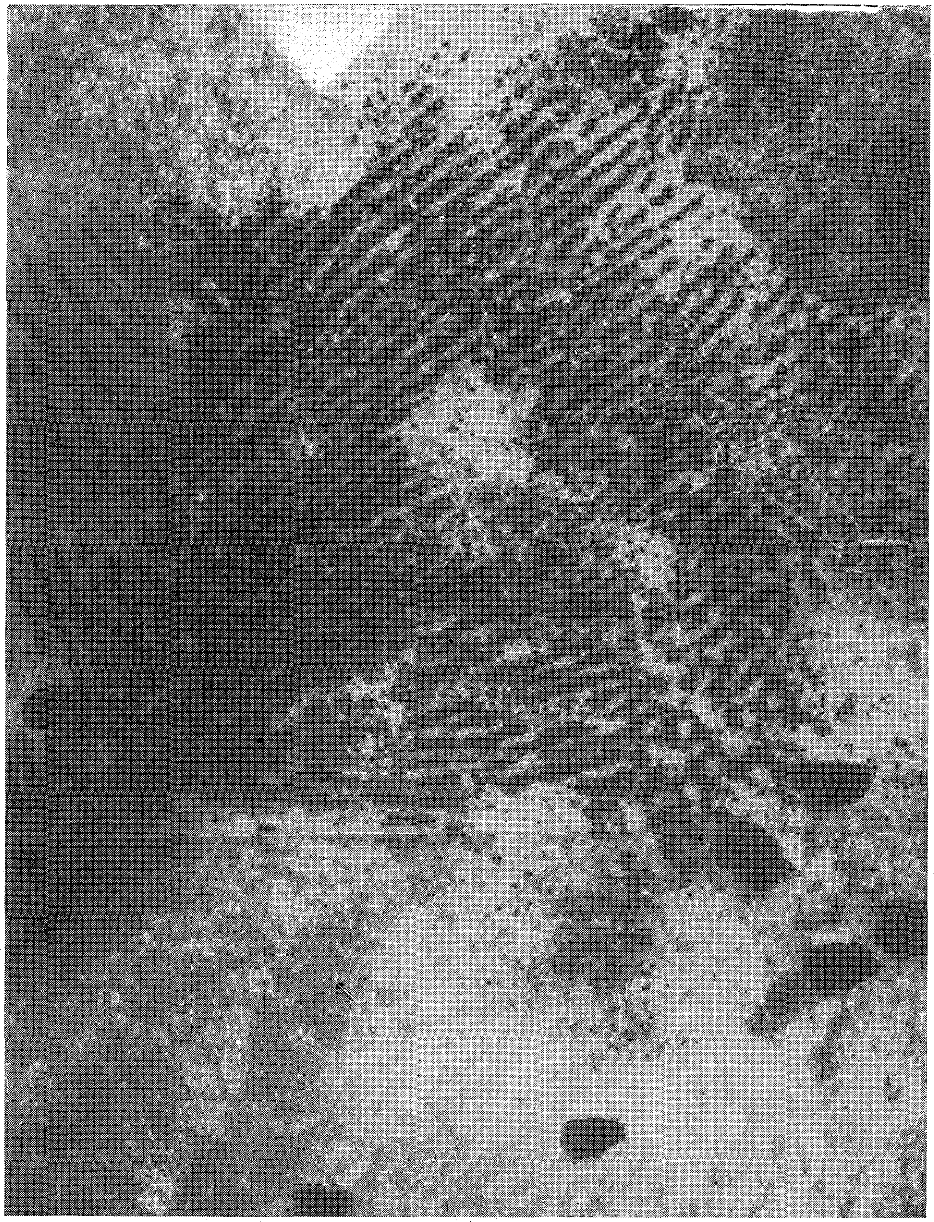
Pl. 1. Patterns in sown pasture, the Drove, Brettenham, Norfolk (Grid Reference, TL/ 915840)

Dark areas within the pattern show where the grass has failed. A variety of transitional forms, many with graphic shapes, occurs between the stripes on the slope in the foreground and the distant polygons. In the middle of the field is an „island" of bushes



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Pl. 2. Polygons and stripes, Thetford Heath, Norfolk (Grid Reference, TL/847798)

The heather shows black against the light background of grass. The spread of bracken (top, right) is slowly masking the patterns. The dark masses at bottom right are trees. The strip of ground in the photo is about 300 metres wide