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OBSERVATIONS ON A STRIPE PATTERN

Abstract

A stripe pattern seen on air photographs occurs on thinly driftcovered chalk from the East Riding of Yorkshire to Wiltshire. Stripes are most common in the Breckland of East Anglia and diminish in importance as a factor governing soil variability away from this locality. With increasing distance from the Breckland, stripes are at higher altitudes and occur most commonly on gently sloping spurs. Soil textures are variable between striped localities.

When mapping soils it is important to know the variability within a map unit and the reasons for it. If there is variability, for instance, in depth to rock, soil horizon sequence or in soil texture this can often only be ascertained by putting down many closely spaced auger borings but this is time consuming. If information on variability is obtained in a number of localities it should be possible to interpolate between these and predict where variability is likely to occur. Occasionally, the variability of soil within a map unit can be seen on air photographs (Evans, 1972), soils on patterned ground have a more complicated horizon sequence and depth to rock is more variable than for similar soils adjacent to the patterned locality. The mode of formation of these soil patterns is such that site factors such as climate, slope, position, and underlying rock control the occurrence of the pattern, not the soil on the pattern. This will be shown for the stripe pattern discussed here. Thus, characteristics of the soil profile such as colour or variability of depth of soil to rock are similar on stripes in different localities but the texture of the soil differs between these localities. Many different profile classes are found on the same pattern, therefore. If characteristics of stripes are known their distribution can be predicted, as can such features as soil depth and variability of depth over chalk.

In certain parts of lowland England soil variability is due to the formation of patterned ground in the last (Vistulian) glacial period. A stripe pattern on slopes, associated with a polygonal pattern on crests was first described by Watt (1955); it is common in the Breckland of East Anglia and also occurs elsewhere on the chalk outcrop of eastern England (Williams, 1964). Air photographs are of use in studying the pattern (Evans, 1972; Perrin, 1962) and plotting its distribution (Williams, 1964). The structure and origin of the pattern are discussed by Williams (1964),

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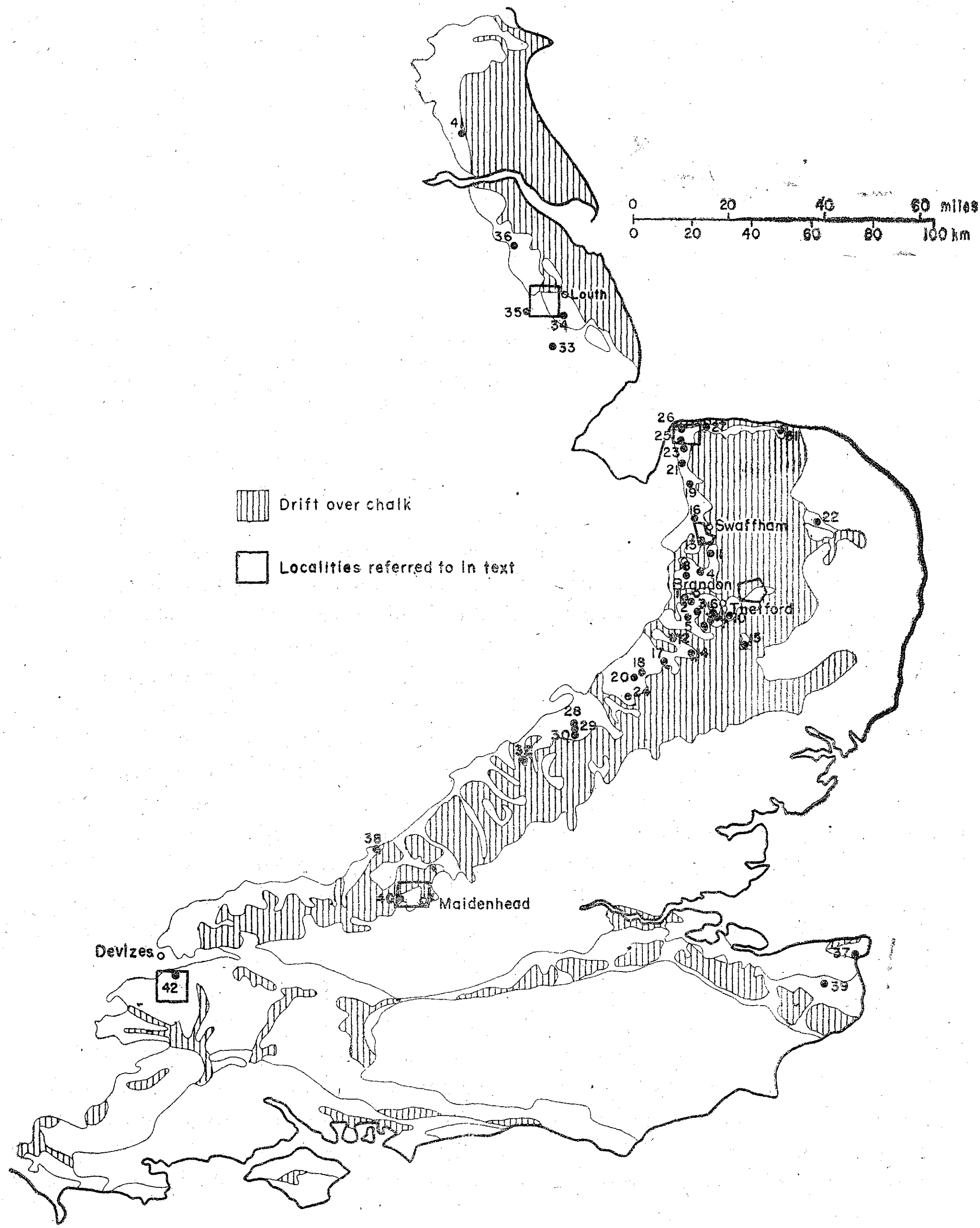


Fig. 1. Distribution of stripes and polygons and their association with the drift-free chalk outcrop

WATT, PERRIN and WEST (1966) and CORBETT (1973) but their conclusions are based on work carried out in the Breckland and may not apply elsewhere. To characterise soils on stripes sites were examined throughout the geographical distribution in England.

The distribution of the stripe and polygon pattern was plotted from air photographs. Vertical and oblique air photographs from the Cambridge University collection were inspected, as were 1 : 10,000 and 1 : 15,000 scale vertical photographs of parts of lowland England obtained for the Soil Survey of England and Wales for mapping soils. In addition, strips of 1 : 10,000 scale vertical air photographs were commissioned of parts of the chalk outcrop in Lincolnshire and the East Riding of Yorkshire in places where stripes had not previously been recorded. Dimensions of pattern, height above sea-level, slope, aspect and landform were noted for all sites examined.

At 42 sites chosen to sample the soils (Fig. 1) a series of bores, usually 10, was made along a contour at 2 m intervals. Soil horizon thickness, colour, texture by hand manipulation and acidity or calcareousness were noted at each bore. The Munsell colour system was used to describe soil colour. Slope angle was measured with an Abney level, readings being taken up and downslope between ranging rods and the mean calculated. Other sites were visited but not all of the above characteristics were noted or fewer bores were made; information from these sites was confirmatory and was not used in regression analysis.

PATTERN AND SITE CHARACTERISTICS

DIMENSIONS

Polygons are about 10 m in diameter and the distance measured between midlines of matching stripes is on average about 7.5 m (WILLIAMS, 1964). At a number of places in the Breckland where stripes are visible as vegetation patterns the width of individual stripes varies from 1.70 m to 5.80 m commonly being between 2.50 m and 2.99 m (Table I). The width of adjacent stripes varies in a regular manner, in the Breckland the ratio of the widths of adjacent stripes is less than 1 : 1.5 but away from Breckland the discrepancy in widths of adjacent stripes becomes greater.

Table I

Width of Vegetated Stripes

Width (metres)	1.50 1.99	2.00 2.49	2.50 2.99	3.00 3.49	3.50 3.99	4.00 4.49	4.50 4.99	5.00 5.49	5.50 5.99
Frequency (% of all sites)	1.7	4.8	30.0	25.4	14.3	12.6	4.8	4.8	1.6

Thus, the measured widths of dark- and light-toned stripes on vertical air photographs are 2.5—3 m and 7.5—10 m respectively in the Lincolnshire Wolds and 1 m and 3—5 m respectively in Berkshire. The ratio between stripes in places oustide the Breckland is generally between 1 : 2 and 1 : 4.

Table II

Width of Stripe Sites

Width (metres)	0—99	100—199	200—299	300—399	400—499	500—599	600—699	700—799	> 800
Frequency (% of all sites)	3.4	25.9	37.9	15.6	8.2	2.4	3.4	1.8	1.3

On air photographs stripes are often seen to be discontinuous along valley sides, being enclosed within lobe-shaped features between 100 m and 300 m in width and length (Tables II and III). In the Breckland several instances are recorded where the width of the stripe outcrop continues along valley side slopes and spurs for up to 1.8 km. Away from the Breckland striped sites i. e. lobe-shaped features, are commonly less than 0.2 sq km in area.

Table III

Length of Stripes

Length (metres)	0—99	100—199	200—299	300—399	400—499	500—599	600—699
Frequency (% of all sites)	9.9	34.2	31.3	12.6	11.0	0.7	0.3

RELATIONSHIP TO RELIEF

Polygons are found on crests and stripes on gently sloping valley sides, spurs and valley heads (Table IV). In areas such as that south-west of Swaffham, Norfolk (Fig. 1) patterned ground occurs on all slopes except valley floors, but away from the Breckland stripes are restricted almost entirely to spurs. Where polygons and stripes are contiguous they are linked by a narrow zone of vermicular and anastomosing stripes. Polygons and stripes lie within well defined slope limits, the slope

Table IV

Characteristic Stripe Sites

Landform	Spur	Spur/Valley Side	Valley Side	Valley Head
Frequency (% of all sites)	60.2	10.3	27.1	2.4

angles at 12 polygon sites being between 0°05′ and 1°00′; at 47 striped sites between 0°50′ and 6°00′; and at 8 vermicular and anastomosing striped sites between 0°15′ and 2°00′.

VISIBILITY ON AIR PHOTOGRAPHS

The pattern, which reflects the undulations of the chalk or chalky drift is seen on air photographs as differences in vegetation in heathland or rough grassland, in ploughed fields as soil colour differences, and as a crop disease or crop ripening pattern (Pl. 1) (BRENCHLEY, 1968). At three sites, the pattern was visible both on the ground and on photographs as differences in natural vegetation and at the remaining sites it was visible only on air photographs of bare ground (32) or crops (7). Often in the field, it is impossible to discern the pattern in bare soil or in crops, as neither colour nor differences in height of the soil surface or within crops are apparent. The pattern is not seen on air photographs of bare ground if the depth to chalk or chalky drift where it approaches nearest the surface is greater than about 50 cm. Thus, at 32 sites the mean depth per site of the five shallowest bores was less than 51 cm. At four sites where the pattern was recorded in crops mean depth of shallowest bores was less than 51 cm, but at three other sites was between 58—71 cm and, presumably, the pattern was caused by differential availability of soil moisture affecting rates of ripening. At these sites patterns probably only show in summer in crops but not on bare ground in winter. The pattern is indistinct on shallow soils with a mean depth of less than 30 cm and an amplitude between deepest and shallowest bores of only 6—10 cm.

DISTRIBUTION

The distribution of the pattern is similar to that shown by WILLIAMS (1964) but additional sites outside his limits were recorded near Norwich, in Berkshire, Wiltshire and Lincolnshire (Fig. 1). Stripes and polygons occur on chalk mapped as drift free by the Geological Survey (Fig. 1). Several striped sites near to, but not on the chalk outcrop occur near Benniworth and Horncastle in Lincolnshire, but at the sites investigated the subsoil was an extremely chalky, impenetrable drift.

Polygons occur infrequently outside the Breckland and were not found west of Cambridgeshire or north of the Wash. The importance of the stripe and polygon pattern as a factor governing variability in soils on chalk decreases markedly away from the Breckland. South-west of Swaffham, Norfolk (Table V, Fig. 1) non-patterned ground occurs only on the valley floors whilst the pattern is less common in the Thetford district because of the depth of sands and gravels over chalk, the permafrost structures possibly being present but not recorded on the photographs.

Table V

Extent of the Pattern in Selected Localities

Locality	Area Examined (sq. km)	Estimated area of pattern as total area (%)
South-west of Swaffham, Norfolk	25	71
North-east of Thetford, Norfolk	70	45
North-west Norfolk	50	8
West of Louth, Lincolnshire	100	1.5
North and West of Maidenhead, Berkshire	85	0.7
South of Devizes, Wiltshire	100	0.2

WILLIAMS (1965) estimates that permafrost structures underlie 50 per cent of the land surface of west Suffolk and Norfolk and Kent. Outside the Breckland stripes are rare and restricted to particular sites.

Away from the Breckland stripes occur at higher altitudes. Thus, stripes in Breckland are between 12—46 m above mean sea level, in north-west Norfolk at 30—52 m and at 38—82 m in Cambridgeshire and Hertfordshire. In Berkshire, Lincolnshire and Yorkshire East Riding the ranges in height are 46—82 m, 61—114

Table VI

Statistical Analysis*

A. Correlation of variates

	Distance from Brandon (km)	Altitude (m)	Soil Depth (cm)	Soil Depth variability (s.d.)	Slope Angle (degree)
Distance from Brandon (km)	1.00				
Altitude (m)	0.75	1.00			
Soil Depth (cm)	−0.55	−0.66	1.00		
Soil Depth variability (s.d.)	−0.71	−0.54	0.63	1.00	
Slope Angle (degree)	0.14	−0.06	−0.06	−0.19	1.00

m and 85—122 m respectively. The highest place recorded is in Wiltshire at 207 m and there is a significant correlation between the straight line distance, measured from Brandon to the 42 sample sites, and increasing altitude of the stripes (Table VI). Slope angle at a striped site is not steeper on higher ground.

B. Analysis of variance

Variates	Per cent. variance accounted for	Regression Coefficients			Significance	
		Intercept	1	2	1	2
Altitude: Distance	55.0	24.44	0.52		0.001	
Soil Depth: Distance	28.2	62.40	−0.13		0.001	
Soil Depth: Altitude	42.3	67.36	−0.23		0.001	
Soil Depth Variability: Distance	49.0	23.20	−0.09		0.001	
Soil Depth Variability: Altitude	28.0	23.46	−0.10		0.001	
Soil Depth Variability: Soil Depth	38.1	0.03	0.32		0.001	
Soil Depth Variability: Distance and soil depth	56.5	11.96	−0.07	0.18	0.001	0.010

* By ICL computer, using the Maximum Likelihood Programme for regression analysis devised by G. J. S. Ross R. D. Jones, R. A. Kempton, F. D. Lauckner and R. M. Payne, Statistics Department, Rothamsted Experimental Station Harpenden, Herts.

PERRIN (1962) notes that patterns occur on slopes facing all directions but most commonly on south facing slopes. This is confirmed here (Table VII); stripes are most common on south-east and north-west facing slopes and least common on west and east facing slopes.

Table VII

Aspect of Stripes

Aspect	North-west	North	North-east	East	South-east	South	South-west	West
Frequency (% of all sites)	16.2	13.4	8.2	6.1	18.1	15.5	15.1	7.3
		37.8				48.7		

SOIL CHARACTERISTICS

SOIL DEPTH

The variability of soil depth to the undulating chalk/soil interface is well shown in cross sections across stripes and polygons in WILLIAMS (1964, Fig. 2) and WATT, PERRIN and WEST (1966, Fig. 3), and in a simplified manner in Fig. 2. Statistical analysis of the site data indicates that soil depth is most variable where soils over chalk are deeper (Table VI). Soils are deepest in the Breckland and mean depth and variability, as measured by the standard deviation from mean depth, decrease as distance from Brandon increases (Table VI). This decrease in soil depth and

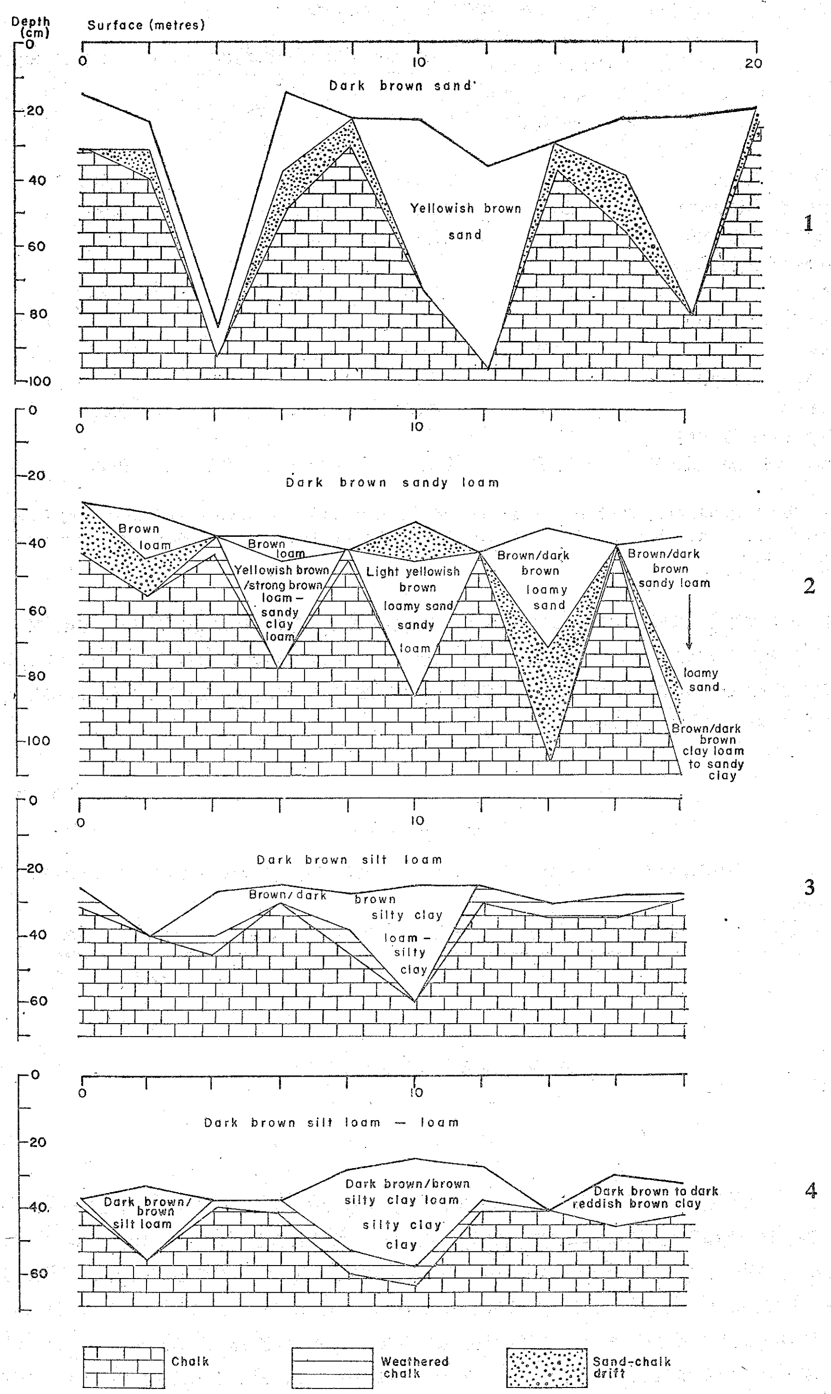
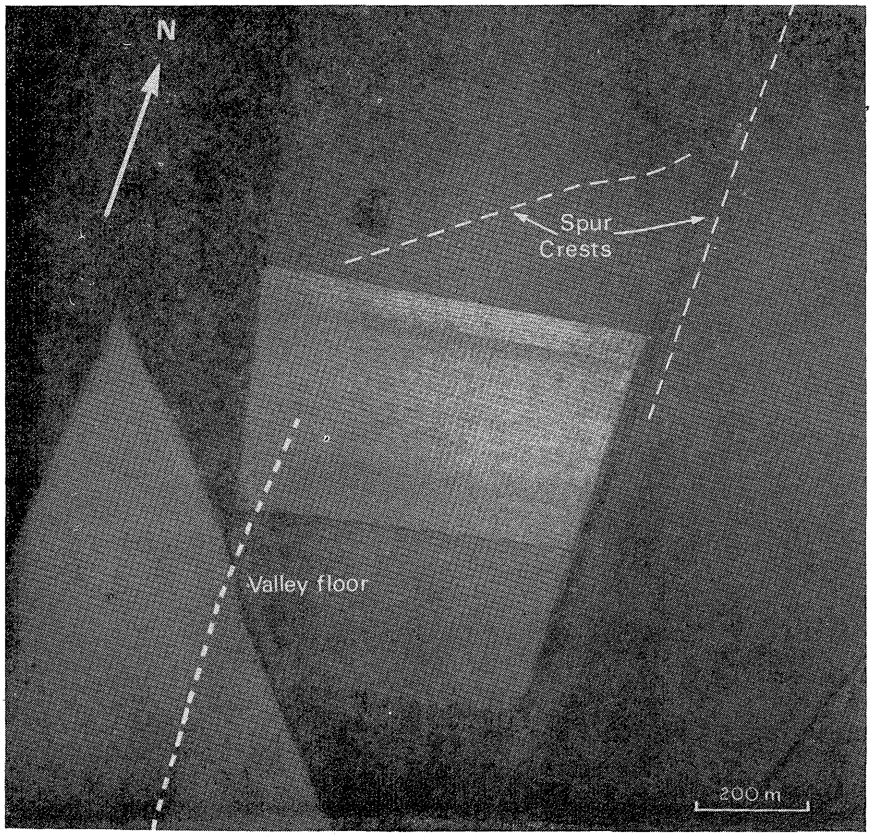


Fig. 2. Sections across stripe sites

1 – Thetford, Norfolk; 2 – Thornham, Norfolk; 3 – Hangham, Lincolnshire; 4 – Bishop Burton, Yorks. East Riding



Pl. 1. Stripe pattern in cereals, West Acre, Norfolk

variability of soil depth is related not to increasing slope angle but to the increasing height and distance of the sites away from the Breckland (Table VI).

SOIL TEXTURES AND COLOURS

Soils over patterned ground in the Breckland are deep sands or loamy sands over a sand-chalk drift over chalk (Watt, Perrin and West, 1966). Generally, surface soil textures on stripes are finer away from the Breckland being sandy loams or loamy sands on the edge of the Breckland, sandy loams and loams in north-west Norfolk and Cambridgeshire, and loams and silt loams in Lincolnshire, Yorkshire East Riding, Kent and Wiltshire (Fig. 3). Textures of sub-surface horizons are variable but reflect this trend. The horizon immediately above the chalk is commonly of weathered loamy chalk and chalk stones mixed with material from the succeeding horizon. Deep sands are generally non-calcareous and can be very acid under heath vegetation and in many soils, other than immediately over the chalk, the matrix is non--calcareous.

Deeper soils on stripes often have a common feature in the presence of a sub--surface horizon of a dark/very dark brown (7.5YR 4/4) or strong brown (7.5YR 5/6) colour. At twenty-eight striped sites some, or all, deeper bores had this characteristic horizon. At ten other sites colours are redder (5YR) or yellower (10YR) in hue but with the same values and chromas (4/4 or 5/6) or, if the values and chromas were not the same i.e. 7.5YR 5/8 and 5YR 4/7, the colour description in the Munsell colour book is, i.e. strong brown and yellowish red respectively.

DISCUSSION

At several non-patterned sites adjacent to stripes, bores were made at 2 m intervals along the contour; soils were less variable than on stripes or were on different parent materials. At these sites one or more of the following features were noted: (1) chalk or chalky drift was not reached within 1 m of the surface; (2) the parent material under the very dark brown or strong brown horizon is not derived from chalk; (3) the very dark brown or strong brown horizon is absent, or (4) there is less variability in horizon depth within the top 50 cm of soil and the horizon sequence is not complex.

Where chalk or chalky drift are not reached within 1 m, ground may be patterned but because of the depth of drift is not seen on air photographs. However, on non-patterned areas adjacent to patterned slopes where relatively unaltered parent material is reached within 1 m this is not chalky, hence stripes are recorded on chalk or drift with much chalk.

Stripes and polygons are types of non-sorted patterned ground (Washburn, 1956) and formed during the last Vistulian glaciation (Perrin, 1962; Watt, Perrin and West, 1966; Williams, 1964). Tricart (1970) states that chalky soils are susceptible to solifluction because silt and colloidal material act as lubricants and on thawing the liquid limit is rapidly reached. Thus, solifluction will take place on low angled slopes. Stripes occur most frequently on spurs and convex valley sides (Table IV) where steepening slopes would have promoted movement of soils, and they are commonly seen to be enclosed within a lobe-shaped feature. Flint (1957) notes that in areas of perennially frozen ground individual solifluction sheets are generally lobate, rarely exceed 3 m in thickness and are found on slopes of 2° where thawing to permafrost in summer is usually limited to a depth of about 1 m. At some places stripes on opposing slopes turn at right angles when approaching the valley floor and converge down valley (Pl. 1). It is probable, therefore, that stripes originated by soil flow. This conclusion is similar to that of Watt, Perrin and West (1966) who consider that stripes probably formed by solifluction downslope of birch-heath tundra polygons.

Stripes are not present on slopes steeper than 6° presumably because solifluction was so active that the upper horizons were completely removed leaving a bare chalky drift surface. Williams (1969) notes that no periglacial structures are found over chalk on slopes steeper than 6°.

The presence of a surficial drift of different texture over the weathered chalk or chalky drift will enhance instability of the regolith, especially when saturated after thawing. In Breckland soils are coarser and deeper and on thawing would not be supersaturated, unlike the finer textured, shallower regolith on stripes away from the Breckland in which band-ice would form (Taber, 1930). A greater weight and depth of this coarser material will be required before flowage takes place over the mobile, supersaturated basal chalky layer. Where the supply of windblown material was great, as in the Breckland, surficial loading would be greater and solifluction would take place on all slopes; where loessial deposits were thin solifluction would be restricted to spur sites and there would be fewer stripes. Thus, away from the Breckland, stripes are more widely spaced on spurs.

The presence of permafrost and associated periglacial structures depends on the interaction of vegetation, snow cover, ground thermal properties and air and ground temperatures (Brown, 1963). Away from the Breckland stripes occur on higher ground although the chalk outcrops lower down in these places and this implies that climate, particularly temperature, is an important factor controlling their formation. The climate of the Breckland is markedly continental in comparison with other parts of the British Isles and this was so in glacial times (Manley, 1964). Away from the Breckland similar winter temperatures would be found only at higher altitudes. Stripes have not been recorded on Salisbury Plain (Williams, 1964) presumably because winter and summer temperatures were too high for permafrost to occur.

The pattern is not recorded on photographs of shallow soils over chalk or chalky drift where the very dark brown or strong brown horizon is absent. This non-calcareous horizon may be due to weathering but is markedly different in texture to the solution product of the underlying chalk which is clay, and it is usually a drift from a non-chalk source. WATT, PERRIN and WEST (1966) consider that on balance the evidence suggests that the sand in the Breckland is a drift, possibly analogous to the 'cover-sands' of the Netherlands and that the sand-chalk drift below is due to periglacial mixing of drift and parent material. If this hypothesis is correct it explains the sandy soils of sites 1 to 13, and outside the Breckland soils on stripes having similar textures and colours are probably of similar origin (sites 16, 19, 21, Fig. 3). Similar soils but with more clay occur at sites 15, 22, 23, 25, 26, 27, 31 and 33 (Fig. 3). In Kent (sites 37 and 39, Fig. 3) the very dark brown or reddish brown soil of fine loamy or clayey texture over chalk is probably a loess of Vistulian age (WEIR, CATT, and MADGETT, 1971) and horizons of similar texture occur over stripes in the Yorkshire Wolds (site 31, Fig. 3). In the Lincolnshire Wolds and Wiltshire the sandy and silty soils are probably also of aeolian origin (sites 34, 35, 36 and 42, Fig. 3). In Oxfordshire and Berkshire this horizon is probably derived from clay-with-flints which caps the adjacent ridges (sites 38 and 40, Fig. 3). Soils on the remaining sites (sites 14, 17, 18, 20, 24, 28, 30 and 32, Fig. 3) are in drift but the age and origin of these drifts is not known.

CONCLUSION

This paper presents data from a larger number of sites than those examined by earlier authors (WATT, 1955; WILLIAMS, 1964; WATT, PERRIN and WEST, 1966); many of them are away from Breckland. The sampling of a larger number of striped sites, even though only a limited number of parameters were recorded, enables a simple statistical analysis to be made. This extra evidence supports the hypothesis of stripe formation put forward by WATT, PERRIN and WEST (1966) and indicates that climate was an important factor controlling this process. Providing that suitable landforms are present and winter temperatures are low enough stripes will form over chalk whatever the texture of the overlying soil; the pattern is not restricted to sandy soils over chalk. It is probable that the material over the chalk is drift but at many places no particular age or process can be ascribed to the depositing mechanism. If the deposits are loessial and were subsequently incorporated into the soils by periglacial processes the Breckland must have been nearest to the centre of dispersion as the deposits are not only coarser, but also deeper there. Soils on stripes are more variable in depth and their horizon sequence is more complicated than on adjacent non-patterned ground on air photos; this variability reflects their mode of formation. The occurrence of stripes can now be predicted; indeed, since the initial work was carried out stripes have been located in other localities on the chalk within the expected height range.

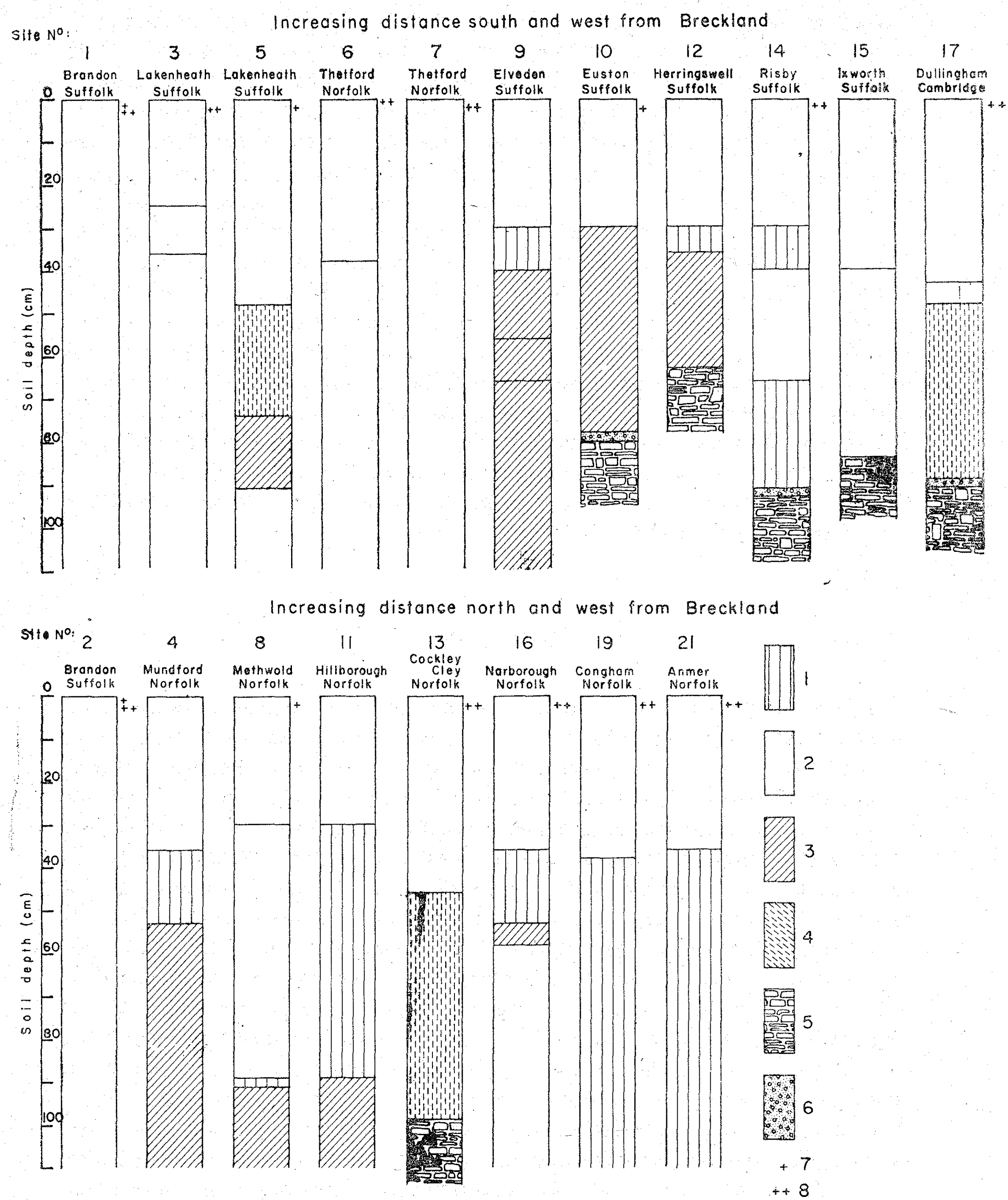
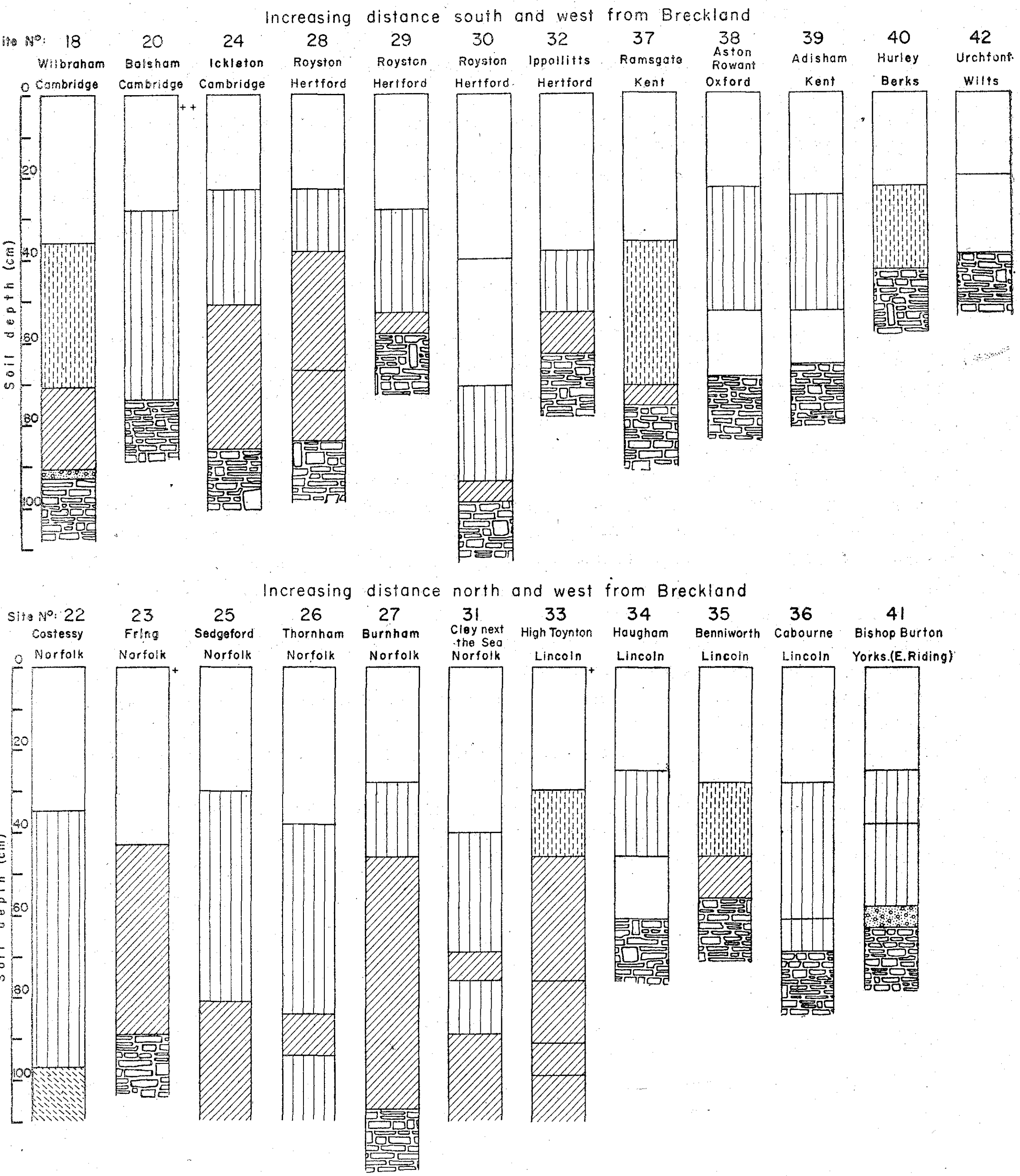


Fig. 3. Soil profiles of deepest bores at stripe sites

1. dark brown/brown or strong brown, commonly non-calcareous, no chalk stones; 2. redder hue but same value and chroma as dark brown horizon, commonly non-calcareous, no chalk stones; 3. yellowish-brown sand-chalk drift, highly



calcareous with high content finely divided chalk; 4. yellower hue, sand marl drift, highly calcareous, with high content finely divided chalk; 5. chalk; 6. weathered chalk; 7. dark brown/brown or strong brown horizon present in other bores; 8. sand-chalk (or marl) drift present in other bores

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