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PRE-WÜRM PERIGLACIAL PHENOMENA IN BRITAIN

Sommaire

Les manifestations périglaciaires préwurmiennes se trouvent pour la plupart dans le sud de l'Angleterre, qui était située en dehors des limites des glaciations les plus étendues (Mindel et Riss). Nous citons dans cette région qui n'a jamais été couverte de glaciers quelques phénomènes périglaciaires afin d'illustrer les méthodes employées pour les dater. Les méthodes de la géologie nous ont permis d'attribuer des dépôts de *coombe rock* et de loess dans la vallée de la Tamise à deux stades de la glaciation de Riss; dans le Weald, grâce aux méthodes de la géomorphologie, on a distingué un dépôt de solifluxion appartenant à la glaciation de Mindel; et la corrélation des dépôts de *head* et de loess près de Chichester avec le Riss a été confirmée par l'étude micromorphologique des sols fossiles. La grandeur des fentes en coin fossiles au nord-est du Yorkshire et des structures superficielles du centre et du midi de l'Angleterre indiquent un refroidissement intense et une profondeur de sous-sol gelé qui ne cadrent pas avec la conception qu'on se fait communément du climat pendant le Wurm. Nous croyons que de larges terrasses d'altiplanation du Dartmoor sont les résultats de plusieurs phases périglaciaires. Mais il faudra de nouvelles recherches avant de pouvoir évaluer la contribution des phases préwurmiennes à la modification cryergique des paysages du sud-ouest de l'Angleterre.

Periglacial phenomena have been recorded from all parts of the British Isles during the past two hundred years (FitzPatrick 1956) i. e., since 1758 when Borlase described a deposit of superficial material in Cornwall of the kind to which De la Beche (1839) subsequently applied the term *head*. In 1851 Godwin-Austen perceived that such phenomena in southern England were the result of processes no longer active; in 1882 Wood understood the significance of involutions, and five years later Clement Reid (1887) explained the origin of *coombe rock*, the solifluxion product of chalk areas.

Although the climatic significance of the relict phenomena was thus early appreciated, attempts to identify them with particular periglacial episodes were perforce delayed until the chronology of the Pleistocene epoch had been established on the basis of the stratigraphy of glacial and interglacial deposits. Consequently it is only during the last two or three decades that comprehensive accounts of the Pleistocene succession in Britain have included details about solifluxion layers, loess horizons and periglacial river terraces which had been recognized many years previously (Bull 1942; Zeuner 1945; Charlesworth 1957). These chronologies frequently indicate the existence of at least two important periglacial phases anterior to the Würm, but recorded phenomena attributed to those phases are predominantly depositional in character. Geological rather than morphological, they appear to have been selected primarily for their stratigraphic significance. Of necessity therefore, this review is concerned more with periglacial deposits than with the less securely dated erosional features.

SOLIFLUXION DEPOSITS AND LOESS

Pre-Würm periglacial phenomena are for the most part confined to southern England which lay beyond the limits of the most extensive glaciations, the equivalents of the Mindel and Riss (fig .1). But this area was

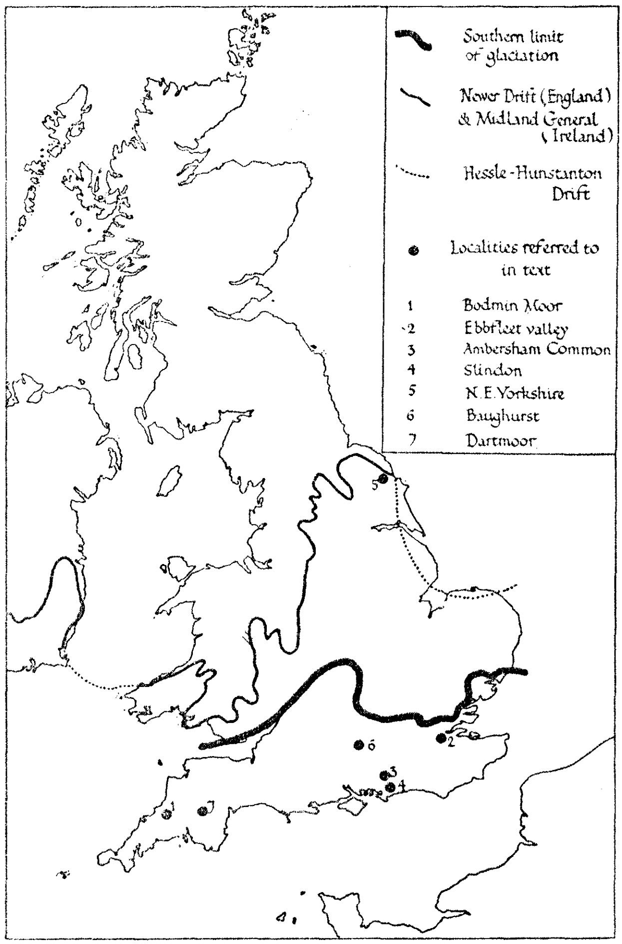

Fig. 1. Map showing the southern limits of the Newer Drift and Older Drift glaciations in Britain (after Godwin 1956) and localities mentioned in the text

also part of the polar- or frost-debris-tundra zone of the Last Glaciation (Büdel 1949). Indeed, the most recent phase of solifluxion in south-west England, at 750 feet on Bodmin Moor, is post-Alleröd and dated to c. 9 000 years B. P. (Conolly et al. 1950; Godwin 1956). Consequently over large parts of this never-glaciated area it would appear to be very difficult to assign the numerous cryergic features to individual periglacial episodes. However, we shall refer to examples of well-authenticated pre-Würm solifluxion and loess deposits selected from different parts of southern England in order to ilustrate the various methods of dating which have been employed.

THE LONDON BASIN

In the Thames valley periglacial deposits have been dated primarily by recognized geological methods i. e., by consideration of their stratigraphic relations with other superficial horizons the relative ages of which have been determined palaeontologically or archaeologically. Nevertheless, relatively few of the very many examples of solifluxion deposits which have been identified and recorded as *head*, *coombe rock* or *trail* can be attributed to pre-Würm phases. Most of the dateable deposits overlie the lower river terraces and are clearly referable to the several phases of the Last Glaciation (King & Oakley 1936). However in the lower Thames valley the existence of periglacial conditions during the Riss is proved at several important sites. Two well-known sections may be chosen from the valley of the Ebbsfleet, a diminutive south bank tributary which runs into the Thames Estuary a few miles below London (fig. 1, site 2). Here, coombe rock covers a wide area and extends down into the Ebbsfleet valley which was cut through the 100-foot or Boyn Hill terrace into the Chalk.

1. The first section (fig. 2), at Baker's Hole (Dewey 1932), shows Chalk at 40 ft. O.D. covered by coombe rock (disintegrated Chalk and Tertiary material) and this is overlain by a series of gravels, sands and brickearth indicating a gradually ceasing aggradation which reached up to 52 ft. O. D. This height is very close to the 60 ft. high sea-level of the Thames Estuary during the Riss—Würm Interglacial i.e., the Main Monastirian 18-metre sea-level.

2. The second Ebbsfleet valley section (Burchell 1933, 1935, 1936 a, b; Zeuner 1945, p. 164-5) is the more revealing (fig. 3). It shows coombe rock on Chalk at c. 20 ft. O. D. separated by an erosional unconformity from coarse gravel, river gravel, two loams, a solifluxion layer, a loam weathered on top, a grey silt bed with temperate shell fauna, and two further

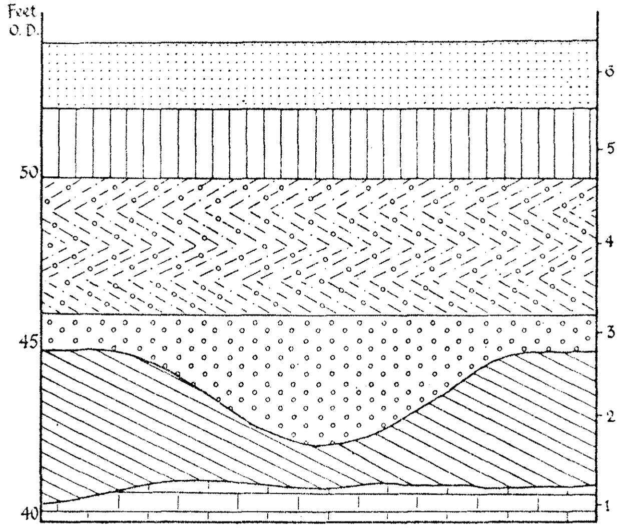

Fig. 2. Section at Baker's Hole (after Dewey 1932)

1. Chalk: 2. coombe rock; 3. gravels, 4. gravels and sands; 5. brickearth; 6. soil

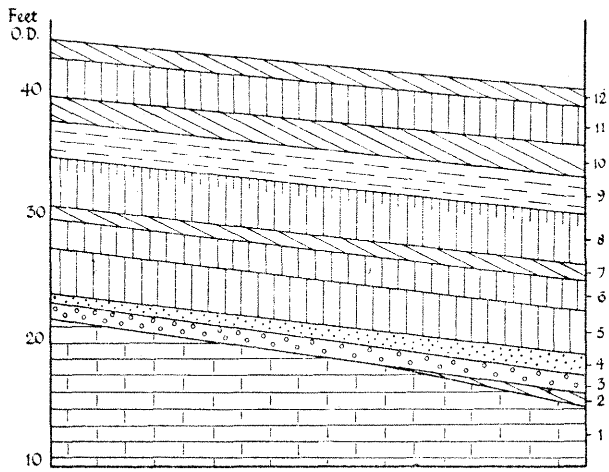

Fig. 3. Ebbsfleet valley section (after Zeuner 1945)

1. Chalk; 2. coombe rock; 3. coarse gravel; 4. river gravel; 5. loam; 6. loam; 7. solifluxion layer; 8. loam weathered on top; 9. silt; 10. solifluxion layer; 11. loam; 12. solifluxion layer

solifluxion layers separated by a loam. Mechanical analyses have shown that the loams are, in fact, loess. The weathered top of the third loess represents an interglacial land surface which was subsequently drowned by a rise of the sea-level to c. 39 ft. O. D. This has been correlated with the Late-Monastirian 7,5-metre sea-level of the Riss—Würm Interglacial. Thus we have evidence of two cold phases prior to the Last Interglacial. The first was marked by intense solifluxion, the second, represented by the loess, was generally drier. Since both phases postdate the formation of the Boyn Hill terrace whose deposits represent the aggradation related to the 32-metre Tyrrhenian sea-level of the Mindel—Riss Interglacial, they have been referred to Riss I and Riss II.

On the basis of evidence from sections such as these it has been demonstrated that, although it was ice-free, the London Basin during the Riss no less than during the Würm experienced climatic conditions which favoured widespread solifluxion and more localized loess deposition. Of Mindel solifluxion there is, however, next to no record, possibly because in the elucidation of the history of this very important phase in the physiographic evolution of the Thames valley evidence from glacial and fluvio-glacial deposits is available for use in conjunction with that from the river terraces (Wooldridge 1938; Clayton 1957; Clayton & Brown 1958). Indeed, Professor Wooldridge (1958) has shown in the most recent comprehensive review of the Pleistocene chronology of the area that the „Chiltern Drift" — stony clays at about 400 ft. O. D. in South Bucks. and Herts. — is a true boulder clay and not, as has sometimes been suggested, a solifluxion deposit.

THE WEALD

Although the two phases of the Mindel are represented by tills and glacial outwash in the London Basin, it would appear that they are manifested farther south by solifluxion deposits. But when we move from the Thames valley with its rich record of superficial deposits to south-east England we are at once confronted with the obdurate problem of dating the phenomena in question. Over large parts of this extra-glacial area we are denied the use of palaeontological and archaeological methods, and the elementary stratigraphic tests of „superposition" and „included fragments" are frequently inapplicable. But it is in just such an area that the „physiographic approach" to the problems of Pleistocene chronology may be employed with profit. Wooldridge (1958) has demonstrated the value of this approach for the elucidation of obscure and seemingly equivocal evidence even in the Thames valley which is so well documented both geologically and archaeologically. Likewise an interpretation of the Pleistocene history of the Derwent valley in Derbyshire (Waters & Johnson 1958) has been based in part on the „morphological setting" of its sparse and widely scattered superficial deposits. Where other methods of determining the relative age of periglacial phenomena cannot be employed a consideration of their relations with dateable morphological facts may provide the chronological information which is sought.

By way of example we may consider the association of solifluxion and loess deposits with certain of the widespread erosion levels which have been mapped over much of south-east England. The 200-foot platform (Wooldridge 1928) is the most prominent and regionally significant of these products of river planation. It is present in the central parts of the London Basin and associated river terraces along the major south bank tributaries of the Thames extend the unit across the Chalk and Greensand outcrops into the Weald where it is widely represented on all of the Lower Cretaceous formations (Green et al. 1934). It is also prominent as a bench along the foot of the South Downs escarpment and in the river gaps through that cuesta (Kirkaldy & Bull 1940).

Its age is well established. In the London Basin it is overlain by boulder clay of the Mindel Glaciation (Wooldridge 1928, 1938; Zeuner 1945, p. 153-4): likewise its altitude suggests that it developed in relation to the 60-metre Milazzian high sea-level of the Günz—Mindel Interglacial.

In the Weald the remnants of this widespread planation almost invariably carry a superficial cover of coarse and unsorted gravels of angular or little abraded flint or chert or other locally derived material which has long been recognized as a solifluxion deposit (Green et al. 1934; Kirkaldy & Bull 1940). Indeed, the angular white flint gravel on the platform at Ambersham Common near Midhurst, Sussex (fig. 1, site 3), has been interpreted as a completely decalcified coombe rock (Wooldridge & Linton 1955).

The fact that the platform underlies Mindel boulder clay in the London Basin and solifluxion deposits in the Weald is clearly no justification for any facile correlation of the two kinds of superficial material. Three periglacial phases succeeded the cutting of the platform in the Weald. Nevertheless, evidence provided by the morphological setting of the gravel-covered platform remnants does enable us to relate the solifluxion to the Mindel. Many of the platform fragments are flat-topped hills and ridges separated by lower ground from the escarpments whence the soliflucted material originated; and it is apparent that in some instances this separation was effected by valley development during the Mindel—Riss Interglacial when local correlatives of the Thames Boyn Hill terrace were formed (e. g., the „Dominant Terrace" of the Mole valley). „Rejuvenation and amelioration of the climate appear to have coincided" (Green et al. 1934, p. 60). Moreover it has been shown that, in places, the river gravel of the lower terrace was mainly derived from the solifluxion gravel of the higher platform (Green et al. 1934, p. 53). Thus the existence in south-east England of widespread solifluxion during the Mindel is attested by the setting of the deposits vis-à-vis the two most important physiographic datum planes of the Pleistocene, the 200-foot platform and the Boyn Hill terrace.

An even earlier solifluxion has been distinguished in the western Weald where the 200-foot platform — here unusually free from superficial material — is surmounted by isolated hills rising to the c. 300-foot level. These represent „an earlier surface of low relief which was dissected and largely destroyed in the formation of the later and lower platform. It is on these hill-tops that coarse chert and sandstone drift is conspicuous" (Wooldridge 1950, p. 185). This soliflucted material — and probably also the large landslips on the Hythe Beds escarpment whence the drift came — would seem to mark the first onset of periglacial conditions in the Weald.

Post-Boyn Hill periglacial phases are more widely attested by coombe rock and loess-like brickearths, some of which have been referred to the Riss (Green et al. 1934; Gossling 1940).

THE SOUTH COAST

The validity of the suggestion that one of the post-Boyn Hill cryergic phases in south-east England should be correlated with the Riss is confirmed by a recent study of fossil soil horizons in the Pleistocene deposits at Slindon (fig. 1, site 4) near Chichester (Dalrymple 1957). The superficial materials at the site are representative of the extensive spreads of coombe rock and raised marine deposits which occur between Portsmouth and Brighton and which have been the object of numerous investigations since they were first described by Reid in 1887 (Reid 1887, 1892; Palmer & Cooke 1923; Oakley & Curwen 1937).

At Slindon the marine sands and pebbles rest on a rock-cut platform at c. 98 to 100 ft. O. D. (Pyddoke 1950) and are overlain by a reddish, unstratified, clayey gravel. That the marine deposits date from the Mindel—Riss Interglacial is attested by altimetric, palaeontological and archaeological evidence (Reid 1892, 1903; Palmer & Cooke 1923; Fowler 1932; Oakley & Curwen 1937; Baden-Powell 1956), and the age and character of the overlying head have now been established by the application of micromorphological techniques of soil fabric analysis.

In 1954 the worked face (fig. 4) in the Slindon pit showed 10 feet 6 inches of head (deep-red clay mixed with chalk rubble), completely unstratified apart from a 6-inch thick orange-brown layer near the bottom and frost-soil phenomena in the uppermost 2 feet. The fabric of the head was found to be of the *rotlehm* type which today characterizes the B horizons of tropical and subtropical soils. By contrast, the orange-brown layer has a *braunerde* fabric with minor *sol lessivé* features similar to those of the B horizons of mull soils of the northern temperate forests.

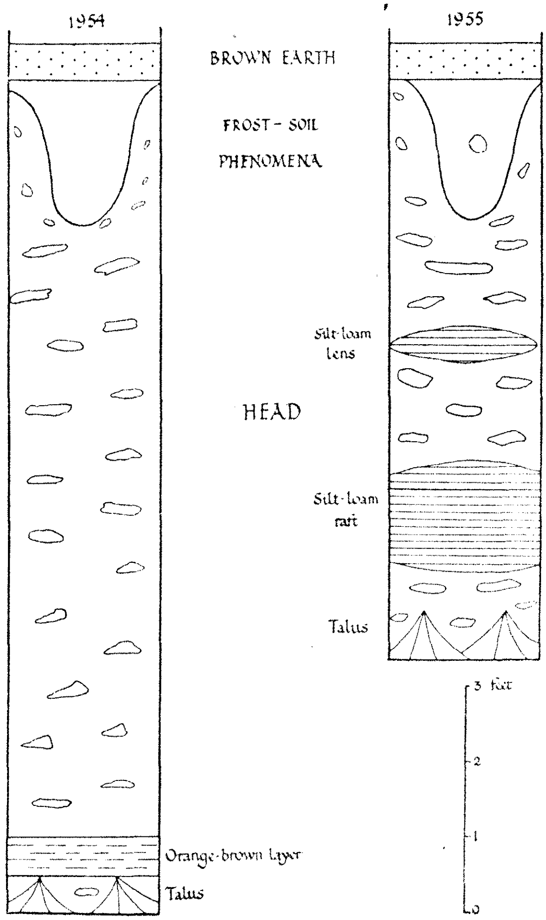

Fig. 4. Sections at Slindon (after Dalrymple 1957)

In 1955 the face showed 7 feet of head with *brodel* phenomena near the top. The orange-brown layer was not seen but within the head were two non-calcareous lenses of silt-loam which were found to have a stable *braunerde* fabric with prominent *sol lessivé* features. This fabric „must result from soil-forming processes acting under temperate climatic conditions" (Dalrymple 1957, p. 300). Similar fabrics have been observed from buried interglacial and interstadial loess soils, and mechanical analysis supports the conclusion that the silt-loams are weathered loess. There is, however, no justification for correlating either of them with the Younger Loess of the Würm.

Consequently, the sequence of events represented by the deposits at Slindon may be summarized as follows:

1. deposition of marine sand and pebbles	Mindel—Riss Igl.
2. solifluxion of fossil soil material, and deposition of loess in an adjacent area	Riss I
3. weathering of head (= orange-brown layer) and loess	Riss I/II
4. solifluxion of fossil soil + weathered loess (= lenses)	Riss II
5. formation of frost-soil structures	Würm
6. weathering of frost disturbed head	Postglacial

Particularly significant is the confirmation of the two Riss periglacial phases identified in the Ebbsfleet valley sections. During these phases south-east England appears to have been subject at times to a more continental climate favouring loess formation and at others to more maritime conditions favouring solifluxion.

TUNDRA POLYGONS, ICE WEDGES AND OTHER MANIFESTATIONS OF DEEP FREEZING

Among the relatively small number of pre-Würm periglacial phenomena which have been recorded from localities in glaciated Britain there are thirteen systems of fossil tundra polygons recognized by Dimbleby (1952) on the Hackness and Tabular Hills in north-east Yorkshire (fig. 1, site 5).

On air photographs many of the polygons appeared to have diameters of c. 30 yards, but on the ground they were found to be subdivided into a network with a c. 15-yard mesh. However, large undivided polygons c. 40 yards across were found on the higher, wetter parts of the area and a progressive decrease in size was noted as the features were traced downhill to better drained and drier parts of the moorland.

Sections dug at right angles to the linear surface depressions separating the polygons showed well-developed ice wedges in the country rock of fine--grained calcareous gritstone whose stratification had been disrupted at the sides of the wedges. The ice-wedge pseudomorphs were seen to have a breadth/depth ratio of 15/30 which places them in Poser's (1948) *Lehmkeile* category and suggests that they developed under intensely continental climatic conditions i. e., under conditions which so far as northern England is concerned „are strikingly at variance with Poser's deductions for the Würm" (Dimbleby 1952). They are filled with either boulder clay or a mixture of boulder clay and locally derived material and are overlain with between one and two feet of „soil" which includes two horizons of soliflucted local material separated by a greatly disturbed forest layer (represented by charcoal) and an uppermost horizon of local material containing erratic pebbles lithologically different from those in the boulder clay.

Dimbleby concluded that the evidence provided by the anomalous size of the wedges in comparison with continental examples attributable with certainly to the Würm, their association with a boulder clay in an area which was not ice-covered in the Last Glaciation and the complex stratigraphy of the material overlying then strongly suggests that the tundra polygons were formed in a pre-Würm periglacial episode.

Other large frost cracks have been recorded from near Cambrigde (Paterson 1940) and near Oxford (Arkell 1947, p. 239—40, pl. VI). They occur in gravels which antedate the Last Glaciation; those near Oxford are on a terrace which has been referred to the Günz—Mindel Interglacial. It is possible that some of the smaller frost cracks which have been reported from other parts of northern England, Scotland and Ireland (Charlesworth 1957, vol. 2, p. 1061 and references therein) may antedate the Würm, but proof is lacking.

Further evidence of the former existence of permanently frozen ground is provided by many large-scale superficial structures. For example, cambering and valley bulges have been recognized in the English Midlands (Kellaway & Taylor 1952; Hollingworth et al. 1944), and Hawkins (1952, 1954) has given a detailed account of the geological consequences of deep frost penetration in a valley cut in Tertiary material overlying Chalk in central southern England (fig. 1, site 6). From borehole evidence a filled, elongate depression was found beneath the valley floor. This depression reaches a maximum depth of 90 feet over a pinnacle of Chalk penetrating the Eocene silts and clays and extends upstream of it. Its filling comprises c. 40 feet of peaty silts with seams of coarse flint gravel of Late--glacial age overlying up to 50 feet of laminated silts and frost-shattered chalk (coombe rock). The chalk pinnacle would seem to represent an intrusive mass which during the uniform downward extension of permafrost resulted from the slow uprise of a bulge underlain by a mixture of ice and frost-shattered chalk that developed a transgressive tendency and penetrated the Tertiary cover. The filled depression probably marks the position of a large ice mass which developed on the upstream side and eventually over the top of the diapiric bulge as the result of the migration of the ground-water within the chalk towards the freezing area. Later melting out from below of the large mass of ground-ice led to surface collapse and the formation of a deep hollow near the pinnacle which was subsequently filled by solifluxion.

Although we have no means of determining the precise age of this example of the effects of deep freezing, the depth of frost penetration and the thickness of the solifluxion layer underlying the Late-glacial peaty silts would seem to preclude its attribution to the Würm. On similar grounds many of the other large-scale superficial structures may be tentatively referred to pre-Würm periglacial phases. Some at least of the mass--movements in the western Weald (Wooldridge 1950) which are associated with solifluxion spreads and appear to indicate the former existence of permanently frozen ground to a depth of 100 or 200 feet would seem to date from the Günz.

PERIGLACIAL LANDFORMS

The morphological expression of the above-mentioned mass-movements is an indication that, as Te Punga (1957) has demonstrated, the landscapes of never-glaciated Britain exhibit abundant evidence of erosion under periglacial conditions. Nevertheless, it must be emphasized that landscape development during the Pleistocene obliterated by no means all of the effects of pre-Pleistocene morphogenetic systems. Between c. 600 and c. 1 000 ft. O. D. extensive remnants of Tertiary erosion surfaces occur in both the English Plain and the Palaeozoic upland of south-west England (Wooldridge 1951), and these relatively flat relict surfaces are largely devoid of the more spectacular manifestations of cryergic moulding.

On the other hand, the „structural relief" so characteristic of the lanscapes of southern England below the level of the relict surfaces is the product of erosion during successive periglacial and interperiglacial phases. Indeed, it would appear that this morphological expression of geological structure is, in large part, the legacy of the periglacial phases and that „interperiglacial erosion, seeing that it was restricted essentially to linear processes", was not competent „to obscure or obliterate earlier developed periglacial landscape form" (Te Punga 1957, p. 410). And equally incompetent have been the latest interperiglacial, or current post-periglacial, processes of erosion.

Equally if not more spectacular examples of the adaptation of surface forms to underlying structures are to be seen above the levels of the relict planation surfaces in south-west England. They are particularly characteristic of the Dartmoor granite upland (fig. 1, site 7) where the wholesale re-distribution of the pre-Pleistocene, deeply weathered regolith by cryergic processes has created a rectilinear pattern of valleys and divides which reveal the structural grain of the granite (Waters 1957) and has given rise to what is probably the purest relict periglacial landscape in Britain. Unfortunately, it is as difficult to date the exposure of the tors (Linton 1955), the creation of the altiplanation terraces (Te Punga 1956) and the formation of the *coulées* and other solifluxion phenomena on Dartmoor as it is to establish the age of the dry valleys in south-east England.

Many of the lower-lying periglacial landforms may eventually be dated by the elucidation of their relations with securely dated interperiglacial terraces i. e., by the adoption of the „physiographic approach". But this method cannot be applied in the upland areas. Although a comparison of the breadth of some of the altiplanation terraces on Dartmoor with that of similar landforms in Vest Spitsbergen would seem to suggest that the relict features are the cumulative result of several phases of periglacial erosion, any quantitative assessment of the extent of the pre-Würm contribution to the cryergic moulding of the landscape must await the outcome of further research.

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