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CRYOPEDIMENTS ON THE CHALK OF SOUTHERN ENGLAND

Abstract

Cryopediments, as distinct from cryoplanation terraces, occur in the Chalk landscapes of Southern England. They exist as extremely gentle concave slopes at the foot of the steeper south-west facing slopes of asymmetrical dry valleys. They are essentially slopes of transportation related to the parallel retreat of the upper steeper slope section under past cryogenic conditions. Their preservation in the dry valleys of the Chalk is thought to reflect the lack of present-day fluvial modification whereas, on other more impermeable lithologies, such forms would have been quickly destroyed.

INTRODUCTION

The term *cryopediment* has recently been used to describe „a gently inclined erosional surface at the foot or valley sides or marginal slopes of geomorphological units developed by cryogenic processes in periglacial conditions" (Czudek and Demek, 1970). As such, cryopediments may be distinguished from the more widely recognised *cryoplanation terraces* (see Demek, 1969) which are erosional surfaces at the foot of frost riven cliffs and scarps, and in the surroundings of tors. The considerable literature upon cryoplanation terraces would suggests that they occur especially in regions built of more resistant rocks both on slopes mainly in their middle and upper sections, and in the summit parts of the landscape. Both cryopediments and cryoplanation terraces apparently develop through the parallel retreat of the overlying steeper slope sections.

This distinction is of importance in an understanding of the Chalk landscapes of southern England since cryopediments, and not cryoplanation terraces, have been found to exist. Whilst not denying the possible existence of cryoplanation terraces upon the Chalk, lithological conditions are not as favourable for their development as upon other more varied and resistant rocks in adjacent areas where such terraces are widely recognised (Te Punga, 1956; Waters, 1962). At the same time, there is no denying the lithological

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favourability of chalk to frost action and cryonival processes in the past, which can be deduced from the widespread distribution of periglacial deposits which cover the Chalk plateaus and valley side slopes.

CRYOPEDIMENT FORMS AND DEPOSITS

All of the cryopediments recognised are located at the foot of the steeper west or south-west facing slopes of asymmetrical dry chalk valleys. Although Ollier and Thomasson, in their study (1957) of the asymmetry of the Little Hampden valley in the Chiltern Hills, did not recognise a footslope or low angled slope extending beneath the maximum angle segment of the south-west facing slope, such a form undoubtedly does exist when the steeper slope is examined without reference to the opposite slope (Plate 1). The proposed interpretation of this form as a cryopediment is inferred from its form, location and surficial deposits, as will be described below. Similar forms have subsequently been found to exist in some of the other valleys of the Chiltern Hills and also in Dorset and Wiltshire, where the 'normal' asymmetry of the chalk valleys is well developed.

Not all of these valleys possess clearly defined cryopediments, however. This may be explained with reference to the model of asymmetrical slope development proposed by Ollier and Thomasson (1957) and extended by the author (1972). In these papers, it is suggested that the asymmetry developed contemporaneous to valley development through a progressive steepening and then subsequent parallel retreat of the south-west facing slope, thus leaving a low angled debris slope. Not all of the Chalk valleys are of the same age and, as a consequence, different valleys possess slopes in different stages of slope development which have been arrested and fossilised by the desiccation of the valleys and the absence of further valley deepening. In the Chiltern Hills this is particularly apparent since both symmetrical and asymmetrical valleys occur, both possessing an asymmetrical pattern of soils and deposits. Two types of asymmetrical valley can be distinguished, depending upon the presence or absence of a footslope or cryopediment upon the steeper slope (Type I and Type II asymmetry respectively). Thus, in terms of the model of slope development proposed, cryopediments are only clearly recognised and delimited where (1) the development of the steeper slope has passed from steepening to parallel retreat and (2) the parallel retreat has not progressed to the extent that the steeper retreating face has been consumed. Where very large symmetrical valleys exist, possessing an asymmetrical pattern of soils and deposits, it is probable that the whole of the south-west facing slopes owe their gentle forms to the operation of periglacial planation processes. These slopes may best be regarded as composite cryopediment surfaces (Plate 2).

The exact form and nature of the Chalk cryopediments and their associated surficial deposits may be established by reference to selected localities where the feature is well developed. In figure 1, the surveyed profiles of the steeper south-west facing slopes of two valleys in the Chiltern Hills, Buckinghamshire, are illustrated. Both of these valleys are now dry and trend in a northwest–southeast direction. The slope asymmetry is recognisable both in the field and from the air, and the valley bottoms are broad but nevertheless well defined. Also typical is the asymmetrical pattern of small tributaries and

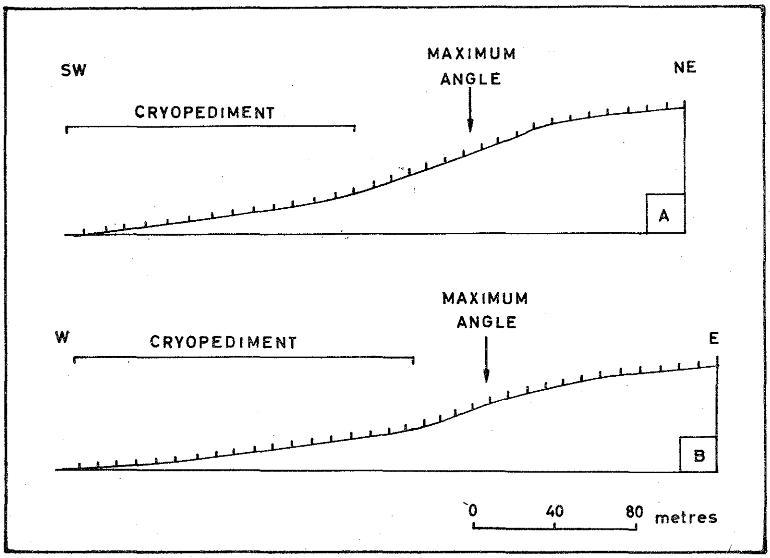


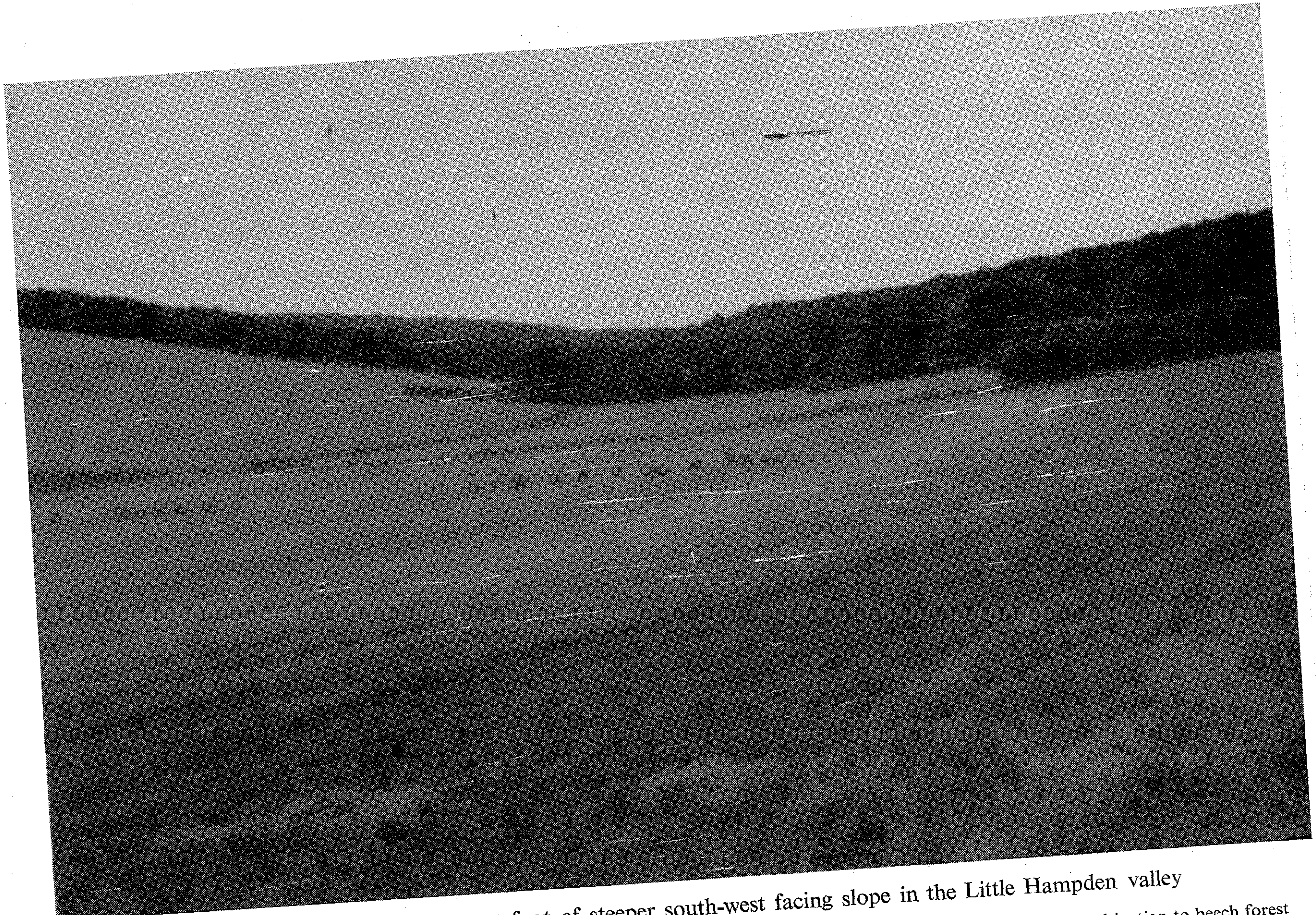
Fig. 1. Surveyed slope profiles illustrating location and form of cryopediments

A – South-west facing slope, Callow Downs valley, Buckinghamshire; B – South-west facing slope, Little Hampden valley, Buckinghamshire

shallow gullies which dissect the gentler north-east facing slopes. On the steeper slopes, the cryopediments are clearly distinguished from the free face or maximum angle sections. In form, the cryopediments are almost rectilinear but, in actuality, are extremely shallow concave forms. Usually, the majority of the feature possesses slope angles of between 5 and 9 degrees and the cryopediments extend up the slopes for distances varying between 20 to 100 metres. For most of their lengths, the cryopediments are covered with a relatively thin layer of surficial materials, often less than 1 metre in thickness. Towards the bottom of the slope, the surficial materials sometimes increase to 2 to 3 metres but, in comparison with the quantity of material that must have been transported across these slopes to enable the steeper slopes to retreat to the extent which they have done, it is clear that the cryopediments are basically slopes of transportation.

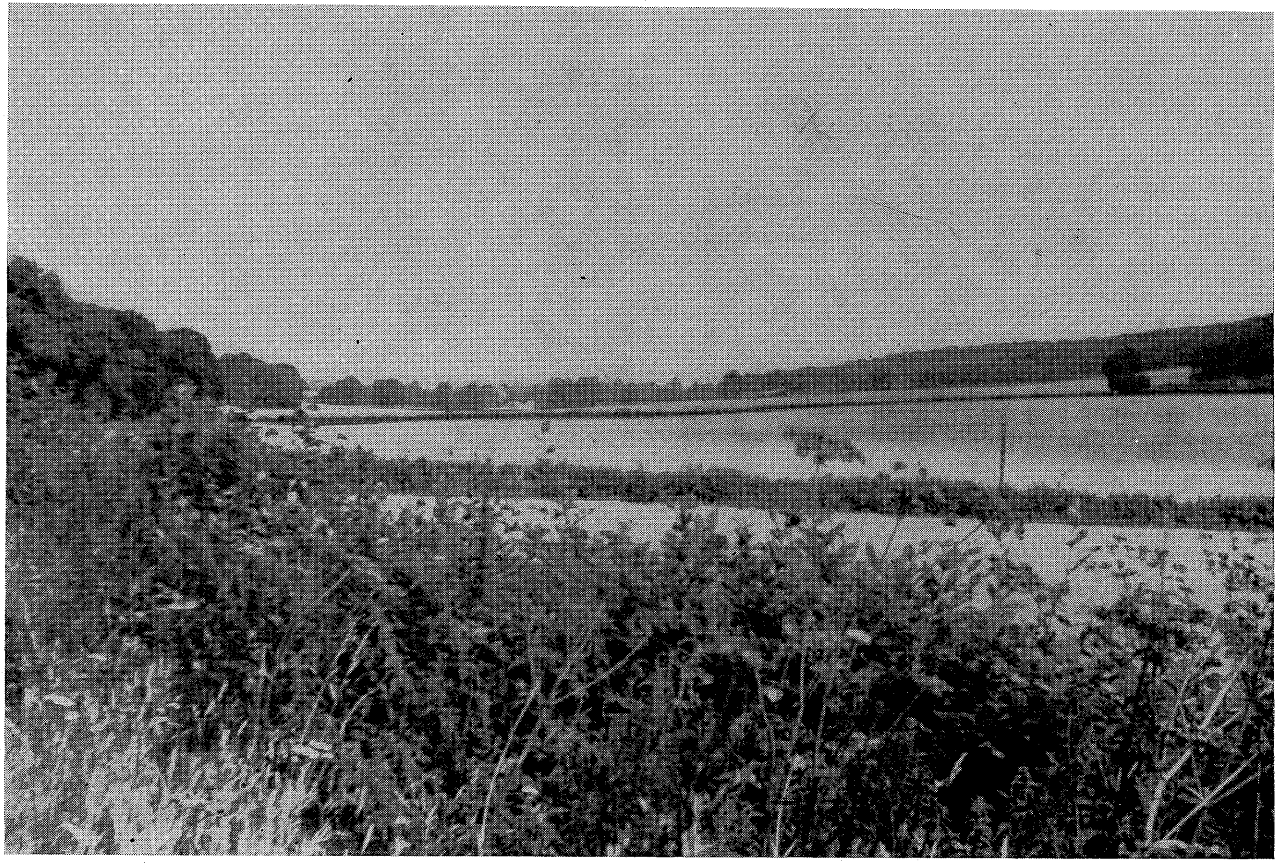
The nature of the soils and deposits on the south-west facing slopes give an indication as to the processes which have fashioned the cryopediments. In the Chiltern Hills, the south-west and south facing slopes present a contrast to the north-east and east-facing slopes by virtue of the predominantly calcareous nature of the soils and deposits (Ollier and Thomasson, 1957; Avery, 1964). Thus, in the Callow Downs Valley, Middle Chalk is found to be exposed on the steepest sections of the south-west facing slope mantled by only a few centimetres of hillwash and colluvium. On the cryopediment below, however, there is a veneer of coarse chalk lumps bound together in a calcareous matrix which merges with the underlying bedrock at depths ranging from 45 centimetres near the top of the cryopediment to depths of over 2 metres near the valley bottom. A typical profile revealed 15 centimetres of grey brown (10YR 5/2) calcareous loam with angular flints and small chalk fragments overlying 45 centimetres of brownish (10YR 4/3) loam, similar to the above but with fewer flints. This merged into a pale brown (10YR 8/4) calcareous clay loam with numerous chalk nodules which in turn graded into hard, unweathered, chalk *in situ.* Over 40% of the surface layers is composed of material in the loessic size range (0.002–0.05 mm) and sorting is relatively poor. It is likely that wind blown materials have been incorporated into the underlying chalky rubbles at some stage by turbulent action, and that the chalky matrix is indicative of predominantly congelifluction processes. The role of sheet-wash and surface rill action appears to have been of only minor importance.

Farther west, in central-southern and south-west England, there is evidence to suggest that cryogenic conditions were restricted during the last glacial period to the higher upland areas (Waters, 1965; Williams, 1969). However, cryopediments have been found to exist in many of the asymmetrical valleys which dissect the Dorset and Wiltshire chalk plateaus, especially in the Marlborough area and also in the North Dorset Downs to the north of Tolpuddle. One such example is to be found within the Devil's Brook valley of North Dorset (Fig. 2) where temporary exposures enabled a study to be made of the relationship between surficial materials and slopes across the valley at a point approximately one mile (1.6 km) north of the village of Dewlish. The asymmetry of the valley is well developed at this point (Reid, 1899, pp. 33-34), and the steeper slope faces almost due west. In contrast to other chalk areas, where the marly impermeable Lower Chalk is generally never reached, many of the valleys of North Dorset either exhibit 'bourne' flow or, alternatively, are wet throughout the year. In the Devil's



Pl. 1. View of cryopediment at foot of steeper south-west facing slope in the Little Hampden valley

Upslope limit of the cryopediment is indicated by abrupt break of slope corresponding to a change in the land use from arable cultivation to beech forest



Pl. 2. View of composite cryopediment surface of southwest facing slope of the Great Missenden valley

Calcareous soils and deposits occur on this slope and slope angles vary between 3 and 10 degrees. The Great Missenden valley is approximately symmetrical in slope angles but possesses an asymmetrical pattern of soils and deposits

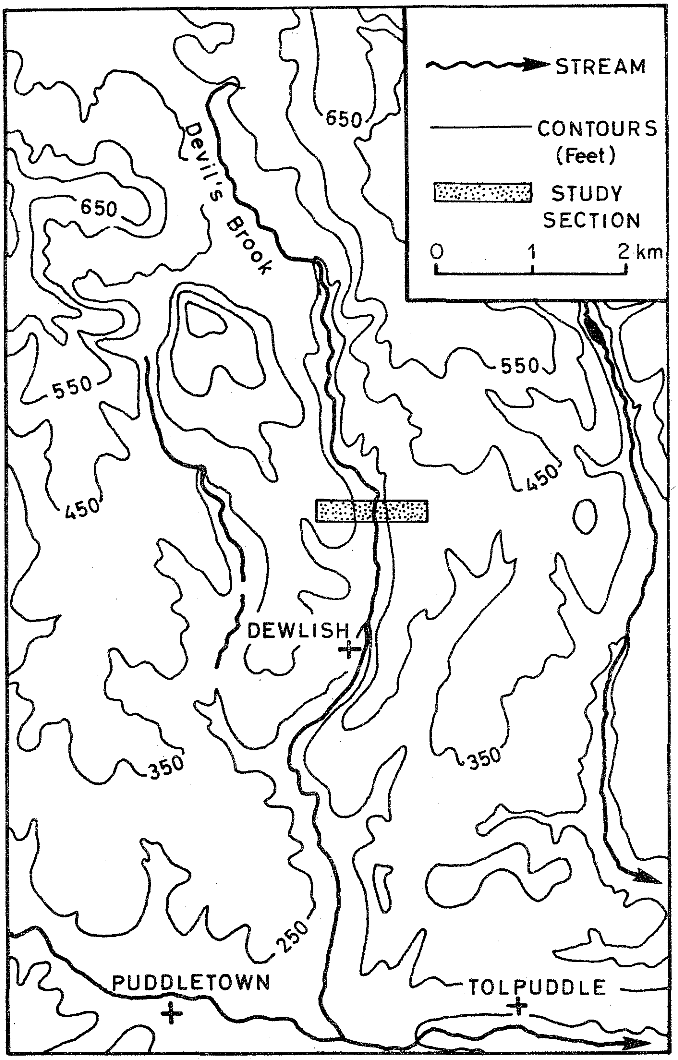


Fig. 2. Location of the Devil's Brook valley, North Dorset and associated drainage and valley patterns

Brook, a small stream flows through the valley deriving its discharge from scarp-foot springs at the Chalk-Gault junction. The stream is blatantly misfit, however, and bears little relationship to the flat valley floor present to the south of Woodsdean and at the point of the cross section.

The relationship between slopes, soils and deposits across the valley is illustrated in Figure 3. At the point of study, the stream has been artificially

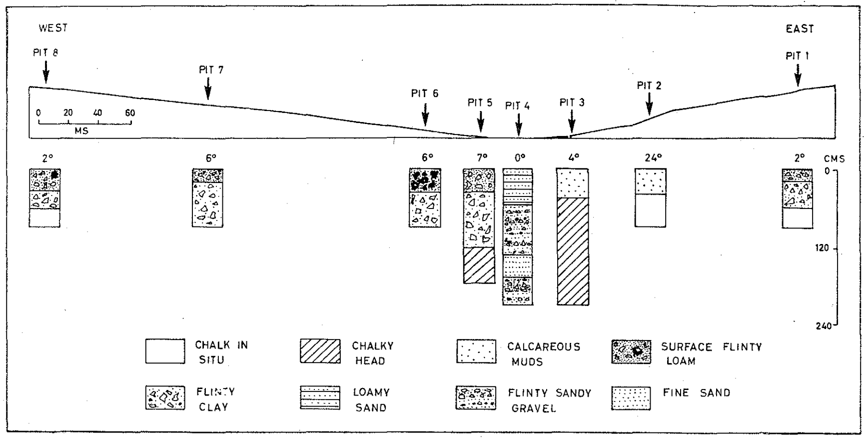


Fig. 3. Relationship between slopes and surficial materials in the Devil's Brook valley approximately one mile (1.6 km) north of Dewlish, Dorset

channelled along the foot of the south-west facing s ope. The cryopediment and the steeper section above are clearly distinguishable upon the south--west facing slope. Both are covered with a veneer of very pale brown (10YR 7/3) chalky muds containing land mollusca and very similar in mechanical composition to the late glacial meltwater muds described by Kerney *et al.* (1964) at Brook, Kent. On the steepest part of the slope these muds appear to rest directly upon, and to be derived from, chalk *in situ* lying immediately beneath. On the cryopediment below, however, the muds appear to have flowed out over an already formed slope of low angle. A faint fossil soil is recognisable developed upon coarse rubbles in a calcareous matrix which grades into unweathered chalk at depths increasing to 3 metres towards the base of the slope. In the flat valley bottom, at least three metres of well sorted fluviatile sands, silts and flinty gravels are present and testify to a much larger stream discharge in the past. On the gentler, north-east facing slope the surficia materials are thicker and non-calcareous, composed of flinty loams and clays. Towards the bottom of this slope, these materials overly chalky rubbles in a similar fashion to that described by Ollier and Thomasson for pits 6 and 7 of the Little Hampden valley in the Chiltern Hills (1957, Fig. 2). This stratigraphic relationship would suggest that the west-facing asymmetry of these two areas is essentially similar, in terms of both the processes operating to induce the asymmetry and also the mechanism of development.

DISCUSSION AND CONCLUSIONS

The field data presented indicates that the erosion and subsequent development of the steeper south-west facing slopes of the Chalk valleys is the cause of the development of the cryopediments. This erosion is closely connected to the presence of the chalky rubbles occurring in the valley bottoms and mantling the cryopediments. The absence of any considerable thickness of such surficial materials upon the cryopediment further suggests that transportational processes were important on the cryopediment. The nature of these transportational processes probably took the form of congelifluction. Although the literature reveals that various forms of surface rill and sheet-wash, acting in association with congelifluction on the pediment and frost shattering upslope, are thought to be equally important in producing periglacial slope planations (e.g. Dylik, 1957; Rotnicki, 1964; St. Onge, 1969) there is little evidence in the form of stratified slope deposits for sheet-wash processes. The reason for this is not clear. In present day periglacial regions the melting of snow patches would often provide the moisture for such processes. However, little is known concerning the nature of wind directions, snow distributions, and snow amounts in the Pleistocene in Southern England. If the prevailing winds were not greatly different from those of today, the snow would have been swept clear of the south-west facing slopes and the permeable nature of the chalk would have resulted in only limited amounts of moisture being made available upon the south-west facing slope through diurnal thawing of the permafrost. Moreover, that moisture which was available would have been subjected to evaporation losses of considerable magnitudes due to the prevailing winds and the absence of a protective vegetation cover. In view of these considerations, it is perhaps not surprising that the chalk cryopediments indicate a greater importance of congelifluction rather than sheet-wash.

No absolute age for the development of the cryopediments can yet be given. They are intimately related to the development of the asymmetry which, in turn, is closely linked to the development of the chalk valleys. Ollier and Thomasson have suggested that differential insolation operated to promote the physical weathering of the south-west facing slope through freeze–thaw processes and that the colder, north-east facing slope remained frozen. The deposits in the Devil's Brook valley indicate that the late-glacial period saw merely a brief renewal of cryogenic and niveofluvial processes upon the south-west facing slope with the cryopediment acting as a slope of transportation for the muds. A middle or early Vistulian age is, therefore, the more likely for the development of the cryopediment and, also, for the development of the asymmetry of the valleys. One cannot rule out the possibility, however, that the asymmetry and the cryopediments are composite features and are the end result of more than one period of cryogenic conditions.

The Chalk appears well suited to the preservation of the cryopediments since the desiccation of the landscape inhibits the destruction of past landforms by fluvial processes. Cryopediments probably formed in other, adjacent, areas of Southern England during the Pleistocene. They are not easily recognisable today since such forms would have been the first to be destroyed or modified by present day fluvial processes in view of their position at the foot of valley side slopes.

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