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SOLIFLUCTION TERRACES IN SOUTH WALES

Abstract

A hypothesis is proposed to explain the formation of certain terrace deposits in the upland valleys of South and Central Wales. It is suggested they were originally formed during late Würm or post-Würm periglacial phases when the substratum was permanently frozen, but thin layers of surface debris moved downslope with periodic freezing and thawing. Solifluction commenced first on the warmer south- and west-facing slopes, and occurred later on the colder north- and east-facing slopes. The resulting material accumulated on the valley floor and also tended to move gravitationally down-valley, a tendency later accentuated by melt water and later by normal stream erosion, causing deformation, and locally the eventual disappearance of, the terraces. Several stages in the development and deformation of terraces can be discerned, but the remains of the terraces below the south- or west-facing slopes are generally more prominent than those at the foot of the north- or east-facing slopes. Steeper south- and west-facing valley sides possibly resulted from more intense physical weathering on such slopes, and the rapid removal of debris to the lower parts of these slopes by solifluction during a number of periglacial phases. The terraces now seen are merely remnants of the last periglacial phase.

INTRODUCTION

Thomas (1959) drew attention to the occurrence of irregular terracing in glacial drift or resorted material at average heights of 20—40 feet above the contemporary river level in the region of Mynydd Eppynt, Fforest Fawr, Brecon Beacons and the fringe of the South Wales Coalfield. He interpreted their general step-like disposition as indicating repeated falls of the river base-level, dissecting the glacial drift. Watson (1961) described terraced features in valleys on the south side of Plynlimon. He interpreted the tendency to occur on one side of the valley, generally the slope facing north or east, as indicating an origin due to solifluction and not to dissection of sheets of glacial drift. Geiger (1950) and Taylor (1958) found that the maximum effective insolation occurs during the early afternoon when the sun is moving to the south-west and, conversely, the minimum operates on slopes facing north-east. Watson has suggested that frost shattering during glacial times would have been relatively more frequent on slopes facing north and east, this being in

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his view the controlling factor in the formation of the terraces below the colder slopes in the Plynlimon region.

Taylor (1961), however, referred to terraces at the base of slopes facing south or west, and suggested that, after the retreat of the ice, solifluction would be more rapid and extensive on the south- and west-facing slopes, these receiving the maximum insolation. Only later with continued amelioration of climate would north and east-facing slopes be involved. Hence, he postulated a cyclical origin with a series of chronological stages where terrace development and subsequent deformation occur at different times and rates on slopes of contrasting insolation. Crampton (1963b) has described the localised induration characteristic of terraces in Fforest Fawr which, following FitzPatrick (1956), may suggest that permafrost once prevailed in these terraces. Cyclic freezing and thawing in the thin surface layer would induce solifluction and hence terrace formation.

The terraces in South Wales are frequently associated with distinctly asymmetric valleys, the south- and west-facing slopes being more steeply inclined than the opposing slopes. Asymmetry has also been described by Ollier and Thomasson (1957) in the Chilterns on Chalk, and tentatively ascribed to solifluction. More recently, Thomasson (1961) invokes a climatic explanation similar to the hypothesis postulated by Taylor (1961).

PHYSIOGRAPHY

For the purpose of this study South and Central Wales may be divided into three broad physiographical regions (Fig. 1):

(1) The Silurian shales and grits of Plynlimon (2468 ft.), continue south-west to Drygarn Fawr (2009 ft.), and east to the Radnor Forest (2166 ft.). In the south-west, igneous rocks and Silurian strata of Mynydd Prescelly reach their peak at Foel-cwmcerwyn (1760 ft.).

(2) To the south-east, Old Red Sandstone marls and sandstones crop out extensively, forming the Eppynt Plateau along the northern crop edge which rises to 1560 ft. at the summit. Conglomerates and sandstones of the Plateau Beds cap the highest points of the Brecon Beacons, 2906 ft. at Pen-y-Fan near the southern margin. The Old Red Sandstone upland continues west of the Beacons in Fforest Fawr, reaching 2632 ft. on Bannau Brycheiniog, and to the east in the Black Mountains (2660 ft. on Waun--Fach).

(3) The Carboniferous sandstones and shales of the Coalfield reach

their highest point on the north crop at Craig-y-Llyn (1969 ft.). The general geological distribution is shown in Fig. 1, which also identifies the particular areas studied.

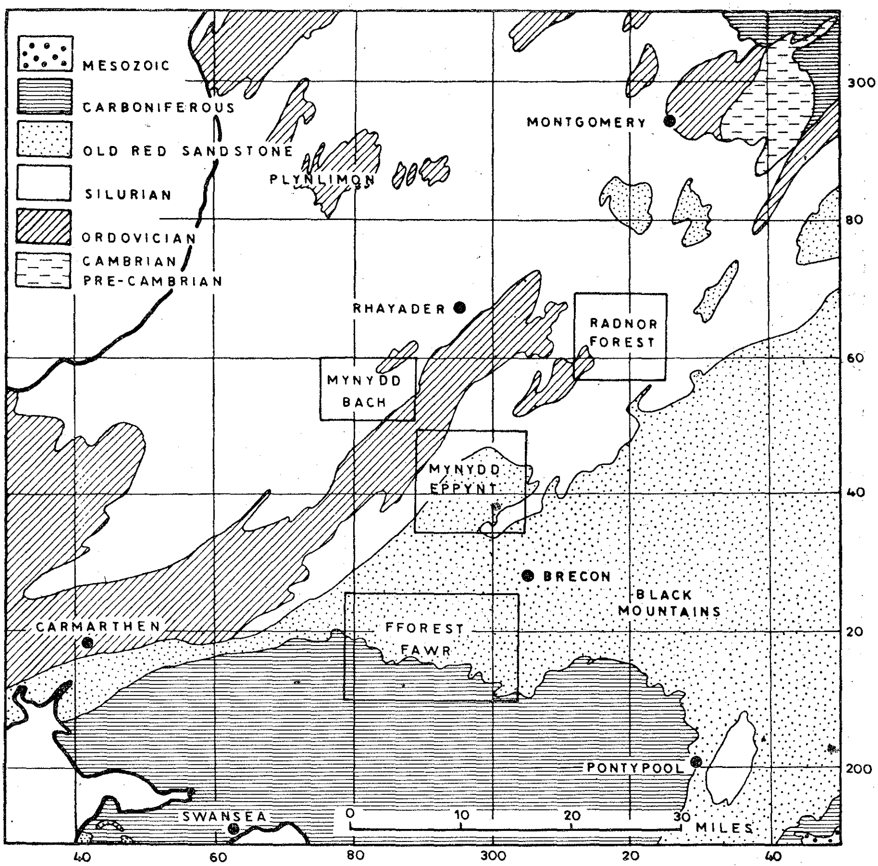


Fig. 1. Solid geology, based upon the 10 miles to the inch Geological Survey Map, showing location of areas investigated

GLACIAL MODIFICATION OF (COLDER) SLOPES FACING NORTH- AND NORTH-EAST

According to Robertson (1932) Cader Idris, Plynlimon, Radnor Forest, Mynydd Eppynt, the Fforest Fawr—Brecon Beacons—Black Mountains range, and the head of Rhondda Fawr were centres of glaciation. Watson (1960) points out that corries are well developed only on the north and east faces of Cader Idris, and that around Plynlimon glacially modified valley heads occur only on the north side.

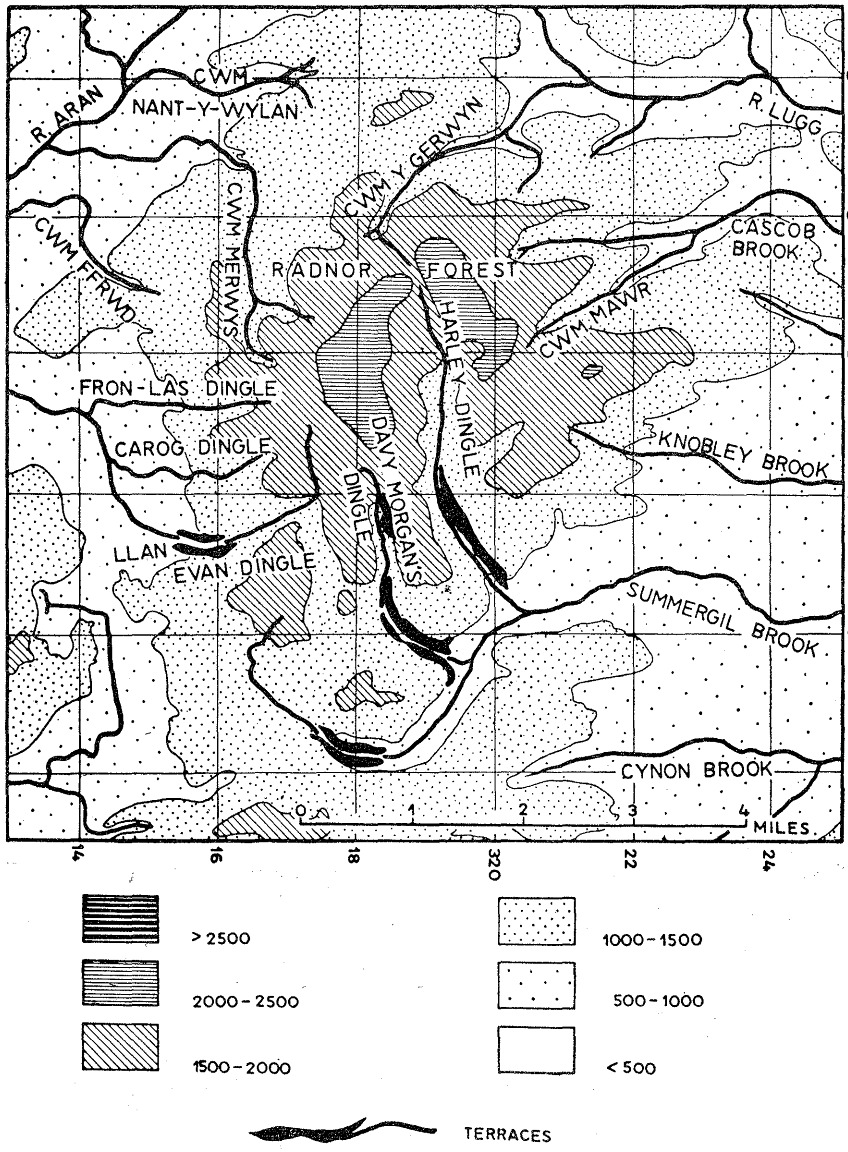


Fig. 2. Distribution of terrace formations (shown in black) in Radnor Forest

Fig. 2 shows the frequency of cwms or corrie-type valley heads on the north-west and north-east facing slopes of Radnor Forest. These and the associated deep, U-shaped valleys are best-developed on the north-east side as in Cwm Mawr and Cwm y Gerwyn. Intense glacial modification of the colder slopes has also occurred in the Fforest Fawr range (Fig. 6). Although glacially modified valley heads have been cut in all north-west, north and north-east facing slopes, those in the north-east slopes of Bannau Brycheiniog and the Brecon Beacons show the most pronounced development. Furthermore, on these slopes valleys are most frequently described as cwms. Cwm Cynwyn and Cwm Sere have been cut deeply into the north-east slopes of the Brecon Beacons.

On the north-facing flank of Plynlimon, glacially modified valley heads occur at Taren Bwlchgwyn (SN/806934), Creigiau-Bwlch Hyddgen (SN/770934) and Uwch-y-coed (SN/827950), and it is significant that the first two face north-east. Elsewhere around the Plynlimon mass, such features are less clearly developed.

The scarp slopes of Mynydd Eppynt (Fig. 5) face north-west, an aspect which yields a cold, but not the coldest possible, slope, and cwms are not well-developed. The north-facing Pennant scarp extending, unbroken, from the Cynon to the Neath valleys, is serrated along its entire length by cwms. The north-east facing slopes of Rhondda Fawr are deeply dissected by the well-formed Cwm Saerbren (SS/933977), Cwm Selsig (SS/915975) and Cwm Parc (SS/926960). The Vale of Neath is aligned south-west and north-east, and its south-east facing slope, although the colder slope, is oriented far from the coldest possible direction. Incipient, corrie-type embayments have been cut into the south-east facing slope, particularly those of the Rheola (SN/834060) and Nant Clwyd (SN/847064) Basins. It is worthy of note that only the flanks of these embayments facing more nearly east have been steepened to form the crags characteristic of cwms. Thus the evidence presented illustrates strong preferential corrie formation on the coldest north-east facing slopes.

Depositional features in these northward opening valleys occur as innumerable morainic mounds of extremely irregular and hummocky appearance, as in the Afon Tarell valley in Fforest Fawr (Plate 1). Cwm Merwys (Fig. 2), entering Radnor Forest on the north-west side, is also floored with a highly irregular morainic deposit.

GLACIAL MODIFICATION OF (WARMER) SLOPES FACING SOUTH AND WEST

Whereas corries or cwms are conspicuously developed on the coldest slopes facing north-east, slopes facing south and west display markedly less severe glacial modification. However, the mouths of shallow valleys opening south- or south-east are warmed during the early afternoon when the sun is moving from south to south-west and is at its most effective (Geiger 1950; Taylor 1958). On the south side of Fforest Fawr (Fig. 6), the valleys open generally southward and are considerably shallower than those opening to the north. Each valley displays terraces on either side of the stream, with bluffs descending by as much as 50 ft. (eg. in Afon Llia, Plate 2). Sometimes a succession of terraces is present (eg. in Nant Tywyn, Plate 3). A terrace may often be located far from the stream, but in places may approach the stream and the bluffs may have been eroded (Plate 2). Fig. 5a reveals that although terraces may occur at the foot of either slope, they are better developed at the foot of the warmer, west--facing slope, as along the valleys of the Taf Fawr, Afon Dringarth, Afon Llia (Plate 2) and Nant Tywyn (Plate 4). The exceptional occurrence of terraces on either side of the River Usk within a northward-directed valley is associated with very wide and shallow valley reaches.

Around Mynydd Eppynt (Fig. 5), the shallow valleys draining the dip-slope are generally directed to the south-east. Terraces are well developed at the foot of both slopes, although a careful scrutiny of Fig. 5 shows there is a slight local preference for development at the foot of the south-west facing slope. In both Fforest Fawr and Mynydd Eppynt, such terrace formations occur only in the wide upper reaches of the valleys.

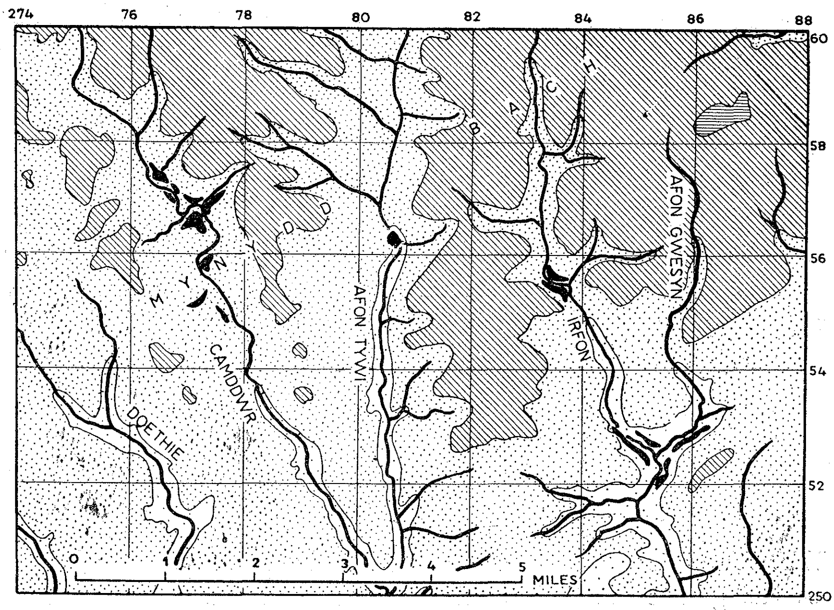


Fig. 3. Distribution of terrace formations in a part of Mynydd Bach

Legend as for Fig. 2

In their lower reaches the valleys become deep and steep-sided and have very narrow floors, inhibiting terrace development. The rivers Tawe and Neath in Fforest Fawr and Yscir Fechan in Mynydd Eppynt are of this character, which is even better displayed by the lower reaches of the Irfon, Afon Tywi and other streams draining the Mynydd Bach (Fig. 3). In their wide upper reaches terraced deposits are well developed on either side of each valley. Plate 4 illustrates terrace development below the colder north-east facing slope, a generally less common orientation except in the Plynlimon area proper (Watson 1961).

The domed form of Radnor Forest (Fig. 2) illustrates particularly well the dependence of the different glacial and periglacial phenomena upon aspect. Whilst cwms are best developed at the heads of the north--east directed valleys, terraces are best developed below the south-west facing slopes in the valleys of Harley Dingle and Davy Morgan's Dingle opening south-east, although those in Harley Dingle may be dependant, in part, upon underlying geological structure. Terraces occur on either side of Summergil Brook but, of those valleys draining to the west, only Llan Evan Dingle contains such formations, and they are not strongly developed.

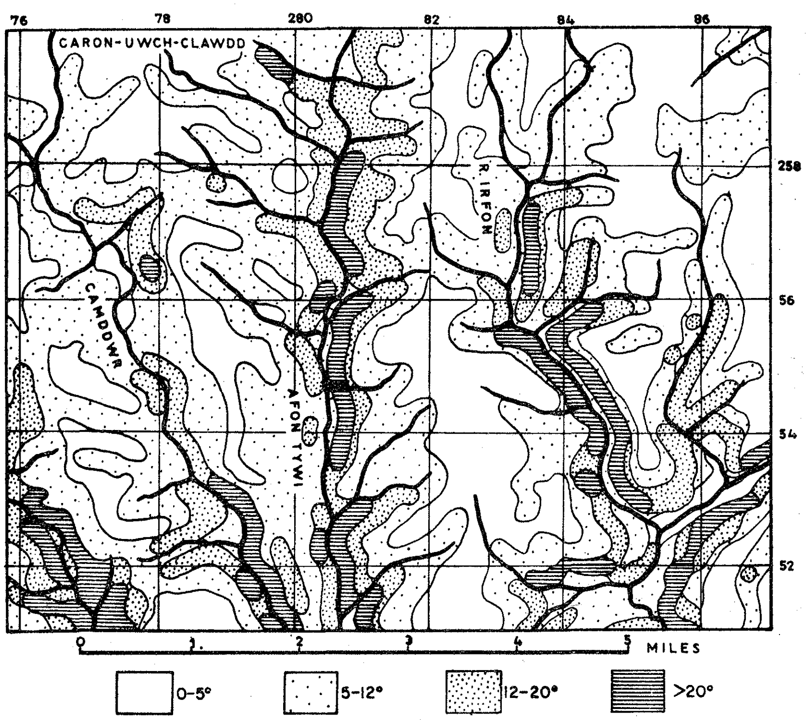


Fig. 4. Slope map of the Mynydd Bach area

Terraces possibly developed in valleys draining the South Wales Coalfield but industrial and urban development has obscured much of the evidence. Such features are still present in the Rhymney valley north of Caerphilly, better developed at the foot of the west-facing slope, and can locally be discerned in Rhondda Fawr. They are also found in the north Coalfield on Mynydd Llangynidr and Mynydd Llangattock, somewhat obscured at Nant Trefil by quarrying operations. East-west valleys are not common in the region, but terraces occur in the valley of Caerfanell where it is aligned east-west before turning northwards to join the Usk valley, and in the east-west valley of Grwyne Fawr where it separates the Sugar Loaf from the Black Mountains mass to the north. Terracing is slightly better developed below the warmer slopes facing south. Terraces are limited in the Black Mountains, and are absent in the Prescelly Mountains.

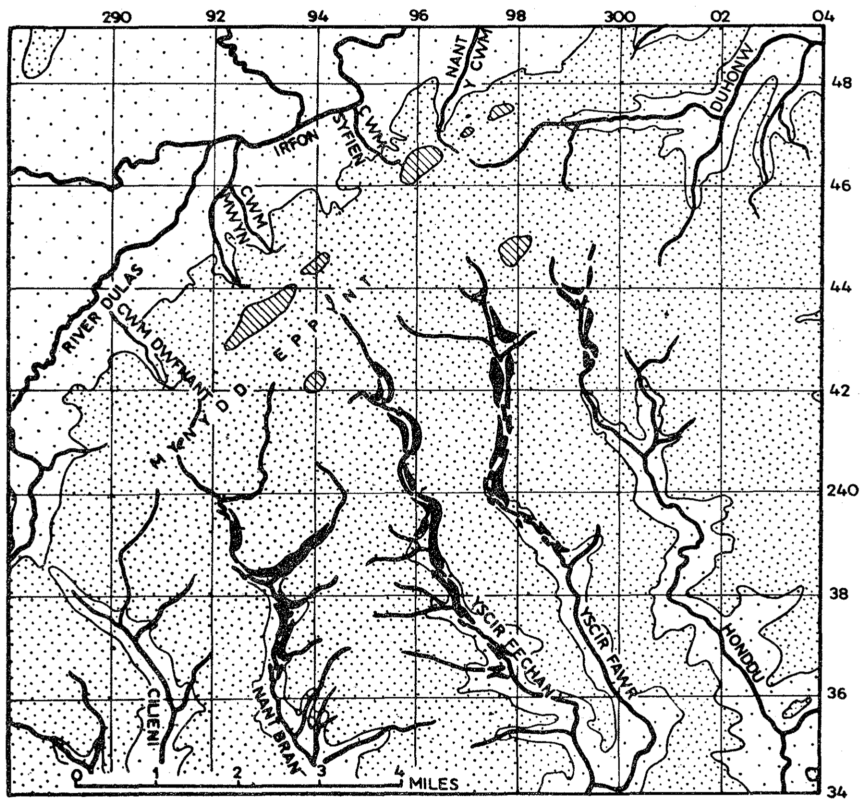


Fig. 5. Distribution of terrace formations in Mynydd Eppynt

Legend as for Fig. 2

VALLEY CROSS-SECTIONS

North or north-east directed valleys, being deep and U-shaped in cross-section, are typical glaciated valleys. Fig. 7 is a section across the southerly dip-slope of Fforest Fawr. Most of the cross-sections display some asymmetry, the west-facing slope being the steeper. The valleys either side of Fan Nedd and Fan Fawr display this feature particularly well, as do certain sections of the Afon Gwesyn (Plate 5), Afon Tywi and Irfon (Plate 4) valleys in Mynydd Bach (Fig. 3). The generalized slope map (Fig. 4) of the area around Mynydd Bach where major valleys trend north-south clearly illustrates a strong association of steeper slopes with north-west, west and south-west aspects. The highly folded character of the rocks does not explain this relationship. In Fforest Fawr the asymmetry of the two higher points only, the Brecon Beacons (Cefn Cûl) and Bannau Brycheiniog (Fan Hir), is partially masked by prominent escarpments arising from the conglomeratic Plateau Beds. Although South and Central Wales is a more rugged area of considerably greater relief amplitude, the form of asymmetry is similar to that described by Ollier and Thomasson (1957) in the Chilterns.

SOIL PROFILE DEVELOPMENT AND VEGETATION PATTERN ON THE TERRACES

Many of the larger, well-formed terraces have a cross-section as exemplified in Fig. 8, and seen in the valley of Afon Llia (Plate 7) and Davy Morgan's Dingle in Radnor Forest. A peaty gleyed podzol occurs on the relatively well drained bluff, usually associated with *Molinia caerulea* and *Nardus stricta*, with some *Agrostis tenuis*. Along the slightly sloping, convex crest of the terrace it gives way to a shallow peaty gleyed soil, associated with *Molinia.* A shallow depression with very impeded drainage, and a deep peaty gleyed soil associated with *Molinia*, *Sphagnum spp*. and *Trichophorum caespitosum*, occur towards the rear of the terrace. The steep west- to south-facing slope against which this elongated depression abuts is occupied by a podzol showing some evidence of gleying in the eluvial horizon (Crampton 1963a), associated with *Nardus*, *Vaccinium Myrtillus* and *Agrostis tenuis*. The less steeply inclined east- and north--facing slopes carry a deeper solum with much rock debris, and gleying is more pronounced in the podzols occupying these slopes. Where the relief amplitude is high the two slopes tend to be associated with different plant communities, a more profuse growth of *Ericaceae* being found on the colder north- and east-facing slope (Crampton 1964).

The peaty gleyed podzol has a periodically waterlogged eluvial horizon above an iron pan, below which the subsoil appears reasonably well aerated. The latter horizon is absent in the peaty gleyed soils which are gleyed throughout the profile. Gleying extends to considerably greater depths in the depression. This sequence is typical of most terrace formations. In a few places at lower elevations, however, where the terraces are narrow, cross-section is simpler, with slopes leading to a shallow bluff overlooking river-level. The soils are freely drained and are utilized as pasture. Such terraces are particularly noticeable in the southern extremities of the valleys draining Radnor Forest and Mynydd Eppynt.

Tributary streams have cut through some terraces revealing that they have no rock core, and that the glacial debris is often very hard. Thin sections reveal that this sporadic induration has not arisen by cementation of the debris. The terrace bluffs contain numerous boulders, up to 2 ft. and 3 ft. in diameter, but nearer the depression against the valley flank the stones are usually smaller, and the fine sand and silt content is higher. In places the main stream has cut into the terrace (Plates 2 and 4), removing the bouldery bluff and exposing finer-textured terrace debris behind. Watson (1961) noted that any flat, platy debris in terraces on the south side of Plynlimon was generally oriented parallel to the slope, a feature often seen also in the deposits of South Wales. A platy structure is associated with the indurated drift, and appears in all the soil profiles except those in the depression where the depth of softened debris is greater than elsewhere.

INTERPRETATION

Bouyoucos and McCool (1928) and Taber (1929) have stressed that frost heave is often considerably greater than can be explained by the expansion of soil water during freezing. Their experimental work reveals that heaving arises when water freezes to form ice columns or ice layers in the surface layers of certain soils, more water being drawn from below by molecular cohesion. In this way more water may be concentrated in the surface soil by ice segregation than would normally be present. Vertical pressures are developed by the upward growth of ice crystals which pushes stones and soil particles upwards and outwards, those nearer the surface being displaced the most and those near the base of the zone of freezing the least. The differential movement results in stones becoming oriented parallel to the surface, (an orientation frequently seen in the terraces investigated).

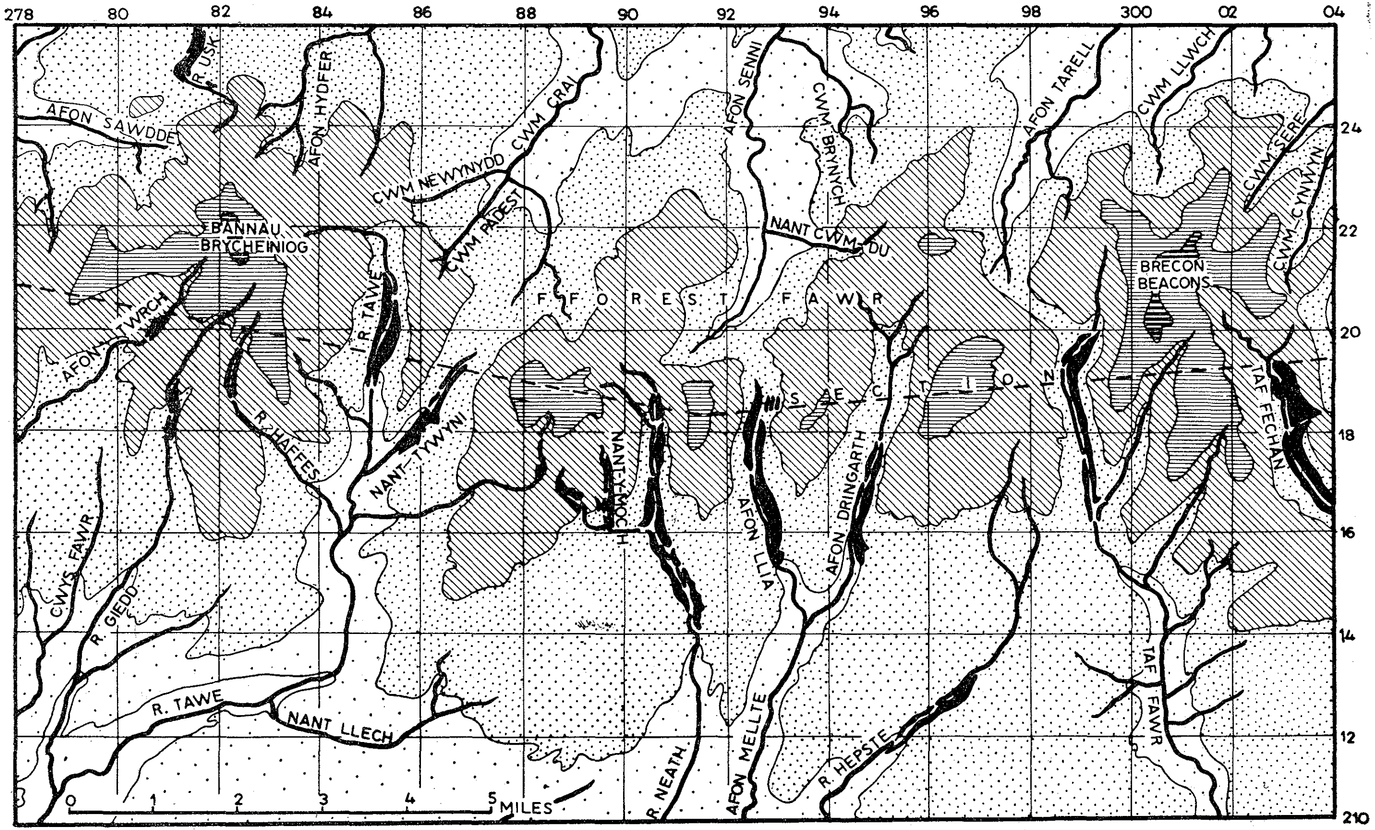


Fig. 6. Distribution of terrace formations in Fforest Fawr

Legend as for Fig. 2

Taber (1930), from laboratory studies of the physical conditions affecting the frost heaving of soils, reported that extensive heaving is associated with high levels of soil moisture, slow freezing or alternate freezing and thawing, and a fine-textured soil. These conditions would have been satisfied where the silty soils of the uplands of the centre, west and north of Wales were under maritime glacial and periglacial climates, especially near Cardigan Bay and the Bristol Channel. Beskow (1935) also, experimentally, found little ice segregation in sandy soils, being at a maximum in silty soils. This was confirmed by Edwards (1958) using prepared soil tilths from local soil materials in West Wales.

Watson (1961) considers the frequent occurrence of terraced detritus in Plynlimon to be related to the extensive outcrop of silty rocks. (Similarly in South Wales the terraces are more frequently associated with the silty Old Red Sandstone rocks than with sandy Coalfield rocks). He considers that solifluction forms terraces in Plynlimon chiefly from the excessive water content of the soil on thawing which renders it unstable and allows movement down quite gentle slopes.

In Central Norway solifluction frequently gives rise to shallow terraces, often only one metre high, which were investigated by Williams (1957). He considers frost heaving as the major factor in the formation of the larger terraces on slight slopes in Central Norway where the water-table is just below the soil surface. Heaving occurs against the force of gravity, the centre of gravity of each particle being moved slightly outwards and downslope, while the resettling occurs under gravity. On sloping ground, therefore, frost-heaved soils will usually have a downslope component of movement, and repeated freezing and thawing will produce a very slow downslope movement.

Johnston (1930) and Taber (1943) describe perennially frozen ground in North America as most prevalent in the zone peripheral to active glaciation. Eakin (1916) has described extensive terraces in Alaska with scarps ranging up to hundreds of feet high, contrasting with the very low terraces described by Williams (1957) in Central Norway. According to Eakin the Alaskan terraces have steep bluffs rich in angular rock fragments, but the proportion of fine material increases towards the back of the terrace, (a relationship commonly observed in South Wales). When small, the terraces tend to be lobate with a sloping surface, but as they become larger the bluffs are straight, and the terrace surface becomes flatter and ultimately concave at the rear and convex at the front above the bluff, (similar to terrace structure in South Wales — Plate 7). Taber (1943) has also described terraces in Alaska, often showing lobate proturberances, sometimes with slightly overhanging bluffs. Vegetation

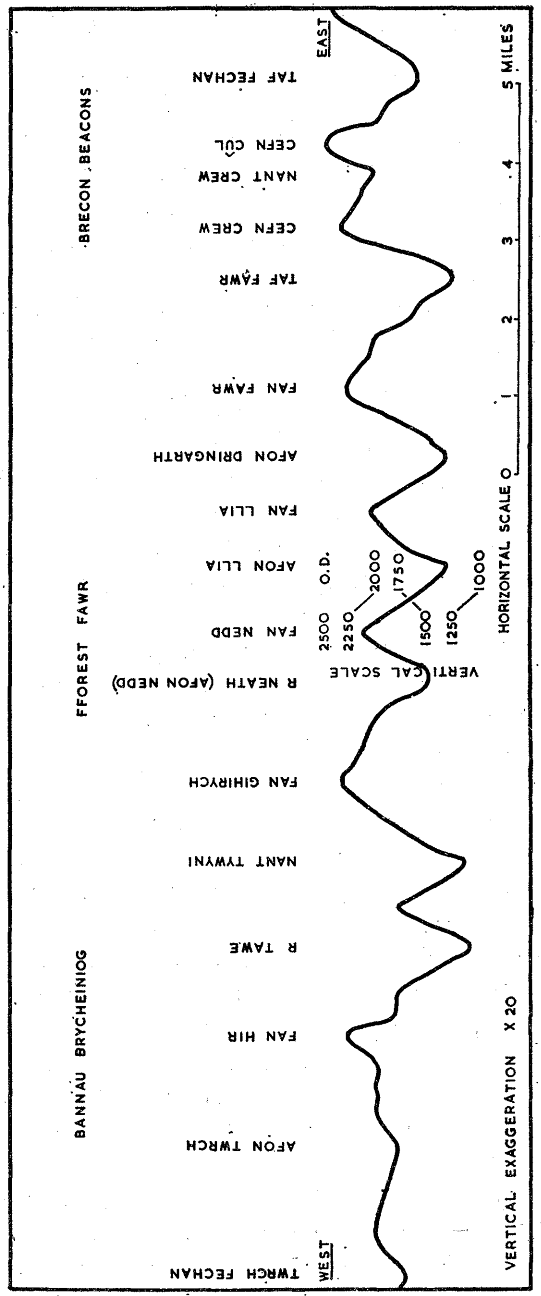


Fig. 7. Relief cross-section of Fforest Fawr

is densest on the bluffs and thinnest near the back of the terrace, where occasionally it is absent due to down-slope movement in the surface layer. Thawing extends deepest under these bare spots in the shallow depressions where drainage is poor and water collects. In South Wales, the shallow depression towards the back of a terrace is similarly occupied by deep, peaty and poorly drained soils and which, by analogy with Alaskan terraces, is probably associated with original terrace formation.

Because the terraces in Alaska are perennially frozen they do not flow as a viscous mass. According to Taber (1943), the detritus remains frozen throughout the summer except for a thin layer at the top. The terraces grow and advance chiefly through freezing and thawing of the surface mobile layer. Whilst little water can be drawn from below because of permafrost, the surface layer is commonly saturated with water when seasonal freezing takes places because the heaviest precipitation occurs during the late summer in Alaska. Most of this water is retained since run-off is minimized by vegetation and by the frozen subsoil which prevents percolation. Freezing tends to concentrate water as ice in the upper part of the surface layer at the expense of water in the lower part, and, where this water is replaced by percolation from upslope, the total water content may be greatly increased locally as a result of freezing.

Taber (1943) notes that this considerable quantity of water set free by seasonal thawing cannot escape through the frozen subsoil. Interstitial water adds to the weight of the soil mass and also acts as a lubricant, thus decreasing stability and facilitating both slow and sudden downhill movements. Rapid thawing and slow drainage are conducive to mud flows. Taber considers this process is additional to, and hastens, the slow downward creep of soil layers due to frost heaving and other factors. It is likely that terraces in South Wales developed in this fashion in a periglacial environment, the mass of the deposited material being permanently frozen with only a thin surface layer moving downslope during cyclic freezing and thawing. The resultant accumulation on the terrace bluffs were buried by further accumulations which in turn were subsequently permanently frozen. Frost heaving and surface flow would both tend to orient platy rock fragments parallel to the surface.

Fitz Patrick (1956) has recently suggested that the induration and platy structure in certain Scottish soils possibly arise from the former occurrence of permafrost, the compaction being due to the pressure developed by the freezing. Experimental freezing of puddled soils produced these features. Compaction and a platy structure frequently observed in the South Wales terraces may also originate from permafrost.

The relation of aspect to a postulated cycle of terrace formation in

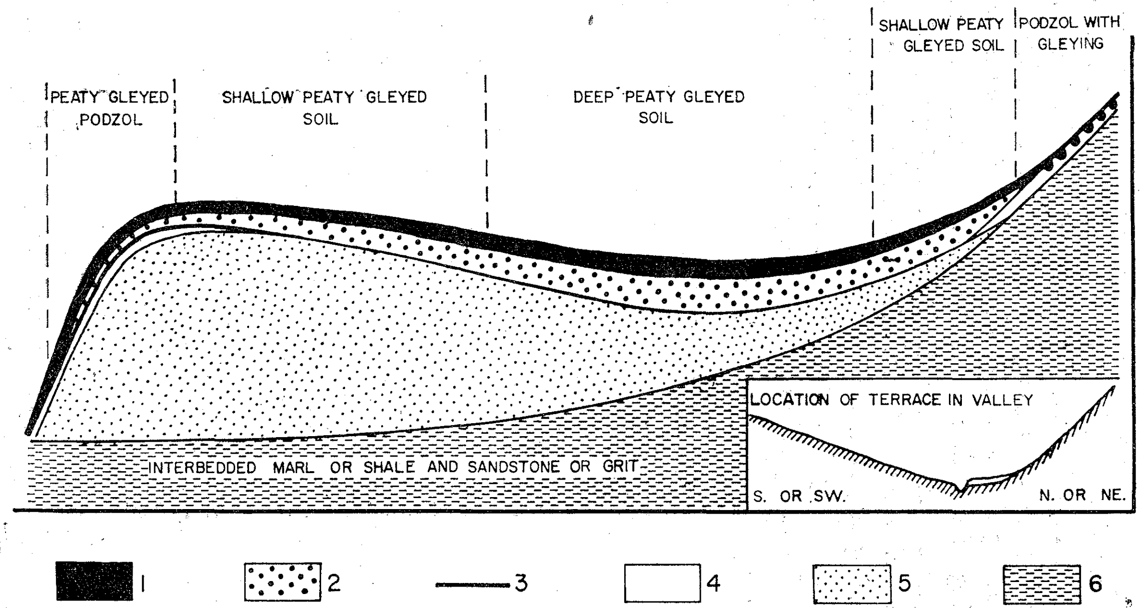


Fig. 8. Diagrammatic representation of transverse section across a terrace

Vertical scale considerably exaggerated

1. horizon of organic matter; 2. horizon of gleying; 3. horizon of iron accumulation; 4. horizon of free drainage; 5. horizon of induration; 6. rock

South Wales is illustrated diagrammatically in Fig. 10. With the onset of the last periglacial phase, solifluction would initially be more rapid and more extensive on the warmer south- and west-facing slopes, at relatively low elevations first, represented in Stage 1. Each terrace would accumulate as already discussed, by means of a mobile surface layer, constantly replenished from soliflucted slopes immediately behind the accumulation, encroaching upon the gently sloping valley floor. Later, higher south- and west-facing slopes would be involved, the terrace building up and encroaching still further upon the valley floor, as illustrated in Fig. 9. As the glaciers retreated further, the increasing warmth would begin to thaw the surface layer of perennially frozen ground on the lower north- and east-facing slopes, and the surface layer would become mobile and commence moving downslope, to freeze again as it accumulated and then decelerated, tending to become stationary at the base of the slope, represented in Stage 3 (fig. 10).

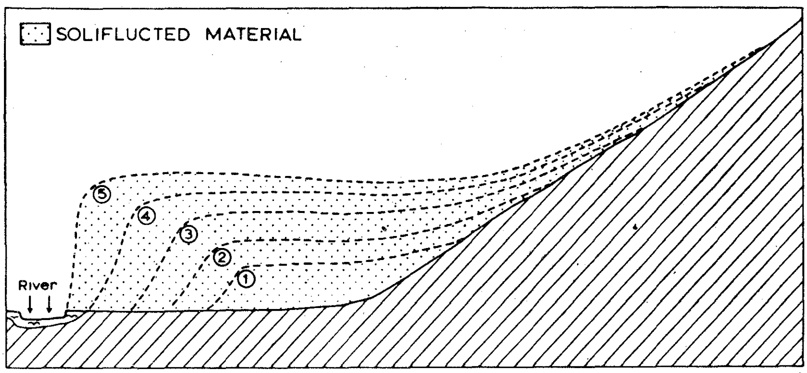


Fig. 9. Diagrammatic series of superimposed cross-sections to show the stages (1—5) in the evolution of a terrace

A down-valley component of gravitational movement in discharge of material downslope is suggested by the way the terraces curl round the southern ends of the ridges, a characteristic chiefly of the terraces at the foot of the south-west facing slopes. Stages 4 and 5 (fig. 10) are characterised by double terrace development, the one below the north- or east-facing slope accumulating and, mostly, encroaching upon the valley floor because of the relatively steep inclination of the terrace surface, whilst the other below the south- or west-facing slope increasingly shows evidence of the down-valley component of movement in the flattening of the terrace surface (*vide* fig. 9), the cross-valley inclination of which is less than the down-valley inclination. Plate 6, the view looking east, shows terraces on either side of a tributary of the Nant-y-gelli (SN/811562). It is worthy of note that the terrace at the foot of the south-facing slope now occurs largely at the junction of the tributary with the Camddwr whilst the terrace below the colder, north-facing slope extends up the tributary valley. This orientation suggests that the terrace material at the foot of the south-facing slope has been moved from the upper reaches of the tributary valley, whereas the terrace below the opposing slope was formed later and has experienced less down-valley movement. Ultimately it is possible that only the terrace at the foot of the colder slope will remain, illustrated in Stages 6, 7 and 8 in Fig. 10.

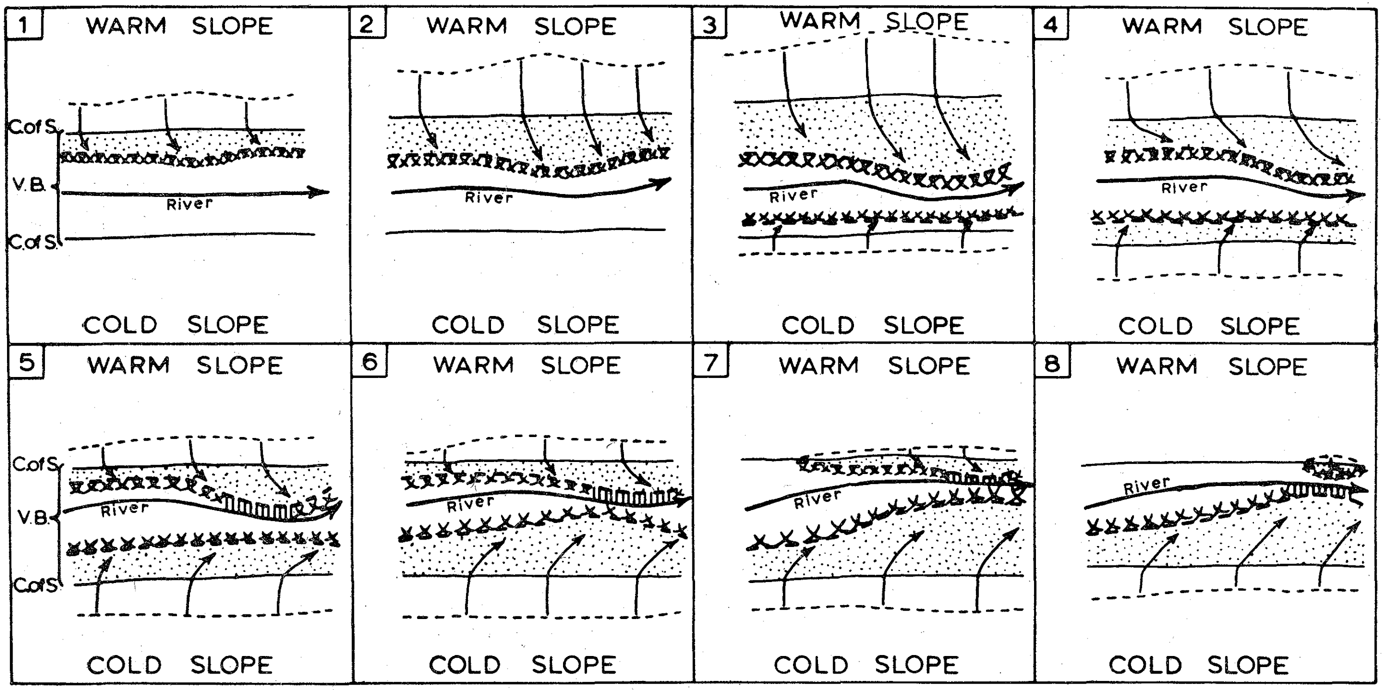
It should be emphasised that in practice these stages could overlap, be incomplete or be complicated and reversed by local geological, structural or corrasion factors, or by a relatively rapid change in climate. For example, because of the slope of the valley floor, it is unusual for the river to meander over a wide tract; but sometimes terrace bluffs are eroded by the river with a gentler long- and cross-profile. That this has occurred in places is indicated by the absence of a bouldery bluff, which is normally present; such a bluff is composed of relatively finer-textured material normally characteristic of terrace structure behind the bluff.

Valley form also affects the postulated cycle of terrace formation. In the region investigated, glacial erosional features are characteristic of most north or north-west directed valleys, whilst glacial depositional features are characteristic of south or south-east directed valleys. Terraces have formed in the upper reaches of the latter valleys where they are sufficiently wide to allow development and sufficiently open to allow the sun's warmth to penetrate, and where the slope of the valley side is adequate for active solifluction (which may occur even on slopes of only 2°), but not so steep as to favour catastrophic transfer of mobile residues in a manner possibly inhibitive to terrace development. Also, straight major valleys reveal scarcely any evidence of terrace features which, in fact, are more common in sinuous tributary valleys. However, terraces are not preserved in an extremely sinuous valley, especially where relatively narrow, because of river erosion. Valleys with gently inclined long-profiles and smaller catchments retain terrace features more effectively than valleys with steeply inclined long-profiles and larger catchments.

The proposed cycle hypothesis is applicable to the majority of terrace formations occurring in those parts of Central and South Wales investigated. All the stages in Fig. 10 can be observed, although that depicted in Stage 3 is the most frequently seen, i.e. terraces occur below both slopes, displaying maximum development at the foot of the warmer slope with south-west aspect. Radnor Forest is particularly illustrative in that successively later stages of the cycle occur moving clockwise from east through south to west (fig. 2). In Harley Dingle, the terrace at the foot of the south-west facing slope is evenly inclined across its total width, representing Stage 2. In Davy Morgan's Dingle Stage 3 is represented, terraces occurring on both sides of the valley, those below the warmer slopes facing west being better developed. The solitary terrace in the upper reaches of the Dingle displays a form closely similar to that in Fig. 8, a shallow depression occurring adjacent to the steep valley side. The down-valley component of solifluction was beginning to affect terrace form below the warmer slope at this stage (assuming repeated rupture of the mobile surface layer and subsequent deeper thawing at the base of the steep valley side, analogous to terraces currently evolving in Alaska and described by Taber, 1943). As a result there would be a greater discharge of material within the mobile surface layer from this point, not directly across the valley but obliquely down-valley. Thus the terrace might develop the transverse profile illustrated in Fig. 8 and displayed in Davy Morgan's Dingle.

The nearly east—west valley of Summergil Brook contains terraces on both sides, that below the north-facing slope displaying a slightly greater development, representing Stage 5 in Fig. 10. The terrace below the colder slope facing north in Llan Evan Dingle is noticeably greater in extent than the opposing terrace, representing Stage 6. This sequence of stages in Radnor Forest suggests that there was less contrast in insolation between the east-facing and west-facing slopes than between the north-facing and south--facing slopes of east—west valleys, and therefore less contrast in the timing and development of the respective cycle stages.

Altitude and relative distance from the sea must be considered in relation to glacial and periglacial climates characteristic of maritime upland regions such as Central and South Wales. The rapid lapse rate of temperature with altitude associated with contemporary cool temperate maritime, climates is equally applicable to glacial and periglacial phases. Colder conditions would persist longer at relatively lower altitudes in a maritime, than in a continental, region or in a less maritime area such as Eastern Britain. This would favour a relative prolongation of both glacial and periglacial conditions at high elevations in maritime Wales, and also a tendency for solifluction to occur in valleys at lower altitudes first and higher valleys later. The terraces observed occur between 800 and 1500 ft. O.D., but



Arrows indicate major directions of movement of soliflucted material.

Surface of Terrace

C.of S.=Change of Slope

XXX = Terrace Bluff

V.B. = Valley Bottom

mmm = Eroded Terrace Bluff

- - - - = Extent of Slope Supplying soliflucted Material

Fig. 10. Diagrams illustrating a hypothetical periglacial terrace cycle for an east—west valley

are concentrated between 850 and 1200 ft. O.D. It is likely that this zone coincides with the climatic controls discussed above. It is possible that in Central and South Wales this zone experienced periglacial conditions for the longest time, the climate of the higher zones staying colder longer, and the lower zones being ameliorated earlier with massive solifluction and subsequent removal of depositional features, including terraces. Within this zone in Plynlimon where terraces below the colder slope frequently show more pronounced development than those below the warmer slope, the periglacial phase probably laster longer than elsewhere.

The terraces are often associated with a valley cross-section characterised by steepened west or south-west facing slopes and less steep east or north-east facing slopes with a deeper cover of rock debris. Ollier and Thomasson (1957) suggest that a similar orientation of steep and gentle slopes (and Head deposits) in the Chilterns arose under periglacial conditions. „The west or south-facing slopes having undergone diurnal or seasonal freezing and thawing while the opposite slope remained permanently frozen, or thawed out for only a short time during the summer" (Ollier and Thomasson, 1957). In the Chilterns those processes were contemporaneous with valley down-cutting. „Periodic freezing and thawing would favour strong physical weathering and solifluction" (Ollier and Thomasson, 1957). If, below south and west-facing slopes in South Wales, this process caused a more pronounced development of terraces by solifluction, which steepened the slope, then solifluction must have been considerably less active on the north- and east-facing slopes which are less steep. Terraces below the latter slopes do not generally show the more pronounced development, but where they do, the opposing smaller terrace has probably experienced considerable down-valley movement. However, the scale of the relief in Central and South Wales is such that it is unlikely that one cycle of solifluction and terrace formation coincides with the total time needed to form asymmetric valleys. The asymmetry has probably developed during many phases, whilst the terraces now seen represent remnants from the last phase.

CONCLUSIONS

It is suggested that solifluction terraces described in South and Central Wales formed in a late Würm or Post-Würm periglacial environment. (Mitchell (1960) has suggested that much of South-West Wales did not have direct glaciation during the Würm period.) The mass of the surface materials was permanently frozen and only a thin surface layer moved downslope during periodic freezing and thawing, the resulting material encroaching upon the valley floor, subsequently to be buried by further accumulation and later to be frozen. Movement across the valley was dominant whilst the terrace surface was moderately inclined across the valley, but with the eventual levelling of the terrace surface the down-valley movement became dominant. The latter movement helped to create a shallow depression at the rear of the terrace. Permafrost probably caused the localised induration characteristic of present-day terraces. Induration occurs very near the surface of the bouldery bluffs, but in the shallow depression of the rear of the terrace peaty gleyed soils have developed in fine-textured debris, softened to a considerable depth.

Maximum effective insolation occurs when the sun is moving to the south-west, and at the onset of the last periglacial phase, solifluction would initially be more rapid on the south- and west-facing slopes. Later (as down-valley solifluction movement began to influence the form of the earlier terrace), solifluction commenced on north- and east-facing slopes. In the later stages of the cycle, the greater part of the material constituting the earlier-formed terrace below the warmer slope was moved down-valley, approaching the river course and being eroded in places, to leave the later-formed terrace below the colder slope as the more prominent feature. All stages of terrace formation postulated can be discerned in South and Central Wales, but generally the terraces at the foot of the south- and west-facing slopes are the more prominent.

The terraces are often associated with steepened west to south-west facing slopes. Diurnal or seasonal freezing and thawing, which promotes more intense physical weathering on the west- and south-facing slopes, might steepen these slopes as well as encourage discharge downslope by solifluction to form terraces below the slope. Solifluction was probably considerably less active on the north- and east-facing slopes which are generally less steep. The asymmetry of valleys probably developed during many periglacial phases, whilst the terraces now seen represent transient remnants from the most recent phases. Previously-formed solifluction deposits would have been removed by the intervening glacial or inter-glacial phases.

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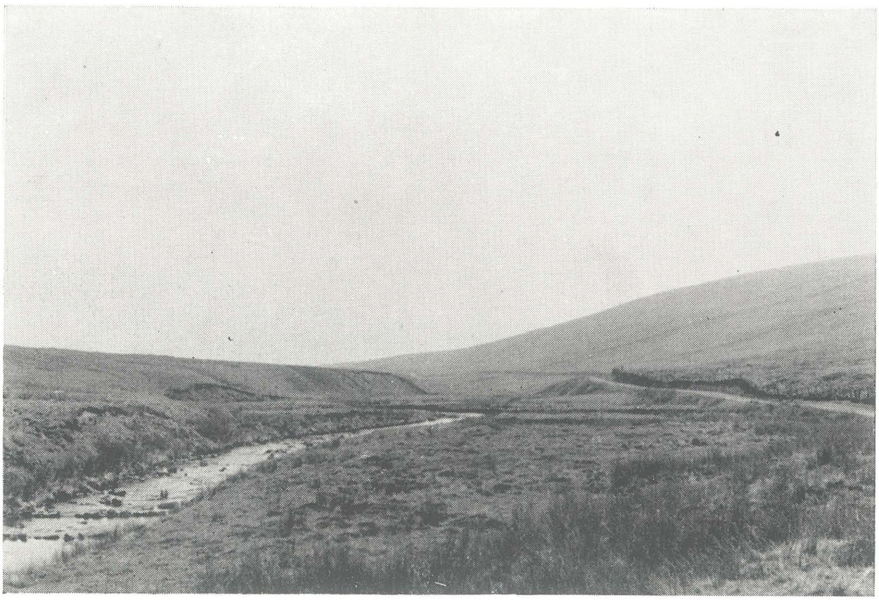
Pl. 1. View looking south (SN/975210) up the valley of the Afon Tarell in Fforest Fawr, showing hummocky deposits in a glaciated, north-directed valley

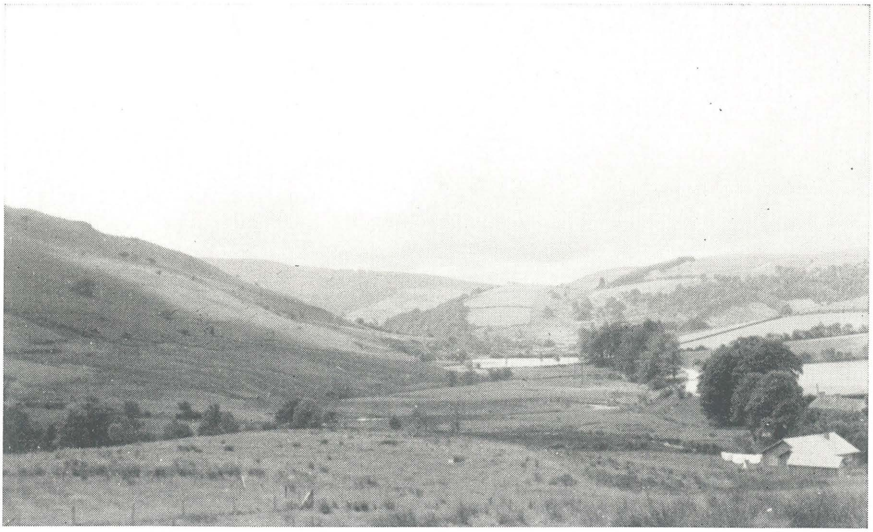


Pl. 2. View looking south (SN/925183) down the valley of Afon Llia in Fforest Fawr, showing terraces below both slopes, but with better development at the base of the west-facing slope i.e. on the left of the picture

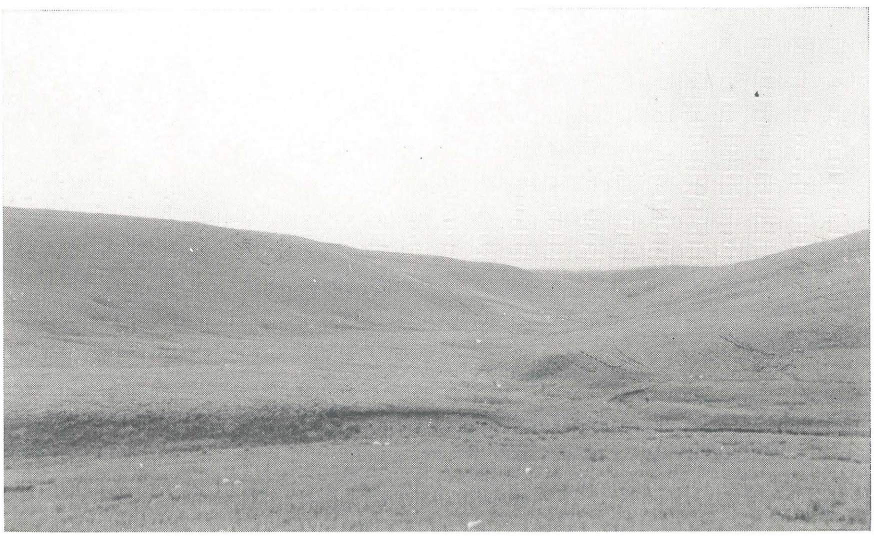
Pl. 3. View looking north-east (SN/858182) up the valley of Nant Tywyn in Fforest Fawr, showing terraces present on the west-facing warmer slope in the form of a succession of flows

Pl. 4. View looking south-east (SN/836555) down the Irfon valley in Mynydd Bach, taken about mid-day

Here the river is cutting into the well-developed terrace at the foot of the cold, north-east facing slope. No terrace development is in evidence on the warmer south-west facing slope. The south-west facing slope is the steeper

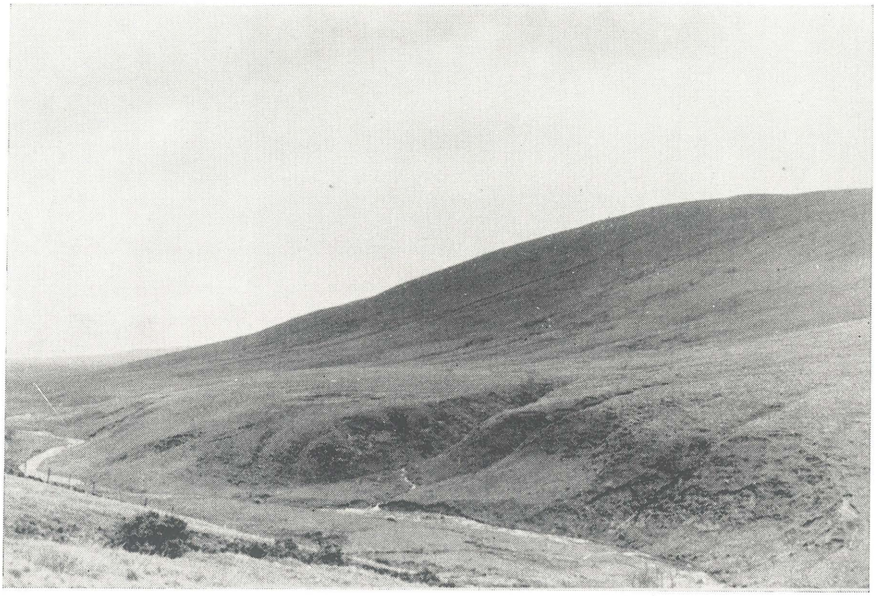


Pl. 5. View looking south-west (SN/853520) down the valley of Afon Gwesyn in Mynydd Bach, showing terrace formation below the steeper, west-facing slope



Pl. 6. View looking east (SN/811562) up the tributary valley of Nant-y-gelli in Mynydd Bach

Terraces are developed below both slopes (cf. Stage 4 in Fig. 10), that at the foot the south-facing slope having been considerably attenuated by movement down-valley. The south-facing slope is the steeper



Pl. 7. View of terrace bluff (river eroded in places), and shallow depression at the back of the terrace (against the major change of slope) in the valley of Afon Llia

This is one of the best terrace formations occurring in Fforest Fawr (Sn/925177). It is a view looking north-east across the the terrace and up-valley