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LATE-GLACIAL SCREE IN WALES

Abstract

Slopes in Wales are often covered by scree deposits. These are relic formations resulting from periglacial conditions in the Late-Glacial period. Many are covered by soil and vegetation, others have been exposed by erosion and are subject to contemporary resorting and accretion. The distribution of these screes covers a wide range of altitude in the areas of Wales which carried glaciers in the Late-Glacial period. Elsewhere, they are restricted to a smaller altitudinal range in hill districts which failed to support glaciers at that time. Their widespread distribution is an indication of the importance of periglacial activity in this glaciated region, in modifying land-forms, and in the consequent influences on soil development and ecology.

INTRODUCTION

It has become increasingly recognised by geologists, geographers and pedologists that periglacial conditions have had as great an importance in glaciated Britain (see, e.g. Waters 1964), as they had earlier been appreciated to have south of the limits of glacier ice (see, e.g. Dines *et al.* 1940). Where such processes were active during the final episodes of Pleistocene history they control the distribution of superficial deposits which form soil parent material (FitzPatrick 1958; Watson 1960, 1961; Stewart 1961; Ball 1961). The results of such processes therefore are of interest to pedologists and ecologists and it is from this approach that the importance and wide distribution of the scree deposits recorded here were recognised.

Solifluction deposits produced by the "slow flowing from higher to lower ground of waste saturated with water" (Anderson 1906), result largely from the presence of perennially frozen ground. With seasonal thawing of the upper horizons of unconsolidated frozen deposits, there is a slumping of water-saturated material downslope over still frozen subsoil. Watson (1960, 1961), has described the results of such action in mid-Wales. Where the slopes subject to this periglacial action were deeply mantled with unconsolidated material such as till (boulder-clay), the solifluction deposit may consist entirely of the reworked and re-orientated

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till. Where the till or interglacial soil cover was thin, the solifluxion deposit on moderate to steep slopes may be of the type called *head* (Dines *et al.* 1940). This contains angular stones resulting from frost-shattering of adjacent rock, in a loamy matrix derived largely from the pre-existing till or soil, which may also contribute rounded stones. *Scree* (talus) is confined to deposits of shattered country rock without appreciable fine-textured matrix. These, like head, accumulate on slopes under gravity but by the fall of material as a result of frost-shattering. Screes of fissile rock show a characteristic parallel orientation of constituent material which results from this mode of deposition. Head and scree grade into each other, but a bedded scree deposit consisting of stones without sand, silt and clay admixture, is very different to typical head or till in morphology and therefore in pedological and ecological influence through such characteristics as drainage.

Exposed rock outcrops on the upper part of a slope are essential at the active stage of scree development. Where unconsolidated soil or drift cover on steep slopes was thin, it was rapidly removed in Late-Glacial times by solifluction so that scree then accumulated from frost-shattering of the outcrop rock. Such screes are particularly well-developed on the fissile Palaeozoic shale and slate rocks in Wales. Jackli (1957, p. 29) has noted that schists and slates produce the most mobile scree, as would be expected on lithological grounds. Strong cleavage naturally facilitates shattering as a result of recurrent freezing and thawing.

It is the number of freeze—thaw cycles, that is the number of times that the temperature passes through freezing point, that is a main factor in frost-shattering (congelifraction) leading to scree formation. Recent studies by Rapp (1960) which discuss this point from work in northern Sweden, are referred to later. Precise limits cannot be given which are of general applicability for the climatic variables that permit periglacial conditions, although in general terms a cold humid climate and a lithologically suitable rock-type are required to allow scree to accumulate. The relationships between precipitation and mean summer temperatures which allow establishment of permanent snow and, therefore, glacier ice, are summarised by Manley (1959, p. 205). The lower the annual precipitation the lower the permissible mean temperature in the summer months. For an annual precipitation, as water, of 180 cm, Manley gives the approximate mean June—September temperature as 2.7° C for permanent snow accumulation. Conditions not quite severe enough to maintain permanent snow will produce periglacial frost-shattering and mass movement of unconsolidated material as a result of the freeze—thaw cycles.

SITE DATA FOR SOME TYPICAL SCREE SLOPES

Table I lists localities of some examples of typical scree deposits in North Wales and northern mid-Wales. Their distribution is shown in Figure 1, which also includes altitude and present rainfall data. The screes were mainly developed on Cambrian, Ordovician and Silurian shale and slate but some are found on rhyolite and other igneous rocks. The table gives the general altitude range through which the scree extends at each

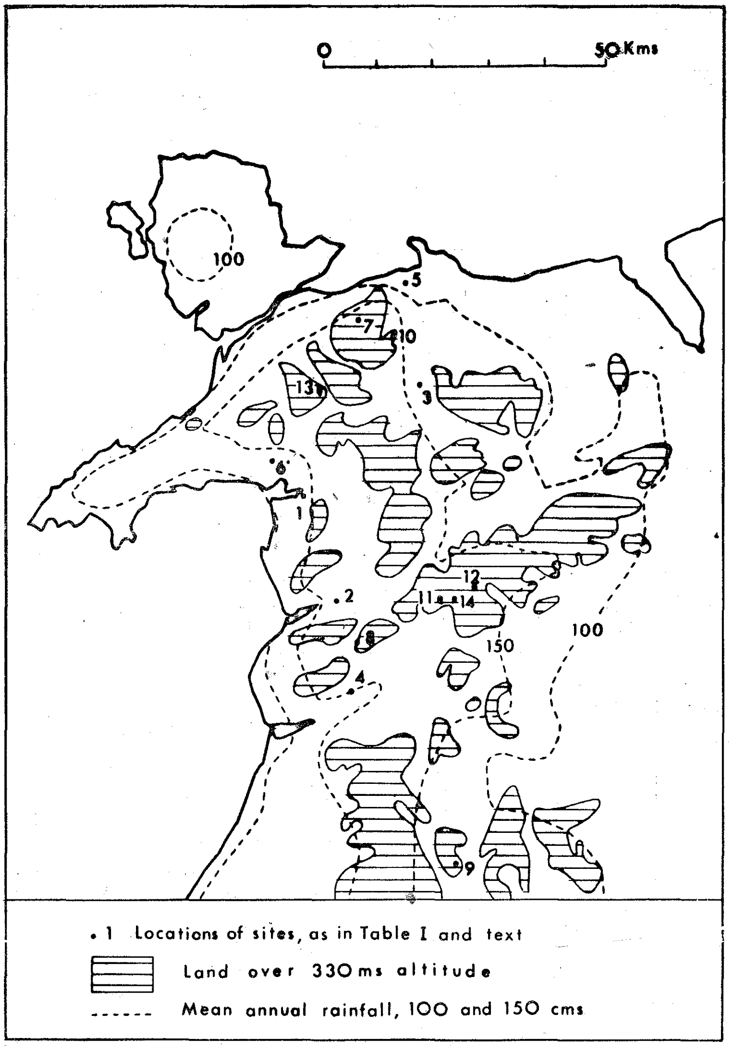

Fig. 1. Distribution of scree sites discussed from North and mid-Wales

Localities of scree sites discussed **Table I**

Site Number	Location	Grid Ref. (Ordnance Survey 1"/ml)	Approximate altitude of scree development	Parent Rock	Aspect	Notes
1	Coed Camlyn, Maentwrog, Merionethshire	Sheet 116, 655397	15—75 m	Cambrian shale	NW	Complete soil cover. Exposures on roadside and in small quarry (plate 1 and 2)
2	No. Llanelltyd on Barmouth—Dolgelley Rd., Merionethshire	Sheet 116, 709196	15—45 m	Cambrian shale	SW	Complete soil cover, small quarry exposure
3	Coedyrallt—Goch, Gwydyr, Betws-y-Coed, Caernarvonshire	Sheet 107, 800595	15—75 m	Ordovician shale	E	Thin soil cover, scree exposed on roadside
4	No. Cwm Cadian, Esgairgeiliog, Dovey Forest, Merionethshire	Sheet 127, 754054	75—105 m	Ordovician shale	W	Complete soil cover. Exposures in forest road. Involutions in upper metre (plate 3)
5	Sychnant, Conway, Caernarvonshire	Sheet 107, 747772	75—105 m	Ordovician rhyolite	S	Completely exposed

6	Cwm Bach, Tremadoc, Caernarvonshire	Sheet 107, 562408	135—150 m	Ordovician shale	SW	Complete soil cover, scree exposed in farm quarry
7	Marian Rhaiadr Fawr, Aber, Caernarvonshire	Sheet 107, 671703	300—410 m	Fine grained acid intrusion with Ordovician hardened shale	NW	Generally exposed but parts still with soil cover (plate 6)
8	Bwlch Llyn Bach, Nr. Cross Foxes, Merionethshire	Sheet 116, 757139	290—310 m	Ordovician shale	SE and NW	Flanking head of pass, partial soil cover, exposures in quarry (plate 4 and 5)
9	Cefn Pen-lan, Nr. St. Harmon, Radnorshire	Sheet 128, 957757	365—400 m	Silurian shale	NE—E	Complete soil cover, scree exposed in farm quarry
10	Hafod-y-Rhiw, Eigiau, Caernarvonshire	Sheet 107, 723647	375 m	Ordovician shale	NW	Scree exposure in road section, involutions in upper metre
11	Craig Ty Nant, Nr. Llanymawddwy, Merionethshire	Sheet 117, 892218	350—420 m	Ordovician shale	SW	Complete soil cover, but scree exposed in erosion gulleys
12	Waun-y-Gadfa, on Bwlch-y-Groes—Lake Vyrnwy Rd., Montgomeryshire	Sheet 117, 919231—930237	450—515 m	Ordovician shale	SE—S	Complete soil cover, scree exposed in road banks, some solifluction effects at surface locally

location. Screes at the highest altitudes, such as on Crib Goch, Snowdon (location 13 on figure 1), which are virtually entirely free of soil and vegetation, have not been included in the table, but are considered in the discussion section. There is apparently no consistent orientation of the scree slopes considering Wales as a whole.

Scree formation in Britain can be expected to begin earlier, as climatic conditions worsen, on suitable north and east-facing slopes than on south and west-facing slopes. There may be local correlation between intensity of scree formation and aspect but on a regional basis the natural local variation in degree and duration of periglaciation obscures such relationships. Emphasis has been placed on those less-readily recognised sites which remain under a soil and vegetation cover because these show most clearly the relic, fossil, character of the scree formation. It is of interest that exposures are frequently found in small quarries which have been opened to provide surfacing material for farm roads. In a minor way, in regions where local gravel supplies are scarce, the screes have provided a useful resource.

MORPHOLOGY OF SCREE DEPOSITS

The morphological characteristics of scree deposits can be illustrated by a typical shale scree from Site 1, Coed Camlyn, Maentwrog (No. 1 of Table I, plates 1 and 2) a National Nature Reserve [1]. The scree occupies the lower half of the wood and its relief expression is as a relatively uniform slope, averaging 25°. The upper part of the wood is generally considerably steeper and of broken relief, with frequent outcrops of the Cambrian shale from which the scree was formed. There is a sharp break of slope between the upper and lower sectors of the slope and the vegetation and soil cover over the scree sector is complete.

Scree exposures are available along the roadside at the base of the wood and in a small quarry (plates 1 and 2) at the western end of the wood, outside the Reserve boundary. In this quarry the internal morphology of a scree deposit is very well seen. Angular shale fragments are orientated parallel to each other. The ground slope closely follows this angle of rest of the scree. Shale fragments have their long axes generally parallel following the dip of the slope. Occasional striated stones are found, perhaps

[1] Permits are required to enter this Reserve, for which application should be made to the Regional Officer (North Wales), The Nature Conservancy, Penrhos Road, Bangor, Caernarvonshire.

derived from frost shattering of previously glaciated outcrops, rather than produced by movement within the scree. A few large sub-angular or rounded erratic boulders are present, derived in this case from hard grit bands within the Cambrian slates (pl. 2), or as relics from previous thin till cover on the upper slopes. There are small wisps and lenses of sand or clay matrix formed in minor interludes between periods of rapid scree accumulation. These are very subordinate, and sand, silt and clay size fraction material is typically absent in the general body of the scree. The soil formed at this particular site is of a well-developed podzolic character. The vegetation is sessile oak woodland (*Quercus petraea*) with a ground flora of bilberry (*Vaccinium myrtillus*) and mosses.

Where screes were formed on more massive rock types such as rhyolite, the rock fragments formed by frost-shattering are much less platy and hence well oriented. Additionally, the overlying soil on these rock types is of sandy, rather than silty texture, and thus more susceptible to erosion.

In two of the examples, at Eigiau (No. 10, Table I) and Esgairgeiliog (No. 4, Table I; pl. 3) there are involutions (micro-folding) in the upper horizons of the screes. Such involutions are normally ascribed to mass-movement of the scree downslope by a slow flow of frozen material, and could result from a worsening of local climate after a period of scree-formation. Galloway (1961) has noted, in a review of many sites showing involutions in Scotland, that the majority seem to result from pressure differences due to ice masses within the deposit, overlying permafrost without a rigid frozen cover. A similar but more marked climatic deterioration apparently took place at Bwlch-y-Groes (No. 12, Table I) where there are minor indications of till or till-derived solifluction deposit in thin lenses over scree.

DISCUSSION

The main points for discussion are the reasons for dating these screes as products of periglacial conditions in the Late-Glacial period and secondly, the light that the observed distribution of these screes throws on the former extent of periglacial conditions in a glaciated region.

Scree produced as a result of frost-shattering of rock outcrops is one of the typical products of periglacial weathering. It is favoured (Charlesworth 1957, p. 580) by the weak vegetation present under a periglacial climate and by the unstable slopes of oversteepened valleys resulting from previous glacial erosion. As previously stated, the lithological character of well-cleaved shales makes them particularly liable to frost-shattering and, therefore, scree formation was widespread on these rocks in Wales and elsewhere, when climatic and relief conditions were suitable. On moderately steep slopes the frost-shattered material fell to accumulate in thick deposits. On gentle slopes, the shattered material accumulated about the rock outcrops. A re-exposed example of this is seen from site 8, Table I, pl. 5, above a deep scree deposit, now worked in a quarry (pl. 4). As the rock fragments broke down to finer particle sizes these too accumulated on slight slopes to give a deposit of angular stones in a loamy matrix. On steep slopes, this fine material was washed away in thaw periods as fast as it was produced. It was only in relatively stable conditions as the periglacial climate disappeared that fine material accumulated on steep slopes among the surface horizons of the scree and, assisted by *in situ* weathering and the growth of vegetation, permitted soil formation.

Where soil cover is complete over the scree, the soil profile developed has similar characteristics, such as degree of podzolisation, to that on other types of drift deposit adjacent to the scree. It is reasonable then to suggest that scree has been available for soil formation for a similar length of time to adjacent till or solifluction deposits. Many screes and the outcrops which were their parent rock, are completely obscured by soil and vegetation cover and it is thus a matter of observation in these cases that no recent accretion to the scree can have occurred.

It has recently been noted in detailed survey in South Wales (Woodland and Evans 1964) that the "bulk of the deposits appear to be the results of a periglacial climate, for even the screes are now largely stabilised over. Under severe winter conditions some movement may still take place..., in a recently active example near Blaina in the Abergavenny district (Monmouthshire), the solifluction flow took place beneath ... the vegetation cover".

Godwin (1956) has shown that in Britain the late glacial period can be defined as comprising two periods of tundra vegetation during which periglacial climates and processes were operative, with an intervening climatic amelioration, the Allerød interstadial (Zone II). The pre-Allerød periglacial period (Zone I) of the three-fold Late-Glacial chronology and stratigraphy succeeded without break the closing episodes of the final glaciation, during which cwm (corrie, cirque) glaciers were active in Snowdonia (Seddon 1957). The Late-Glacial period has been dated by C_{14} determinations from a number of British stations (Godwin and Willis 1959) mainly in northern England but including one site each from Ireland, North Scotland and Cornwall. The dating was closely synchronous from site to site and may reasonably also be applied to conditions in Wales. Zone I commenced about 15,000 B.C. and ended about 10,000 B.C. with the onset of the Allerød interstadial. This lasted from 10,000 to 8,800 B.C. and was followed by the post-Allerød climatic recession (Zone III) from 8,800 to 8,300 B.C. It has been shown by Seddon (1957, 1961 a, b) that cwm glaciers were again active in Snowdonia in this period, with surrounding areas of periglacial conditions. After the close of this period, pollen analytical data (Godwin 1956; Seddon 1957, 1961a, b) indicate no return of periglacial conditions to this region. The close of Zone III is the definitive Late-Glacial to Post-Glacial boundary.

It is probable that the scree deposits under discussion were formed during one or both of the Zones I and III. Solifluction was strong in Zone III and many of the screes may have developed at this time. The involutions and superimposed deposits noted at sites 4 and 12 (Table I) may possibly have resulted from solifluction movement in Zone III affecting screes previously formed in Zone I.

At Eigiau (site 10) post-Allerød periglaciation is likely to have been largely responsible foı the scree, a minor short-lived deterioration in climate producing the micro-involutions.

Rapp (1960) has described weathering and mass-movement processes in Kärkevagge, near Narvik, Northern Lapland. This area is one very much poised on the fringe of glacier-forming conditions and may be comparable to Late-Glacial conditions in Wales. There was a relatively recent glacial maximum in the area in the 17th or 18th century but glaciers have retreated rapidly since 1920. The area now is stated by Rapp to be a periglacial environment of an arctic maritime type (the nearest climatic station gives the following data: annual mean temperature 1.5 °C; mean temperature of warmest month +10.6 °C; June—September mean temperature, c. 7.5 °C; c. 60 freeze—thaw days per annum; precipitation c. 80 cm p. a.; permafrost present). Among the features of slope morphology discussed by Rapp are the formation of talus (scree) slopes and the degree of accumulation and movement of such screes. Their morphology is described and is closely similar to that of the shale-derived screes discussed here. On a fissile mica-schist in Kärkevagge, 1—3cm depth of fresh material was added annually to a particular scree-zone, this being one of the highest values recorded for accumulation in the region. It is impossible to say that periglacial climatic conditions in Wales were of the type now found at Kärkevagge. However, on a crude comparison, the depth of scree at Camlyn is of the order of 6 metres at the base of the slope and many of the other screes are of similar depths, 4—9 m. For such depths of scree accumulation, if conditions at Kärkevagge apply, and a mean value of $1^1/_2$ cm per annum accumulation is taken, then the Welsh screes could have taken some 300 to 500 years to develop. Such comparisons are of course purely speculative, but the time obtained is in general keeping with the known time-scale of the Older Dryas part of the pre-Allerød (Zone I c) and Zone III.

The periglacial screes in Wales occur in some areas over a wide altitude range, while in other regions this range is more restricted. In the high mountain massifs of greatest precipitation. Late-Glacial glacier-ice accumulated in the cwms giving local till deposits as moraines. Surrounding these cwm-glaciers were relatively wide periglacial zones where solifluction movement occurred, with associated boulder-strewn blockfields and extensive frost-shattering. Screes accumulated here over the full altitudinal range from the highest peaks down to sea-level (examples are sites 1—8 and site 10 of Table I). Watson (1960, p. 21—33) has also noted the association of screes with Late-Glacial cwms about Cader Idris and mentions particularly site 8 of Table I and others in the Tal-y-Llyn Valley. In this region, as in Snowdonia, screes formed on volcanic rock are observed by Watson to be more blocky and to have suffered more from erosion than screes formed from mudstone and shale. In the lowlands peripheral to such massifs, periglacial weathering can influence soil pattern where preexisting drift cover was thin as in Anglesey (Ball 1961) but such weathering is probably largely of earlier date, contemporary with more widespread glaciers in Snowdonia and the Irish Sea.

In lower altitude hill-masses, the climate was not severe enough in the Late-Glacial period to support cwm glaciers, but did bring many of the central and western Welsh hill areas between 350 and 750 metres into the periglacial zone, or frost-shatter (high alpine) belt as defined by Büdel (1948). These areas probably carried a sparse tundra-like vegetation of lichens and mosses so that where till-cover was thin, widespread scree formation took place on steep slopes, and *in situ* weathering on gentle slopes. Many of the valleys leading into these hill-masses, for example those of the Cynllwyd from Llanuwchlyn and the Rhiwlech from Llanymawddwy to Bwlch-y-Groes (site 14 on fig. 1; pl. 7) have V-shaped upper reaches affected by periglacial weathering and carrying screes on their slopes. The lower reaches, below the frost-shatter zone in the Late-Glacial period, are U-shaped and mantled by drift, possibly re-sorted by solifluction and affected by permafrost. In the lowland areas away from the high massifs, scree formation was not general and deep scree deposits are relatively infrequent.

Thus scree distribution indicates the former extent of a high alpine or frost-shatter (congelifraction) type of periglacial climate. This distribution in Wales appears to indicate similar relative distribution of precipitation and temperature in Late-Glacial times to those of today although of course the temperatures were lower. The highest hill-masses supported both

Late-Glacial cwm-glaciers and a wide periglacial zone; hill-blocks of intermediate height had only their highest sectors in periglacial conditions of the frost-shatter type.

In Table I are cited two screes formed entirely on largely from rhyolite and other fine-grained igneous rock. The moderately high altitude scree at Marian Rhaiadr Fawr, Aber, (No. 7, Table I and pl. 6) is of considerable interest as providing a link between sites where soil and vegetation cover remains complete such as Coed Camlyn (No. 1, Table I) and those of bare scree as Sychnant (No. 5, Table I). At Marian Rhaiadr Fawr, the greater part of the scree is bare and has been subjected to much re-sorting by erosion through gaps in the cliff outcrops at the head of the scree. Between these gaps, however, there are protected areas where there remains a soil and vegetation cover. These have remained beneath small cliffs which have prevented erosion from above, in just the sites where scree would accumulate, if the formation was recent or contemporary. Photographs taken in 1929 (brought to my attention by Dr. R. E. Hughes) show essentially the same distribution of bare scree and soil cover as found today. The region of the Aber Valley was one of intense pre-historic and mediaeval settlement (Royal Commission, 1957). The native woodland most probably began to deteriorate at an early date from sites such as Marian Rhaiadr Fawr where it is likely to have been relatively thin and weak in growth, to be replaced by grassland and heath communities. The sandy soils on the rhyolite scree are markedly subject to erosion and this will have been accentuated by burning and stock-grazing. This development has progressed to completion at Sychnant, where, with a lower altitude and rainfall, a completely bare scree has resulted from erosion, probably due largely to burning on the naturally highly erodible loose sandy soils.

By analogy with sites such as Marian Rhaiadr Fawr and Sychnant, where the relic character of the screes is clear, it could be suggested that the highest-level screes in Wales, such as on Crib Goch, Snowdon (site 13, fig. 1, sheet 107, SH 625551), are periglacial in formation though subject to much contemporary re-sorting and probably to additional post-glacial accretion. Scree formation is apparently active under the present day near-alpine conditions on some of the highest Scottish peaks, such as Beinn Eighe (1,000 m.) in western Ross (FitzPatrick 1958). There does not appear to be any evidence regarding present day formation of fresh scree material on the highest Welsh peaks, such as in Snowdonia, as distinct from re-sorting of largely relic material. However, there are recorded rockfalls, or boulder-falls as defined by Rapp (1960) and such a fall was reported from Cwm Idwal in May, 1957 (Evan Roberts, pers. comm.). There had been snow and frost in January and February, but the late spring was rather dry. After a day of heavy rain the fall of a massive block from the upper cliffs of Glyder Fawr created a small scree avalanche, and a large part of the boulder ended near the shore at the head of Llyn Idwal. Although initial loosening of the boulder was probably caused by freeze — thaw, the time of fall resulted from heavy rains. This contrasts with the true periglacial conditions described by Rapp, where nearly all the falls correlated directly with thaw periods, and only to an insignificant extent with heavy rains. Much re-sorting of scree in Snowdonia took place in July, 1964, after a torrential downpour in which 3.4 cm of rain fell in 15 minutes (Dr. R. E. Hughes, pers. comm.). There is evidence for some active features of periglacial morphology in Snowdonia, such as the small transient frost polygones reported by Tallis and Kershaw (1959) from the ridge of the Carneddau. Here in level bare detritus at c. 900 ms polygons apparently formed in 1957 in a particularly cold winter with little snow-cover. Heavy rains later in 1957 caused the polygons to reform as stone-stripes.

In conclusion, it is suggested that the recognition of the extent and distribution of scree in an area is a useful guide in interpretation of Late-Glacial conditions. It is the most recent Pleistocene activity which is often of pedological and ecological significance in these hill regions and presence or absence of scree is an important key to the nature of this activity. The fact that these screes can be shown to be periglacial relics which in many cases retain a complete soil and vegetation cover emphasises the role of man and his land-management policies in producing bare scree in many places. Although the examples are taken from Wales, it is likely that the considerations of distribution of such screes are of general applicability in glaciated uplands. Contemporary scree movement has been measured in the Lake District of Northern England by Caine (1963) but no quantitative data are available from Wales. Further detailed studies both of distribution of srees and of contemporary processes in covered and exposed scree would be valuable.

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References

Anderson, J. G. 1906 — Solifluction, a component of subaerial denudation. *Jour. Geol.*, vol. 14.

Ball, D. F. 1961 — Glacial and periglacial deposits as soil parent materials in Wales. *Welsh Soils Discussion Group, Report no 2*; p. 3—10.

Büdel, J. 1948 — Die klimamorphologischen Zonen der Polarländer. *Erdkunde*, Bd. 2.

Caine, T. N. 1963—Movement of low-angle scree slopes in the Lake District, N. England. *Rev. Géomorph. Dynam.*; p. 172-178.

Charlesworth, J. K. 1957 — The Quaternary Era. Arnold, London.

Dines, H. G., Hollingworth, S. E., Edwards, W., Buchan, S., Welch, F. B. A. 1940 — The mapping of head deposits. *Geol. Magazine*, vol. 77; p. 198—226.

FitzPatrick, E. A. 1958 — An introduction to the periglacial geomorphology of Scotland. *Scot. Geog. Magazine*, vol. 74; p. 28—36.

Galloway, R. W. 1961 — Ice-wedges and involutions in Scotland. *Biuletyn Peryglacjalny*, no 10; p. 169—193.

Godwin, H. 1956 — The history of the British flora. C.U.P. Cambridge.

Godwin, H., Willis, E. H. 1959 — Radiocarbon dating of the Late-Glacial Period in Britain. *Proc. Roy. Soc. B.*, vol. 150; p. 199—215.

Jackli, H. 1957 — Gegenwartsgeologie des bundenrischen Rheingebietes. *Beitr. Geol. Schweiz., geotechn. Serie*, 36; Berne.

Manley, G. 1959 — The Late-Glacial climate of north-west England. *Liverpool Manchr. Geol. Jour.*, vol. 2; p. 188—215.

Rapp, A. 1960 — Recent development of mountain slopes in Kärkevagge and surroundings, northern Scandinavia. *Geogr. Annaler*, vol. 42; p. 73—200.

Royal Commission on Ancient Monuments, 1956, *Caernarvonshire*, vol. 1 (East). H.M.S.O., London.

Seddon, B. 1957 — Late-Glacial Cwm glaciers in Wales. *Jour. Glaciology*, vol. 3, no 22; p. 94—99.

Seddon, B. 1961 a — Late-Glacial deposits at Llyn Dwythwch and Nant Ffrancon, Caernarvonshire. *Phil. Trans. Roy. Soc. B.*, vol. 244; p. 459—481.

Seddon, B. 1961 b — The Late-Glacial vegetational and climatic history of Snowdonia. *Welsh Soils Discussion Group, Rept. no 2*; p. 23—28.

Stewart, V. I. 1961 — A perma-frost horizon in the soils of Cardiganshire. *Welsh Soils Discussion Group, Rept. no 2*; p. 19—22.

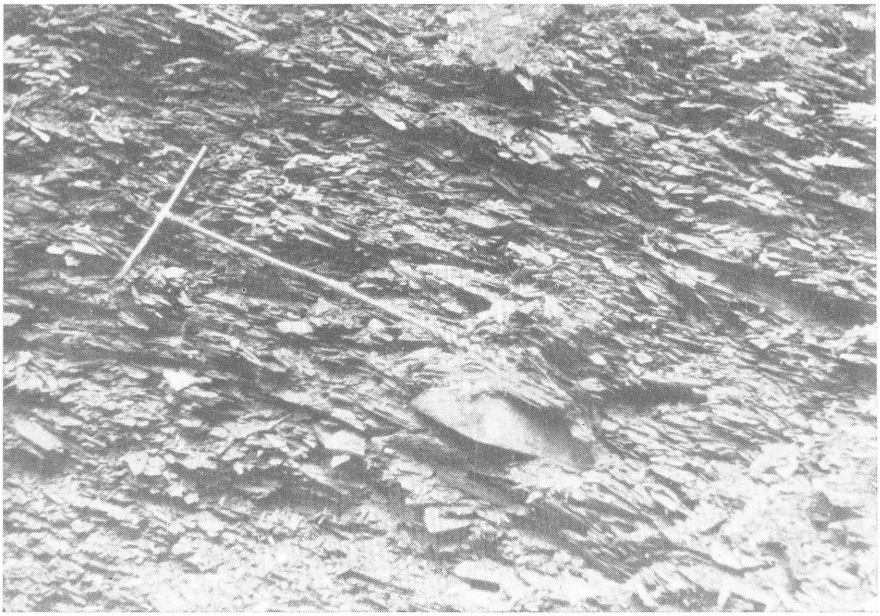
Tallis, J. H., Kershaw, K. A. 1959 — Stability of stone polygons in North Wales. *Nature*, vol. 183.

Waters, R. S. 1964 — Great Britain (Reports of the Commission on Periglacial Morphology). *Biuletyn Peryglacjalny*, no 14; p. 109—110.

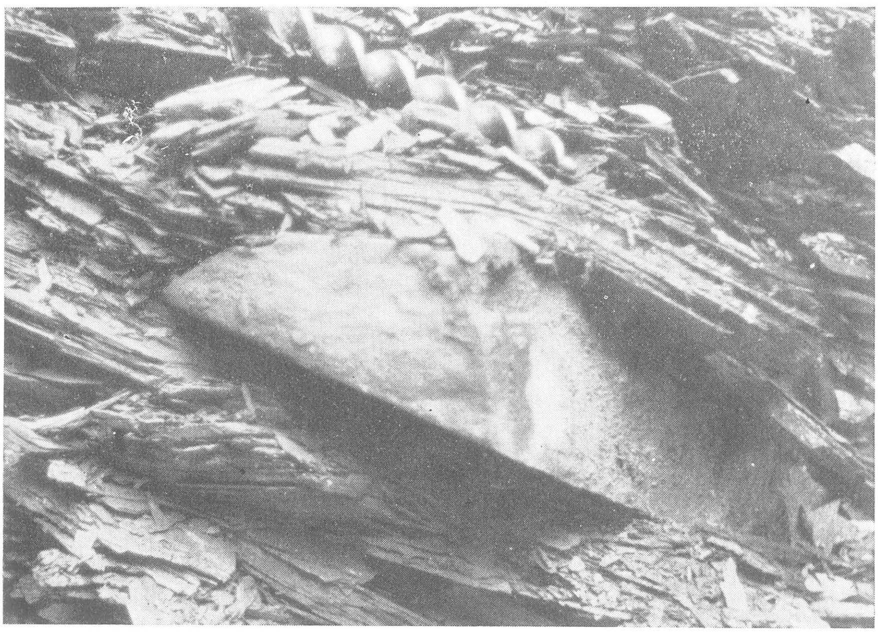
Watson, E. 1960 — Glacial landforms in the Cader Idris area. *Geography*, vol. 45; p. 27—38.

Watson, E. 1961 — Periglacial action in the Uplands of mid-Wales. *Welsh Soils Discussion Group, Rept. no 2*; p. 11—14.

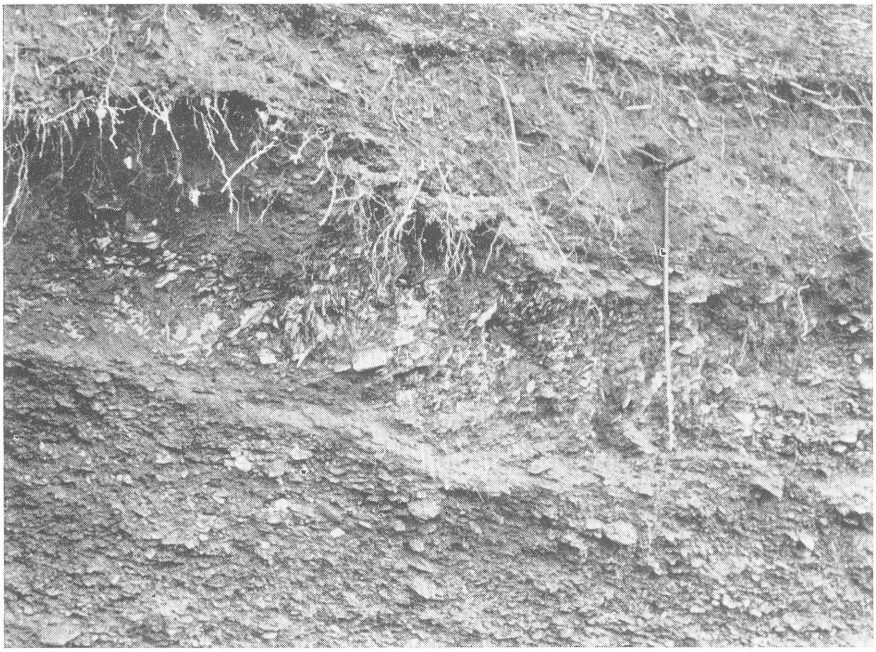
Woodland, A. W., Evans, W. B. 1964 — The geology of the south Wales coalfield Pt. IV, Country around Pontypridd and Maesteg. H. M. S. O., London.



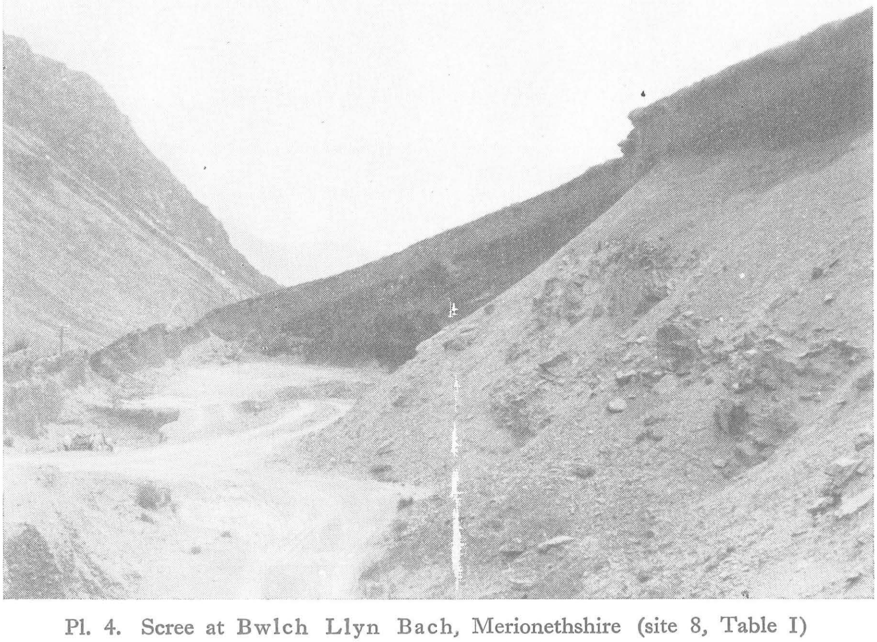
Pl. 1. Scree of Cambrian shale at Coed Camlyn, Merionethshire (site 1, Table I)
Bedded deposit with angle of rest of stones generally parallel to slope, indicated by auger in bottom right of photo



Pl. 2. Detail of scree at Coed Camlyn, showing orientation of fissile shale around inclusion of a massive grit boulder

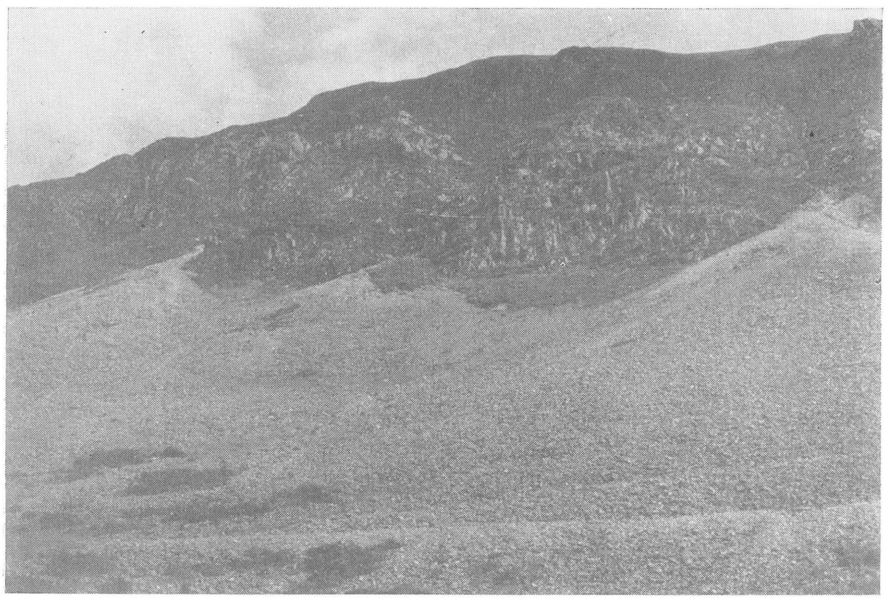


Pl. 3. Scree at Cwm Cadian, Esgairgeiliog, Merionethshire (site 4, Table I)
Uniformly bedded at base with disturbed surface scree showing micro-folding resulting from mass-movement



Pl. 4. Scree at Bwlch Llyn Bach, Merionethshire (site 8, Table I)
Deep fine scree filling head of pass

Pl. 5. Detail above quarry at Bwlch Llyn Bach, showing exposure of original outcrop and surrounding scree



Pl. 6. Scree at Marian Rhaiadr Fawr, Aber, Caernarvonshire (site 7, Table I)
Scree generally exposed by post-glacial erosion. Resorting of scree fans through gaps in cliffs above scree slope. Protected lobes of original soil and vegetation cover below cliff faces

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Pl. 7. The upper reaches of the Afon Rhiwllech, nr. Bala, Merionethshire (site 14, Fig. 1, O.S. 1″ Sheet No. 117, SH 910 215

Scree mantled slopes of the periglacially modelled upper valley